UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
PROGRAM PLANNING AND INTEGRATION
Silver Spring, Maryland 20910

AUG - 1 2011

To All Interested Government Agencies and Public Groups:

Under the National Environmental Policy Act (NEPA), an environmental review has been performed on the following action.

TITLE: Environmental Assessment for Proposed Amendment 38 (Annual Catch Limits) and Amendment 39 (Snow crab rebuilding plan) to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs [RIN 0648-XA209]

LOCATION: Exclusive Economic Zone off Alaska

SUMMARY: The environmental assessment analyzes two actions to amend the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). Action 1 would amend the FMP to specify the method by which the North Pacific Fishery Management Council (Council) will establish annual catch limits (ACLs) and accountability measures (AMs). ACLs and AMs are required by the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). ACLs would be established based upon an acceptable biological catch control rule set forth in the FMP to account for the uncertainty in the overfishing limit and any other scientific uncertainty. Action 2 would amend the FMP to rebuild the snow crab stock in compliance with the Magnuson-Stevens Act. This document addresses the requirements of the National Environmental Policy Act by analyzing the impacts of the alternatives considered under both actions upon crab resources, fishery participants, habitat, marine mammals, and other groundfish resources. The analysis contained in the Environmental Assessment shows that the proposed actions will not significantly impact the quality of the human environment.

RESPONSIBLE
OFFICIAL: James W. Balsiger
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The environmental review process led us to conclude that this action will not have a significant impact on the environment. Therefore, an environmental impact statement was not prepared. A copy of the finding of no significant impact (FONSI), including the environmental assessment, is enclosed for your information.

Although NOAA is not soliciting comments on this completed EA/FONSI we will consider any comments submitted that would assist us in preparing future NEPA documents. Please submit any written comments to the Responsible Official named above.

Sincerely,

Paul N. Doremus, Ph.D.
NOAA NEPA Coordinator

Enclosure

ENVIRONMENTAL ASSESSMENT

For Proposed Amendment 38 (Annual Catch Limits) and Amendment 39 (Snow crab rebuilding plan) to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs

July 2011

Lead Agency:	National Oceanic and Atmospheric Administration National Marine Fisheries Service Alaska Region Juneau, Alaska
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Abstract: This environmental assessment analyzes two actions to amend the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). Action 1 would amend the FMP to specify the method by which the North Pacific Fishery Management Council (Council) will establish annual catch limits (ACLs) and accountability measures (AMs). ACLs and AMs are required by the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). ACLs would be established based upon an acceptable biological catch (ABC) control rule set forth in the FMP to account for the uncertainty in the overfishing limit (OFL) and any other scientific uncertainty. Three alternative methods to establish the ABC control rule are considered: (1) a constant buffer approach where the ABC for each stock would be set by application of a constant pre-specified buffer value below the OFL; (2) a variable buffer approach where the ABC would be annually calculated from a pre-specified percentile of the distribution for the OFL (noted as P*) and using a probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty; and (3) a blended approach that uses a variable buffer for stocks in Tiers 1 through 4 and a constant buffer for stocks in Tier 5. A range of constant buffers and probabilities are considered under each alternative approach. For Action 1, the Council recommended the blended approach with a P* of 0.49 and a process for appropriately quantifying and accounting for scientific uncertainty for stocks in Tiers 1 through 4 and a constant buffer of 10% below the OFL for stocks in Tier 5. Action 2 would amend the FMP to rebuild the snow crab stock in compliance with the Magnuson-Stevens Act. A range of alternative time frames are considered for rebuilding the stock. For Action 2, the Council recommended maintaining the existing rebuilding plan but defined rebuilt as the first year that the stock reaches the biomass level estimated to produce maximum sustainable yield. This document addresses the requirements of the National Environmental Policy Act by analyzing the impacts of the alternatives considered under both actions upon crab resources, fishery participants, habitat, marine mammals, and other groundfish resources.

EXECUTIVE SUMMARY

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). 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 Fishery Conservation and Management Act (Magnuson-Stevens Act or MSA), and other applicable federal laws.

There are two proposed actions contained in this analysis:

Action 1- Establish Annual Catch Limits and Accountability Measures for ten crab stocks: The first proposed action would establish annual catch limits (ACLs) and accountability measures (AMs) to meet Magnuson-Stevens Act requirements. ACLs would be established based upon acceptable biological catch (ABC) control rules which account for the uncertainty in the overfishing level (OFL) point estimate and any other scientific uncertainty. To meet the ACL requirements, the North Pacific Fishery Management Council (Council or NPFMC) considered alternatives that establish ABCs and ACLs such that ACL = ABC. The ABC control would be used for the annual calculation of the maximum ABC. Annually, the Council's Scientific and Statistical Committee (SSC) would recommend ABCs for crab stocks at or below the maximum ABC.

Action 2- Revise rebuilding plan for snow crab: The second proposed action is a revised rebuilding plan for the eastern Bering Sea (EBS) snow crab stock. On September 24, 2009, the NMFS Alaska Region notified the Council that the EBS snow crab stock would not be rebuilt by the end of the rebuilding time period, 2009/10, and that a revised rebuilding plan must be developed for that stock and implemented within two years of that notification.

Both actions must be implemented prior to the start of the 2011/12 crab fishing year. They are considered together in this analysis as the implementation timing is identical and the actions themselves are related in the interplay between rebuilding plan catch constraints and ACL catch constraints for the EBS snow crab stock. For the remaining nine BSAI crab stocks, rebuilding provisions are not considered in this analysis and only Action 1 (establishment of ACLs) applies.

Additionally, Pribilof Islands blue king crab remains overfished. The current rebuilding plan has not achieved adequate progress to rebuild the stock by 2014. The Pribilof Islands blue king crab fishery has remained closed since 1999 and bycatch mortality in 2008/09 was below the OFL. To comply with section 304(e)(7) of the Magnuson-Stevens Act, the Council is preparing an amended Pribilof Islands blue king crab rebuilding plan. This rebuilding plan will be analyzed in a separate document because the primary rebuilding alternatives address bycatch in groundfish fisheries.

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 federal implementing regulations and, therefore, the Regulatory Flexibility Act does not apply, and review under Executive Order 12866 is not required.

Action 1: Annual Catch Levels for BSAI Crab Stocks

The proposed action is to amend the FMP to specify the method by which the Council would annually establish ACLs and AMs to meet the Magnuson-Stevens Act requirements. ABCs would be annually established under an ABC control rule and ACLs will be set such that ACL = ABC. The ABC control rule would be set forth in the FMP and accounts for the uncertainty in the OFL point estimate and any other scientific uncertainty.

The provisions of the Magnuson-Stevens Act, as amended in 2007, establish, either expressly or by logical extension, five basic requirements that relate to the FMP and require some action to amend the FMP. NMFS's Guidelines for National Standard 1 of the Magnuson-Stevens Act (50 CFR 600.310; NS1 Guidelines) provide guidance to Councils about how to satisfy the Magnuson-Stevens Act obligations.[1] These five requirements may be paraphrased as follows:

(1) The FMP must provide for the specification of ACLs that will prevent overfishing;
(2) The FMP must establish measures that will ensure adherence to ACLs, which, at a minimum, address any overages that may occur;
(3) The Council must establish an ABC control rule based on the scientific advice of its SSC, and which accounts for relevant sources of scientific uncertainty, and the FMP must describe the ABC control rule;
(4) The Council's SSC must provide the Council with periodic recommendations for specifying the ABC for each fishery; and
(5) The FMP must describe the maximum sustainable yield (MSY) and assess and specify the optimum yield (OY) for the fishery.

Additional information is contained in section 1.2 of the analysis regarding specific provisions and requirements of the Magnuson-Stevens Act and the NS1 Guidelines.

Four alternatives are considered under Action 1, with multiple options under Alternative 2 and Alternative 3.

Alternative 1-Status Quo

Alternative 1 would continue the current practice of annually establishing OFLs for the 10 crab stocks based on the five-tier system in the FMP. No ABC control rule or ACLs would be established. Annually, the OFL for each of the 10 BSAI crab stocks is computed using the five-tier system. Stocks are assigned to one of the five tiers based on the availability of information for that stock (Table ES-1-1). Tier assignments and model parameter choices are recommended through the Crab Plan Team (CPT) process to the SSC. Each June, the SSC recommends the final tier assignments, stock assessment and model structure, and parameter choices, including whether information is "reliable" for the assessment authors to use for calculating the OFLs based on the five-tier system. After the most recent survey data are incorporated and the status determinations made, the appropriate control rule is applied to calculate the OFL for the upcoming year. The CPT reviews the status determinations and resulting OFL in September.

[1] The Guidelines reflect mandates imposed by the Magnuson-Stevens Act and present "the Secretary's interpretation of the national standards so that [the Councils] will have an understanding of the basis on which FMPs will be reviewed" for consistency with legal requirements. The Guidelines employ the word "must" "to denote an obligation to act; it is used primarily when referring to requirements of the Magnuson-Stevens Act, the logical extension thereof, or of other applicable law." 50 CFR 600.305(c)(1) (emphasis added). This document identifies several of the obligations under the Magnuson-Stevens Act that are denoted in the NS 1 Guidelines as steps that "must" be taken.

NMFS then determines the final OFLs prior to the October Council meeting to enable the State to announce the total allowable catches (TACs) by October 1 for the fisheries that open on October 15. The State sets TACs[2] or guideline harvest levels (GHLs) for each crab stock below the OFL level such that total catch $\leq$ OFL using the criteria outlined in the FMP and State harvest strategies.

Table ES-1-1 BSAI crab stocks in the FMP and the 2010 tier assignments.

Tiers	Stocks by tier for 2010 assessment cycle
1	None
2	None
3	Bristol Bay red king crab (BBRKC) Snow crab
4	Tanner crab St. Matthew blue king crab (SMBKC) Pribilof Islands red king crab (PIRKC) Pribilof Islands blue king crab (PIBKC)[3] Norton Sound red king crab (NSRKC)
5	Aleutian Islands golden king crab (AIGKC) Pribilof Islands golden king crab (PIGKC) Adak red king crab (ADAK)

In June 2010, the Council identified status quo as their preliminary preferred alternative and requested that staff describe how current State management could be used in satisfying the new required provisions of the Magnuson-Stevens Act and NS1 Guidelines. Flexibility and expertise exercised by the State in managing BSAI crab fisheries is acknowledged in the FMP and is the basis for deferral of management authority to the State. On an annual basis the State conducts a review of current crab stock status trends, biomass estimates, stock distribution, and fishery performance. Evaluation of the scientific uncertainty inherent in each of these estimates is an integral component of State crab management. This vetting process allows the best available scientific information to be integrated into State harvest control rules when setting annual TACs/GHLs. Additionally, a thorough description of status quo management in the analysis would provide better information to evaluate the impacts of more complex proposals under the other alternatives. The EA was revised to include a more robust discussion of status quo from which the Council could develop the recommended Alternative 4. Appendix 4 contains a more detailed discussion of the Council's June action.

Alternative 2, 3, and 4 - Establish an ABC control rule and set ACL equal to ABC

Alternatives 2, 3, and 4 were designed to explicitly address the requirements of the Magnuson-Stevens Act and NS1 Guidelines. These alternatives specify the ABC control rule and the process by which the SSC will annually recommend the ABC to the Council, and the accountability measures that are enacted if the ACLs are annually exceeded. Under each alternative, the Tier system in the FMP would be amended to explicitly provide for the ABC control rule in addition to the current OFL control rules. The Tier system was designed to accommodate changes in stock assessment information and stocks may move between tiers based explicitly on availability of information in the stock assessment. However, while the

[2] Under the FMP, the State sets TACs for the crab fisheries under the Crab Rationalization Program: snow crab, Tanner crab, Bristol Bay red king crab, St. Matthew blue king crab, Pribilof Islands red and blue king crab, Aleutian Islands golden king crab, and Adak red king crab. GHLs are set for the remaining crab fisheries: Pribilof Islands golden king crab and Norton Sound red king crab.

[3] Note that for Pribilof Islands blue king crab, since the directed fishery is closed, the OFL is set for bycatch only using the Tier 5 control rule (NPFMC 2010).

current Tier 3 stocks have fairly consistent information available, there is a wide disparity in available information amongst the Tier 4 and Tier 5 stocks. A schematic of the current Tier system is provided in Figure ES 1 with indication of how the ABC would be included by tier.

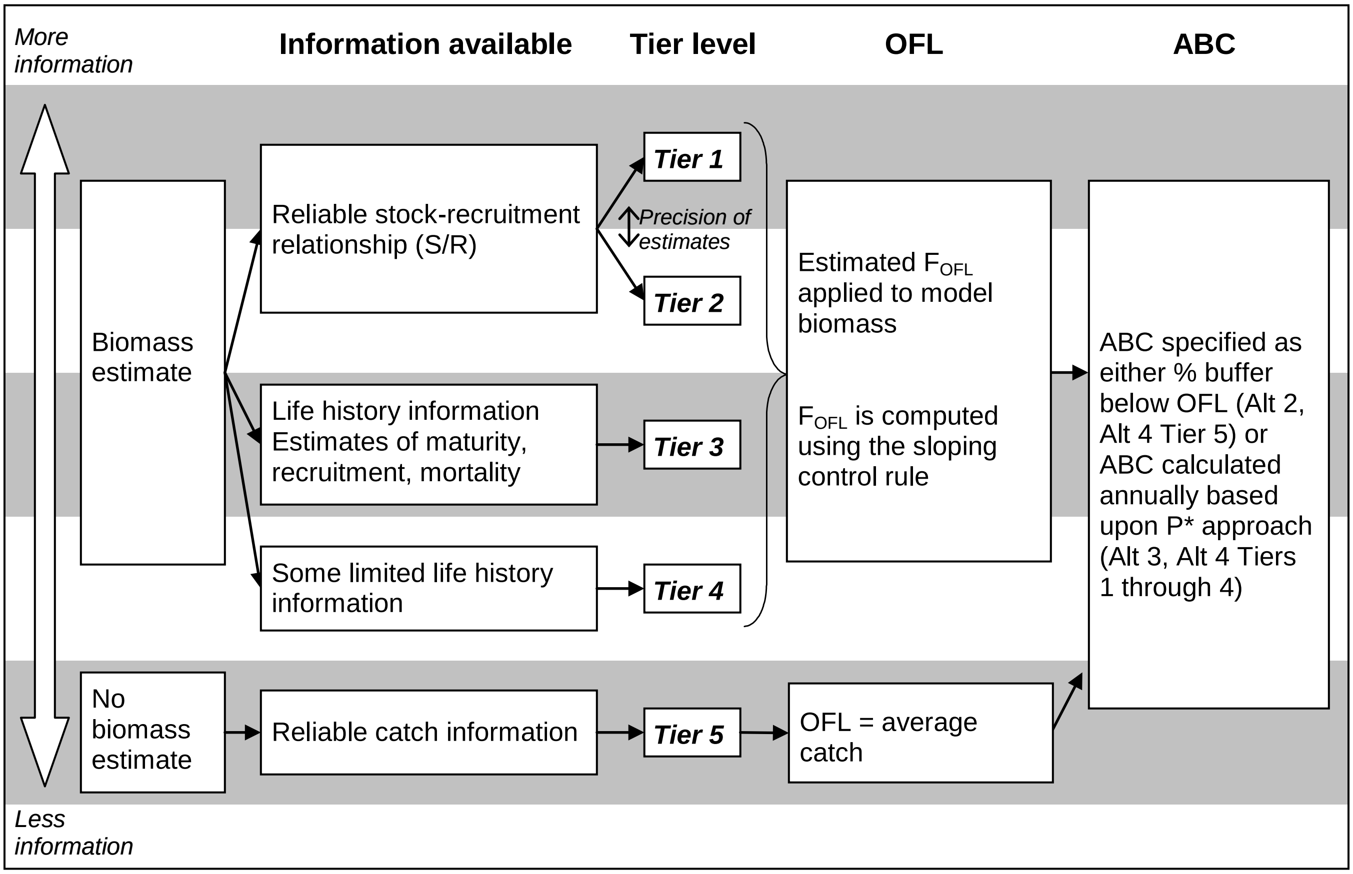
Three approaches are considered for the specification of the ABC control rule. Alternative 2 is a constant buffer approach to establish an ABC below the OFL. Once selected, that buffer value does not change over time. Alternative 3 also employs a buffer to establish an ABC below the OFL, but this buffer is not fixed and can vary annually depending upon the annually assessed extent of uncertainty. Alternative 4 employs a variable buffer for stocks in Tiers 1 through 4 and a constant buffer for stocks in Tier 5. The analysis of each alternative provides an estimate of the relative risk of overfishing to enable understanding of this relative risk of each ABC control rule. The impact analysis for each alternative and each approach considers the extent of scientific uncertainty in the OFL and any other scientific uncertainty.

Under each alternative, the SSC may recommend an ABC less than the maximum ABC calculated by application of the ABC control rule, but it must provide the rationale for this recommendation.[4] The process would begin with the stock assessment authors' recommended ABCs (at or less than the maximum ABC), followed by CPT review and recommendations by the CPT to the SSC, and the final ABC recommendation by the SSC to the Council.

Under these alternatives, the TAC/GHLs must be set sufficiently below the ACL so that total catch will not exceed the ACL. The FMP defers the determinations of TACs and GHLs to the State following the criteria in the FMP. Under these alternatives, determinations of TACs and GHLs will continue to be set by the State, however, the requirement to set TACs and GHLs at a level to prevent exceeding the ACL would be an additional consideration in setting TAC/GHL.

[4] "The SSC must recommend the ABC to the Council. An SSC may recommend an ABC that differs from the result of the ABC control rule calculation, based on factors such as data uncertainty, recruitment variability, declining trends in population variables, and other factors, but must explain why." 50 CFR 600.310(f)(3).

Figure ES-1 Schematic of the current OFL tier system and proposed ABC specification



The alternatives differ in the annual consideration of uncertainty in the ABC control rule specification, which is an important consideration for a range of stocks with varying levels of scientific uncertainty. For example, consider two hypothetical stocks with differing levels of stock information (Figure ES-2). The OFL point estimate for these two stocks is identical. However, the relative uncertainty surrounding the OFL is considerably higher for the stock with less precise information than for the one with more precise information. Under a constant buffer approach (Figure ES-2A), an ABC value set at 86% of the OFL (i.e., a buffer of 14%) results in a different relative risk of overfishing (conveyed by P*) should total catch equal ABC. Thus, the same buffer value employed to set ABC as a percentage of OFL is riskier for stocks with high levels of uncertainty than for stocks with low levels of uncertainty. This analysis provides an estimate of risk for each buffer, but the risk would not be considered annually in the ABC setting process because the buffer values would be fixed.

Under a variable buffer (or P*) approach (Figure ES-2B), consideration of risk is the primary decision point in specifying the P* value, with the resulting buffer value calculated annually based on the probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. A constant P* (here set at P* = 0.25 or a 25% risk of overfishing should total catch equal ABC) results in different buffer values for the two stocks even though they have the same OFL. Thus, a larger buffer value is necessary for the stock for which less precise information is available to maintain the same risk of overfishing. As information for a stock improves, a constant P* may result in gradually decreasing buffers over time.

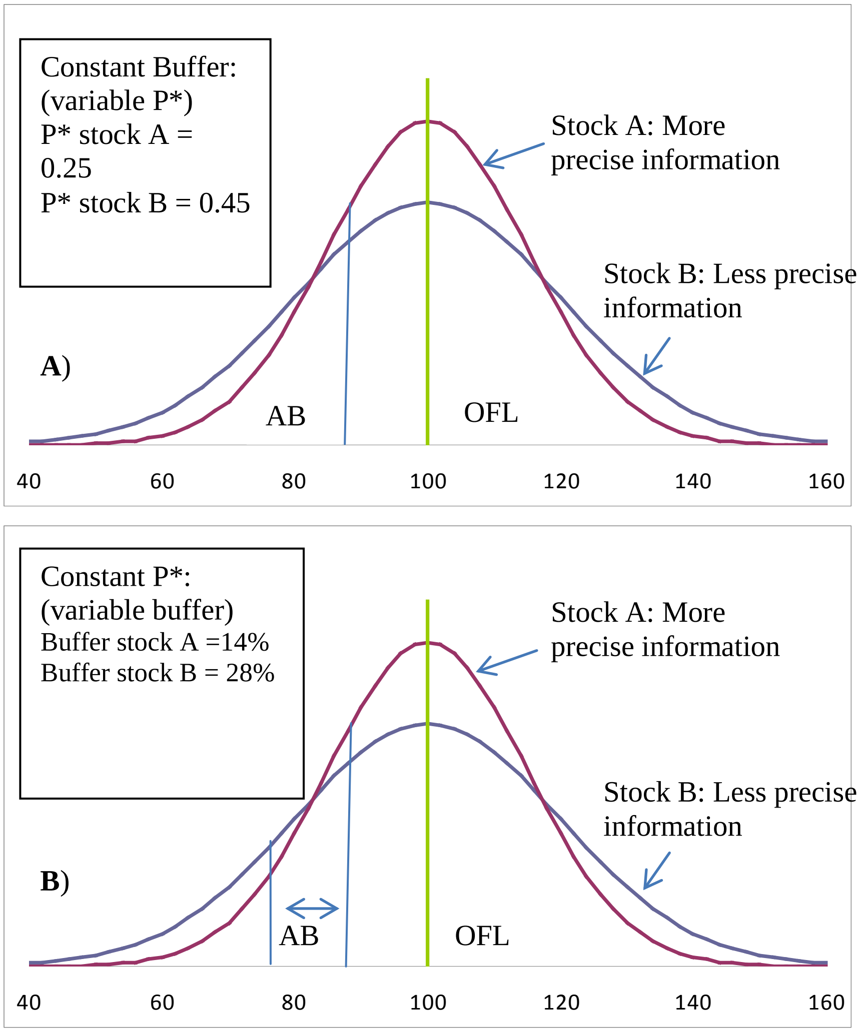


Figure ES-2 **Schematic of ABC control rule approaches. Two stocks are considered in each panel, with the same OFL point estimate but with different levels of information available and hence a different level of uncertainty around that point estimate. The top panel (A) shows a constant buffer approach for both stocks with different resulting P*s for each stock, while the lower panel (B) shows a constant P* approach resulting in different buffer levels for each stock.**

Alternative 2- Constant Buffer

Alternative 2 would establish an ABC control rule for crab stocks to annually calculate the maximum ABC below the OFL using a fixed buffer. The ACL would be set equal to the ABC. The maximum ABC for each stock would be set to the product of 1-x (where x is a constant pre-specified buffer less than 1) and the OFL. Alternative 2 would specify in the FMP the buffer value(s) and the stock(s) or tier(s) to which the specified buffer value(s) will apply. Buffer values under consideration in this alternative include the following:[5]

Option 1: ABC = OFL (no buffer)
Option 2: ABC = 90% of OFL (10% buffer)

[5] Note that other buffer values may be selected within these ranges. ABC reflects the maximum ABC resulting from application of the control rule.

Option 3: ABC = 80% of OFL (20% buffer)
Option 4: ABC = 70% of OFL (30% buffer)
Option 5: ABC = 60% of OFL (40% buffer)
Option 6: ABC = 50% of OFL (50% buffer)
Option 7: ABC = 40% of OFL (60% buffer)
Option 8: ABC = 30% of OFL (70% buffer)
Option 9: ABC = 20% of OFL (80% buffer)
Option 10: ABC = 10% of OFL (90% buffer)

Alternative 3- Variable Buffer

Alternative 3 would specify in the FMP the ABC control rule for crab stocks and the P* value(s) and the stock(s) or tier(s) to which the P* value(s) would apply. The ACL would be set equal to the ABC. The maximum ABC would be established based upon a pre-specified percentile of the distribution for estimates of the OFL. This method directly accounts for the annually assessed scientific uncertainty regarding the estimate of the OFL. This method establishes a variable buffer between the ABC and the point estimate of the OFL, in order to prevent the ABC from exceeding the "true" OFL (noted as OFL'). The probability of the ABC exceeding the OFL' is equal to a specified P* value (P(ABC>OFL')).[6]

A range of P* values are considered and result in stock-specific percentage buffer values which vary over time depending on the assessed extent of scientific uncertainty. Once the P* value is selected, the ABC would be annually established below the OFL using the buffer which corresponds to the selected P* and taking account of the annual assessed extent of scientific uncertainty, as recommended by the SSC. P* values under consideration in this alternative include the following:[7]

Option 1: P* = 0.5
Option 2: P* = 0.4
Option 3: P* = 0.3
Option 4: P* = 0.2
Option 5: P* = 0.1

Alternative 4 - Preferred Alternative

The Council took final action to recommend a preferred alternative in October 2010. Alternative 4, the Council's preferred alternative, blends Alternatives 2 and 3 and establishes a set of ABC control rules within the current tier system for crab stocks. Annually, the ABC control rule would be used to calculate the maximum ABC in the stock assessment.

For stocks in Tiers 1 through 4, the Council recommended the control rule that follows a P* approach, which implies a variable buffer between OFL and ABC. Alternative 4 specifies P* = 0.49. For stocks in Tier 5, the Council recommended a constant buffer of 10%. Modification to the P* value or the constant buffer for establishing the maximum ABC would require an FMP amendment. While the SSC recommended a P* approach for stocks in all tiers because it is "more directly responsive to changes in our understanding of uncertainty" (June 2010 SSC minutes), they did note that the Council may not be comfortable with a P* approach for data-poor stocks. In deciding whether to use a P* or buffer approach by tier, consideration was given to ensure that the implied buffer increases as information decreases. This was noted by the SSC in their June 2010 minutes "…such an approach would have to be carefully

[6] Further information on the background rationale and utility of P* as a reference value for risk is contained in chapter 3.
[7] Note that other P* values may be selected within these ranges.

designed to ensure that the implied buffer increases with tier level to reflect higher levels of uncertainty for data poor stocks and provide a continued incentive to move stocks into higher tiers." Thus, the buffer value for Tier 5 is higher than those resulting from a P* approach for Tiers 1 through 4.

In recommending Alternative 4, the Council recognized that a P* of 0.49 meets the requirements of the MSA because it provides for a probability of overfishing that is less than 50% and it incorporates relevant scientific uncertainty in the ABC-setting process. In addition, by taking this approach, the Council acknowledges that the precautionary approach that is currently employed by the State in setting TAC/GHL will further reduce the risk of realizing overfishing at this P* level, by incorporating variable scientific information that cannot be quantified in a control rule.

Under Alternative 4, scientific uncertainty is to be considered in characterizing the probability distribution (probability density function or pdf) of the OFL for each stock. This probability distribution for the OFL accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. However, Alternative 4 does not prescribe the approach for quantifying all out-of-model uncertainty that was used to analyze the impacts of Alternative 3. Alternative 4 relies on the State TAC/GHL-setting process to address the additional uncertainty while requesting that the CPT and SSC continue to work to understand and quantify those sources of uncertainty in the OFL point estimate that should be incorporated into the ABC control rule.

In developing this approach, the Council recognized that some scientific uncertainty is not applicable to the OFL setting process and is better addressed through the State TAC/GHL setting process. Alternative 4 relies on the State to incorporate additional buffering to account for uncertainty in the annual TAC/GHL specification process. The Council directed the CPT and SSC to identify (1) factors influencing scientific uncertainty that could be incorporated into the ABC control rule, and (2) factors influencing scientific uncertainty that are best reserved for State consideration on an annual basis in TAC/GHL setting. Annually, the CPT and the SSC would evaluate and make recommendations, as necessary, on the specification of the probability distribution of the OFL, the methods to appropriately quantify uncertainty in the ABC control rule, and the factors influencing scientific uncertainty that the State will account for on an annual basis in TAC/GHL setting. The end result will be to incorporate some additional outside-of-model uncertainty into the ABC control rule where possible while continuing to consider time-sensitive aspects of uncertainty in the TAC/GHL-setting process. The State also has the flexibility to use the expertise of its managers and biologists to set the TAC or GHL below the harvest levels that would result from applying existing harvest strategies to prevent overfishing and meet State management goals and federal requirements.

Many factors that influence estimates of scientific uncertainty are currently considered by the State in TAC-setting and are time-sensitive. The Council recognized that it would not be possible for the CPT and SSC to make scientific recommendations regarding the incorporation of these factors in the ABC control rule. Understanding how to account for these factors should be based on the best and most timely information available, and the Council recognized that the most appropriate method to do so is through the existing annual State TAC/GHL setting process. This choice by the Council recognized the State's role and expertise in crab research and management under the FMP.

The Council's intent in crafting this preferred alternative was to meet MSA requirements while maintaining the shared management regime of the FMP that makes use of existing State resources to achieve National Standard 1 goals, rather than implement new management measures that could limit the flexibility to incorporate the best available science. In recommending this alternative, the Council indicated that this action confirms their current risk strategy as it relates to crab management under shared management FMP but does not preclude the Council from continuing to evaluate the impact of this risk strategy on crab stocks and to potentially modify this approach in the future should information indicate that it is necessary.

For Tier 5 stocks, the ABC control rule will be established as ABC = 0.9*OFL resulting in an ABC 10% below the OFL. No annual consideration of uncertainty is required in the ABC control rule for Tier 5 stocks because uncertainty is incorporated in the size of the buffer. In selecting a fixed buffer approach for Tier 5 stocks, the Council recognized that a fixed buffer was more appropriate than a P* approach because the OFL estimate for Tier 5 stocks is based on average catch. There is little inter-annual variability that would necessitate the use of a P*, thus a buffer of 10% adequately mitigates the risk.

Accountability Measures

The Magnuson-Stevens Act requires that FMPs include AMs to prevent ACLs from being exceeded and to correct for overages of the ACL if they do occur. Accountability measures to prevent TACs and GHLs from being exceeded are currently used in crab fisheries management and will continue to be used to prevent ACLs from being exceeded. These accountability measures include: individual fishing quotas and the measure implemented under the Crab Rationalization Program to ensure that individual fishing quotas are not exceeded, measures to minimize crab bycatch in directed crab fisheries, and monitoring and catch accounting measures.

AMs in the ABC-setting process would include the downward adjustments to ACL in the fishing season after an ACL has been exceeded. As an accountability measure, the total catch estimate used in the stock assessment will include any amount of harvest that may have exceeded the ACL in the previous fishing season. For stocks managed under Tiers 1 through 4, this would result in a lower maximum ABC in the subsequent fishing season, all else being equal, because maximum ABC varies directly with biomass. For Tier 5 stocks, the information used to establish the ABC is insufficient to discern the existence or extent of biological consequences caused by an overage in the preceding fishing season. Consequently, the subsequent fishing season's maximum ABC will not necessarily decrease. However, when the ACL for a Tier 5 stock has been exceeded, the SSC may recommend a decrease in the ABC for the subsequent fishing season as an accountability measure.

Given that the State sets the TAC, Amendment 38 also includes accountability measures for the State to exercise in the annual TAC-setting process. First, Amendment 38 would require that the State establish the annual TAC for each crab stock at a level sufficiently below the ACL so that the sum of the total catch (including all bycatch mortality and any uncertainty in bycatch estimates) and the State's assessment of additional uncertainty in the OFL estimate will not exceed the ACL. Additional uncertainty includes (1) management uncertainty (i.e., uncertainty in the ability of managers to constrain catch so the ACL is not exceeded, and uncertainty in quantifying the true catch amount) and (2) scientific uncertainty identified and not already accounted for in the ABC (i.e., uncertainty in bycatch mortality, estimates of trends and absolute estimates of size composition, shell-condition, molt status, reproductive condition, spatial distribution, bycatch of non-target crab stocks, environmental conditions, fishery performance, fleet behavior, and the quality and amount of data available for these variables).

Second, if an ACL is exceeded, the FMP would require that the State implement accountability measures to account for any biological consequences to the stock resulting from the overage through a downward adjustment to the TAC for that species in the following fishing season. Note that this is in additional to the downward adjustment to the ABC in the ABC-setting process discussed previously. This accountability measure would be under the FMP's category 2, which means that the State has the discretion under the FMP to determine the most appropriate method to account for any catch above the ACL in setting the TAC for the subsequent fishing season.

The Council recognized that these accountability measures place the burden of accountability only on the directed crab fishery. Measures to minimize crab bycatch in the groundfish fisheries include prohibited species catch limits and area closures. The Council has initiated a comprehensive analysis of crab bycatch in the BSAI groundfish fisheries to assess these existing crab protection measures and to determine whether changes or additional measures are necessary to further minimize crab bycatch in the groundfish fisheries. This analysis will likely be available within the next year for review by the Council thus current accountability measures should be considered as an interim step until additional measures are reviewed and recommended by the Council.

Process for ABC recommendation

Alternatives 2, 3, or 4 would implement a process for annual ABC specification under the FMP. In order to allow the SSC to make the final ABC recommendation to the Council on an annual basis, four options are considered:

Option 1:	SSC recommends ABC levels annually at October Council meeting (delayed TAC-setting)
Option 2:	SSC recommends ABC levels annually prior to October Council meeting (shift timing of October Council meeting)
Option 3:	SSC recommends ABC levels annually prior to October Council meeting (convene special SSC meeting prior to TAC-setting)
Option 4:	SSC recommends ABC levels annually in June

The Council recommended Option 1 as part of Alternative 4. Under Option 1, the SSC would annually recommend final ABCs for most crab stocks to the Council at the October meeting. TAC/GHL-setting by the State would be delayed until after the SSC has provided the Council with ABC recommendations. The ABC recommendation for Tier 5 stocks, Norton Sound red king crab, and Aleutian Islands golden king crab would occur at the June meeting. This approach would be the least disruptive to the current process for stock assessment and TAC/GHL setting because it allows for the use of the most recent survey and fishery data. Use of the most recent survey data is critical in assessing crab stocks because survey estimates can be highly variable from one year to the next, therefore it is very important to retain the ability to incorporate the most recent data into stock assessments and to use consistent data in both the stock assessment and TAC-setting processes.

Optimum Yield specification

As a housekeeping measure, the FMP will be amended to insert the OY definition resulting from Amendment 24 that was omitted from the amendment text for Chapter 6 of the FMP. The current specification for OY under the FMP should read “OY range 0 to < OFL catch”. In conjunction with this FMP amendment (for Action 1: Crab ACLs and AMs) the FMP will be revised for this housekeeping change.

For crab stocks, the OFL is the annualized maximum sustainable yield (MSY) and is derived through the annual assessment process, under the framework of the tier system. Recognizing the relatively volatile reproductive potential of crab stocks, the cooperative management structure of the FMP, and the past practice of restricting or even prohibiting directed harvests of some stocks out of ecological considerations, this OY range is intended to facilitate the achievement of the biological objectives and economic and social objectives of the FMP (see sections 7.2.1 and 7.2.2) under a variety of future biological and ecological conditions. It enables the State to determine the appropriate TAC levels below the OFL to prevent overfishing or address other biological concerns that may affect the reproductive potential of a stock but that are not reflected in the OFL itself. It enables the State to establish TACs at levels that maximize harvests, and associated economic and social benefits, when biological and ecological conditions warrant doing so.

Summary of impacts of Action 1

The analysis provides the projected impacts of the alternatives on stock abundance and catch. Results for both the P* and buffer approach are indicated for each stock. Results are characterized for the short-, medium-, and long-term time frames to understand the immediate implications of the predicted ABC value as well as the medium-term implications on harvest constraints and the long-term biological and economic implications. Summary figures are provided for each stock in Tiers 3 and 4 to indicate the risk-assessment choices in selecting an appropriate P* value (or to determine the likely risk of overfishing at various buffer values).[8]

The treatment of uncertainty is a critical aspect in this analysis. The NS1 Guidelines state that the ABC control rule must articulate how ABC will be set compared to the OFL based on the scientific knowledge about the stock and the scientific uncertainty in the estimate of the OFL and any other scientific uncertainty (50 CFR 600.310(f)(4)). NMFS has described the characterization of the uncertainty in the OFL as a scientific decision.[9] The policy decision lies in determining the appropriate level of risk of overfishing, by selecting between buffers or P* values in the ABC control rule. The ABC control rule encompasses both the policy decision for the buffer or P* value and the annual consideration of scientific uncertainty.

Two aspects to scientific uncertainty are considered: within-assessment uncertainty and additional uncertainty. For stocks in Tiers 3 and 4, each chapter contains stock-specific OFL distributions that indicate the relative uncertainty characterized within the assessment itself due, for example, to the ability of the population dynamics model to mimic the observed length-frequency and survey biomass data. The extent of uncertainty regarding the OFL "within" the assessment is quantified by the standard deviation of the logarithm of the estimate of mature male biomass at the time of mating (MMB) for the last year of the assessment (σ_w). The stocks with the most precise estimates of within-assessment uncertainty (σ_w) are the following: Bristol Bay red king crab, snow crab, St, Matthew blue king crab, Norton Sound red king crab, Aleutian Islands golden king crab, and Tanner crab. However, of these, the OFL for some stocks (St. Matthew blue king crab, Tanner crab, Norton Sound red king crab, and Aleutian Islands golden king crab) should be based on higher (assumed) levels of additional uncertainty than for the Tier 3 stocks, despite the low uncertainty associated with the estimate of the OFL from the assessment itself.

Within-assessment uncertainty is not be sufficient to adequately capture the true uncertainty of the stock's true, but unknown, OFL because the assessment does not consider all of the sources of uncertainty. Assumptions are made in estimating the OFL that introduce uncertainty into the estimate of OFL, which is often not reflected in the calculation of "within assessment uncertainty." In particular, most assessments pre-specify (do not estimate) some of the parameters that influence the OFL estimate (such as natural mortality, survey catchability, and the fishing mortality at which MSY is achieved). Additional

[8] While Pribilof Islands blue king crab is in Tier 4, given the stock status and the fact that the directed fishery is closed, a short term analysis was not conducted. Additional, while Aleutian Islands golden king crab is in Tier 5, the draft stock assessment model was used to analyze these stocks under Tier 4.

[9] Comments on the proposed NS1 Guidelines stated that "accounting for scientific uncertainty is a matter of policy, not science and therefore should be delegated to the Council." The agency's response disagreed with the position voiced in this comment: "NMFS believes that determining the level of scientific uncertainty is not a matter of policy and is a technical matter best determined by stock assessment scientists as reviewed by peer review processes and SSCs. Determining the acceptable level of risk of overfishing that results from scientific uncertainty is the policy issue." 74 FR 3192; January 16, 2009. (Comment 42 and Response).

uncertainty needs to be characterized and reflected in the ABC control rule to best approximate the 'true' uncertainty in the assessment and thus establish ABC levels which are reflective of the 'true' uncertainty of the OFL. For this reason a qualitative section is included in each chapter outlining the additional sources of uncertainty that are not captured in the assessment itself but should still be considered when evaluating the true uncertainty associated with the estimate of the OFL. The sources listed for each stock are restricted to calculation of OFL in the short-term and do not consider issues such as changes over time in productivity and habitat loss. Additional uncertainty has a substantial impact on the size of the resulting buffer value.

For this analysis, additional uncertainty was included as a range of constants which represent low, medium, and high levels of additional uncertainty as σ_b, and the CPT and SSC recommended default values for these levels of 0.2, 0.3, and 0.4. The analysis also includes a value of 0.0 (no additional uncertainty). Total uncertainty regarding the model estimated OFL is calculated as σ_b plus σ_w. A sensitivity analysis was conducted to evaluate the impact of these values for quantifying additional uncertainty on the resulting buffer. The impacts of accounting for these levels of additional uncertainty compared to only employing the buffer resulting from the within-assessment variability can be substantial (

). Alternative 4 does not prescribe the method to account for additional uncertainty and instead directs the CPT and SSC to identify the factors influencing scientific uncertainty that should be incorporated into the ABC control rule and the factors influencing scientific uncertainty that should be accounted for by the State in TAC/GHL-setting.

It is not possible to estimate the extent of uncertainty associated with the OFL for Tier 5 stocks in a manner similar to stocks in Tiers 1 through 4 due to lack of reliable biomass estimates. Thus a different characterization of uncertainty was employed for Tier 5 stocks.

Table ES-2 Relationship between the size of the buffer between the OFL and the ABC for a P* of 0.4 with different values for additional variability, σ_b, based on the assumption that the OFL is log-normally distributed about its best estimate. Note that additional variance of 0.3 was calculated for all 'medium' level stocks as well as some additional stocks for comparative purposes only. Shading indicates the σ_b values used in this analysis.

P* 0.4		Additional uncertainty, σ_b			
Stock	**0**	**0.2**	**0.3**	**0.4**	**0.6**
Bristol Bay red king crab	1%	6%	11%	16%	28%
EBS snow crab	3%	8%	--	16%	29%
Pribilof Island red king crab	50%	50%	54%	58%	69%
St. Matthew blue king crab	0	0	0%	1%	11%
Norton Sound red king crab	5%	8%	13%	16%	28%
Dutch Harbor golden king crab*	3%	10%	15%	20%	32%
Adak golden king crab*	9%	11%	15%	19%	29%

* These two stocks comprise the Aleutian Islands golden king crab stock (results shown for the Tier 4 analysis).

A summary of the analysis of alternatives is provided below to highlight the distinction between the policy choice of a constant buffer by stock or tier and a variable buffer by stock or tier. The P* value for each stock (or tier) would be specified depending on an understanding of the relative risk of overfishing. Once the P* decision is made, the buffer value associated with that level of risk is calculated annually and results in a buffer level for that particular stock taking into account scientific uncertainty. As information improves for each assessment, the buffer value calculated will likewise decrease for the same P*, resulting in a gradual decrease in the ratio of the OFL to the ABC over time. Table ES-2 provides a summary of the buffer values calculated for a range of P*s for the current fishing year using the additional uncertainty values shown in Table ES-2. To meet the statutory requirements, the ABC must not result in a greater than 50% chance of overfishing, thus a P* ≥ 0.5 is not a viable option.

Table ES-3 Buffer values for 8 stocks for a range of P*s under Alternative 3 using the additional variance values (σb). Shading indicates P* choices that would result in a 50% chance of overfishing.

P*:	0.5	0.4	0.3	0.2	0.1
Stock	**Buffer**				
Bristol Bay red king crab	0%	6%	11%	17%	24%
EBS snow crab	3%	8%	13%	18%	16%
Tanner crab	18%	34%	49%	NA	NA
Pribilof Island red king crab	30%	68%	73%	100%	100%
St. Matthew blue king crab	0%	0%	6%	16%	28%
Norton Sound red king crab	0%	16%	26%	34%	44%
Dutch Harbor golden king crab	0%	15%	21%	27%	36%
Adak golden king crab	0%	15%	23%	29%	44%

Table ES-3 presents similar information for Alternative 2. The policy decision is to select an appropriate fixed buffer level by stock (or tier), taking into account the estimated risk of overfishing indicated in the analysis. Once the policy decision is made on the choice of a fixed buffer level (i.e., ABC = x% OFL, where 1-x is the buffer level selected), that buffer level would be used annually for that stock regardless of any modification in information contained in the stock assessment annually. For this analysis, the P*s associated with a range of buffer values were calculated for the current fishing year using the recommended levels of additional variance and the current estimates of variance are summarized in chapter 2. Again, an alternative that would lead to greater or equal to a 50% chance of overfishing, thus a zero buffer (equating to a P* ≥ 0.5 for all stocks) is not permitted under the NS1 Guidelines. Under Alternative 4, the Tier 5 stocks would have a 10% buffer.

Table ES-4 P* values for 8 stocks for a range of buffer values under Alternative 2 using the additional variance values (σ_b). Shading indicates P* choices that would result in a 50% chance of overfishing.

Buffers	0	10%	20%	30%	40%
Stock	**P***				
Bristol Bay red king crab	0.50	0.25	0.11	0.04	0
EBS snow crab	0.50	0.36	0.18	0.07	0.01
Tanner crab	>0.50	>0.50	0.49	0.43	0.36
Pribilof Island red king crab	>0.50	>0.50	>0.50	>0.50	0.49
St. Matthew blue king crab	0.50	0.26	0.16	0.09	0.05
Norton Sound red king crab	>0.50	0.48	0.37	0.25	0.15
Dutch Harbor golden king crab	0.50	0.47	0.32	0.16	0.07
Adak golden king crab	0.50	0.45	0.35	0.19	0.10

Alternative 4 specifies that P* = 0.49 for stocks in Tiers 1 through 4. Annually, stock assessment authors would calculate the probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. The additional scientific uncertainty that is not applicable to the OFL setting process would be accounted for through the State TAC/GHL setting process. The Council directed the CPT and SSC to identify factors influencing scientific uncertainty that could be incorporated in the ABC control rule, and factors that are best reserved for State consideration in TAC setting.

At this point, it is not possible to predict how the additional scientific uncertainty will be specified, quantified, or incorporated into the ABC control rule. Therefore, for this analysis, the estimated buffers resulting from a P* = 0.49, and σ_w to characterize uncertainty, are shown in Table ES-5 in comparison with similar buffer values at a range of P* values between 0.4 and 0.5 with σ_b included in estimating uncertainty. Also note that for this comparison table, the median was used to calculate the probability distribution of the OFL. As discussed in section 3.2.4.2, the choice of using the mean or the median for the probability distribution of OFL has a huge impact on the size of the buffer under different P* values for many the Tier 4 stocks. The mean was used to calculate the probability distribution for Tier 4 stocks in the previous tables (Table ES-2 through Table ES-4) and the analysis in the stock-specific chapters. The method used to calculate the probability distribution of the OFL would be an annual decision and specified in the stock assessment.

Annually, the CPT and the SSC shall evaluate and make recommendations, as necessary, on the specification of the probability distribution of the OFL, the methods to appropriately quantify uncertainty in the ABC control rule, and the factors influencing scientific uncertainty that the State will account for in TAC/GHL setting. The Council also requested the CPT and SSC continue work to improve understanding of scientific uncertainty in the estimation of crab OFLs and to ensure that crab stock assessment models and OFLs are risk-neutral. The Council expects that crab assessment and management staff will continue to work to evaluate all sources of uncertainty in assessments, develop methods to accurately quantify uncertainty, and to provide for SSC review. The goal of this work is to incorporate some additional outside-of-model uncertainty into the ABC control rule where possible while continuing to consider time-sensitive aspects of uncertainty in the State TAC/GHL-setting process.

This approach relies on the State's TAC/GHL-setting process to address additional uncertainty recognizing that many factors that influence estimates of scientific uncertainty are currently considered by the State and are time-sensitive. This is consistent with the State's role in collecting and analyzing scientific data on BSAI crab and in establishing TACs/GHLs under the FMP. The Council recognized that it would not be possible for the CPT and SSC to make scientific recommendations regarding the incorporation of many types of scientific uncertainty in the ABC control rule. The State also has the flexibility to use the expertise of its managers and biologists to set the TAC or GHL below the harvest levels that would result from applying existing harvest strategies to prevent overfishing and meet State management goals and federal requirements.

Table ES-5 Estimated P* values between 0.4 and 0.5 with total uncertainty estimated with recommended values for additional uncertainty (σ_b) and with model-estimated (σ_w) uncertainty only. In bold are the buffers resulting from the P* = 0.49 without any additional uncertainty in the ABC control rule.

P*:	0.5	**0.49**	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41	0.40
Stock	Buffer (% reduction of OFL)										
Bristol Bay red king crab											
$\sigma_w + \sigma_b$	0.00%	0.52%	1.03%	1.54%	2.05%	2.56%	3.06%	3.57%	4.08%	4.58%	5.09%
σ_w	0.00%	**0.13%**	0.25%	0.38%	0.50%	0.63%	0.75%	0.88%	1.00%	1.13%	1.26%
EBS snow crab											
$\sigma_w + \sigma_b$	0.00%	0.54%	1.08%	1.62%	2.16%	2.69%	3.23%	3.76%	4.29%	4.82%	5.36%
σ_w	0.00%	**0.21%**	0.43%	0.64%	0.85%	1.06%	1.28%	1.49%	1.70%	1.92%	2.13%
Tanner crab											
$\sigma_w + \sigma_b$	0.00%	0.83%	1.65%	2.46%	3.27%	4.07%	4.88%	5.67%	6.47%	7.26%	8.05%
σ_w	0.00%	**0.35%**	0.70%	1.05%	1.40%	1.74%	2.09%	2.44%	2.79%	3.14%	3.48%
Pribilof Island red king crab											
$\sigma_w + \sigma_b$	0.00%	1.74%	3.45%	5.13%	6.79%	8.42%	10.02%	11.61%	13.17%	14.72%	16.24%
σ_w	0.00%	**1.43%**	2.84%	4.23%	5.60%	6.96%	8.30%	9.63%	10.94%	12.24%	13.53%
St. Matthew blue king crab											
$\sigma_w + \sigma_b$	0.00%	0.85%	1.69%	2.53%	3.36%	4.18%	5.00%	5.82%	6.63%	7.44%	8.25%
σ_w	0.00%	**0.40%**	0.80%	1.20%	1.59%	1.99%	2.39%	2.78%	3.18%	3.58%	3.97%
Norton Sound red king crab											
$\sigma_w + \sigma_b$	0.00%	1.04%	2.06%	3.08%	4.08%	5.08%	6.07%	7.06%	8.04%	9.01%	9.98%
σ_w	0.00%	**0.28%**	0.56%	0.83%	1.11%	1.39%	1.66%	1.94%	2.22%	2.49%	2.77%
Dutch Harbor golden king crab											
$\sigma_w + \sigma_b$	0.00%	0.75%	1.50%	2.24%	2.98%	3.71%	4.44%	5.17%	5.89%	6.61%	7.34%
σ_w	0.00%	**0.05%**	0.11%	0.16%	0.21%	0.26%	0.32%	0.37%	0.42%	0.48%	0.53%
Adak golden king crab											
$\sigma_w + \sigma_b$	0.00%	0.75%	1.50%	2.24%	2.98%	3.71%	4.45%	5.17%	5.90%	6.62%	7.35%
σ_w	0.00%	**0.07%**	0.14%	0.20%	0.27%	0.34%	0.41%	0.48%	0.54%	0.61%	0.68%

Directed Harvest Constraint (Short-term)

The analysis discusses the impacts of a range of ACL buffer values on the short-term harvest, i.e., whether the ABC control rule at different buffer values would constrain the retained catch for that stock. The State harvest strategy was used to calculate approximate TAC for future years, and the retained catch is assumed to equal the TAC. Alternative 4 and buffer values (and corresponding P*s) less that those noted below would have no short-term impacts relative to status quo, except for St. Matthew blue king crab. Buffer values larger that those noted would constrain harvest relative to status quo. From this analysis, the application of the State harvest strategy would result in buffers between catch and the OFL of between 10% and 80%. These buffers protect against overfishing. The following is a brief summary of the short-term directed harvest constraint for each crab stock:

- For Bristol Bay red king crab, the retained catch would be constrained at buffer values greater than 10% (i.e., a 10% buffer, or ABC established at < 90% of the OFL).
- For snow crab, buffer values greater than 10% would constrain the retained catch based upon the 2009/10 TAC level.
- For Tanner crab, buffer values greater that 40% would constrain the retained catch based upon the 2009/10 TAC.
- For Pribilof Islands red king crab, any buffer (i.e. even at a 0% buffer or ABC established at the OFL) would constrain the State harvest strategy (note that, as described in chapter 7, this fishery is closed and the State harvest strategy has not been employed for this stock since 1993 given concerns with the potential for bycatch of the Pribilof blue king crab in a directed Pribilof Island red king crab fishery and uncertainty in Pribilof Island red king crab stock abundance levels).
- For Pribilof Islands blue king crab, the directed fishery is closed so there is no short-term impact of any buffer value on the retained catch component of the ABC for this stock.
- For St. Matthew blue king crab, the retained catch would be constrained at all buffer values.
- For Norton Sound red king crab, only buffer values greater than 50% would constrain the retained catch.
- For Aleutian Islands golden king crab, only buffers greater than 80% would constrain the retained catch.[10]
- For Pribilof Island golden king crab, buffer values greater than 20% would constrain the retained catch (based on the 2010 GHL amount).
- The Western Aleutian Islands red king crab fishery is currently closed, so buffer values considered do not impact retained catch for this stock.

Probability of Overfishing

More constraining buffers (or lower values for P*) decrease the probability that stocks will become overfished in the future. A stock is overfished when biomass declines below the minimum stock size threshold (MSST). The probability that a stock will become overfished is shown quantitatively for those stocks for which biomass estimates and projections of stock status are possible. However, this is highly dependent on individual stock status and recruitment assumptions inherent in the stock assessment models. Therefore, additional information by stock is considered in evaluating long-term implications of the alternatives.

Figure ES-3 and Figure ES-4 present a depiction of the tradeoff between the risk of reducing the stock below the MSST and the relative cost of implementing ACL measures to reduce risk. For each of the nine BSAI stocks for which stock assessment models and surveys are available, stock simulations under a range of ACL multiplier values ranging from 0 to 1.0 (i.e., 1.0 buffer level, where buffer ranges from 1.0 to 0.0) were used to forecast stock biomass, ABC, and directed catch values for the medium (5 years, Figure ES-3) and long-term (30 years, Figure ES-4) period of analysis. Results are presented for all Tier 3 and 4 crab stocks, as well as Western Aleutian Islands golden king crab, and are based on stock assessment model forecasts using the recommended additional uncertainty parameter (σ_b) value for each stock, and crab market price forecasts and discounted present value (r=2.7%) of estimated future gross revenues. Directed catch estimates were combined with probabilistic forecasts of first wholesale market prices for king crab and snow crab to produce estimates of the value of future crab production under the

[10] Based on the Tier 4 model estimated output as shown in chapter 11, section 11.2. For Tier 5 results see chapter 11, section 11.4.3

alternatives. Detailed methods and results are presented in following chapters, and these figures provide a summary of those analyses.

In this executive summary, the results are presented in terms of percentage change in total present value (TPV) resulting from the alternatives relative to expected economic value of a zero buffer (ABC=OFL), and assuming that total catch equals the OFL. This allows equal comparison across fisheries of different scale and value. A zero buffer does not reflect the State of Alaska control rules for TAC/GHL setting that reduce catch below the OFL; therefore a zero buffer does not reflect status quo. Additional results are presented in each species specific chapter.

The upward sloping curve in each figure shows the relatively linear relationship for most crab stocks between ACL buffer sizes and the forecasted percentage reduction in TPV relative to the baseline alternative over the 5- and 30-year period, respectively, although snow and Tanner crab, and to a lesser degree Bristol Bay red king crab, display an increasing incremental reduction in TPV as the buffer level increases.

The downward sloping curve in each figure shows the tradeoff between risk of the stock becoming overfished and the percentage change in foregone economic value. The nonlinearity of the tradeoff is of particular note in the consideration of the alternatives. With the exception of Pribilof Islands red king crab, most stock projections display a decreasing incremental reduction in probability of the stock becoming overfished as buffer sizes and catch and revenue reduction increases from 0 to 100%, with relatively large risk reduction from a zero buffer at relatively modest economic impact. Model simulations for all stocks (with the exception of Tanner crab, for which the simulation reflects the status of the stock as currently overfished) indicate that the probability of becoming overfished in the next thirty years with a zero buffer is somewhat below 0.5. Again, this would not be the probability of becoming overfished under status quo because this analysis does not account for the constraining effects of the TAC/GHL.

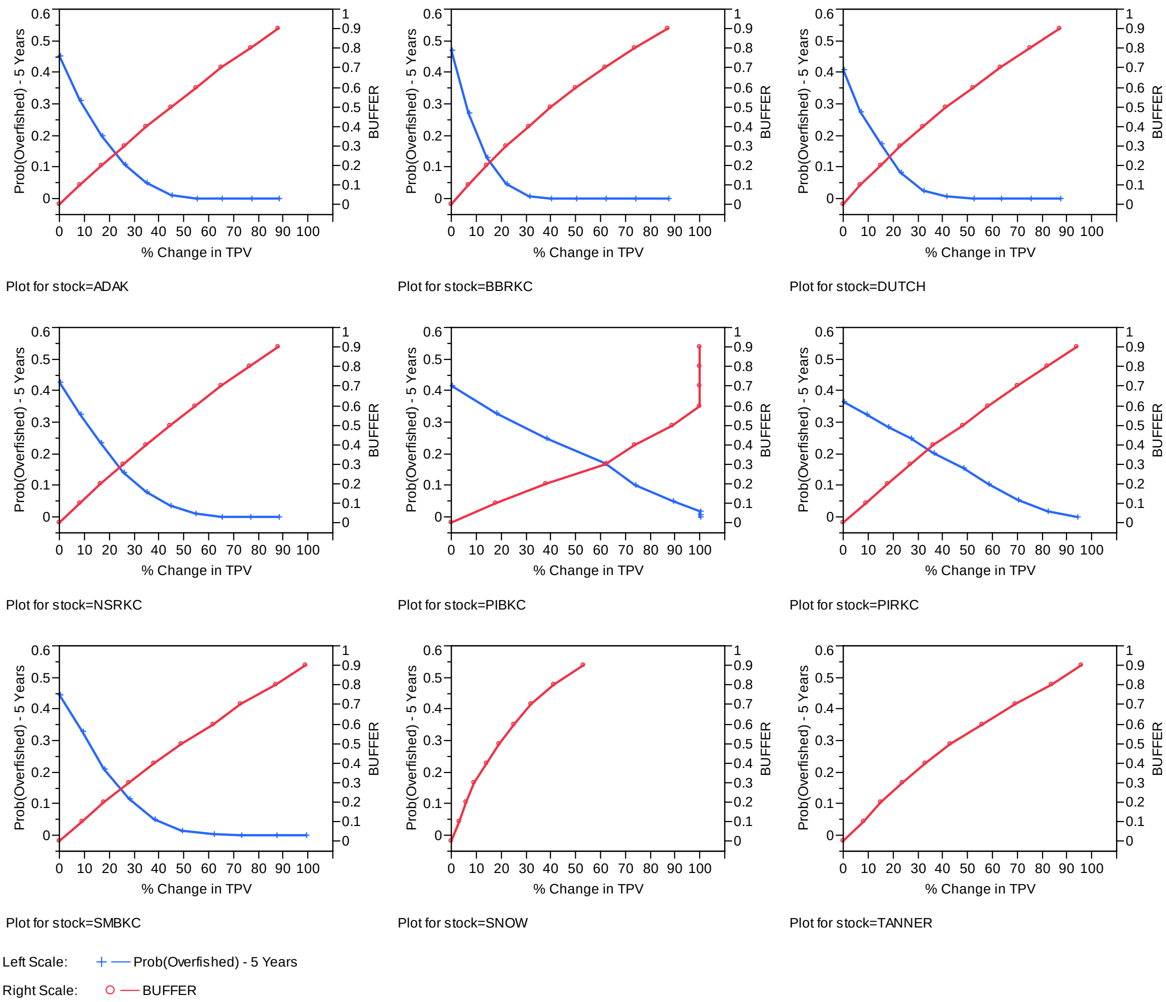


Figure ES-3 **ACL buffer size and estimated probability over 5 years that BSAI crab stocks will decline below the MSST overfished limit under ACL alternatives, compared to the estimated percentage change in total present value of crab production associated with reduced catch rates.**

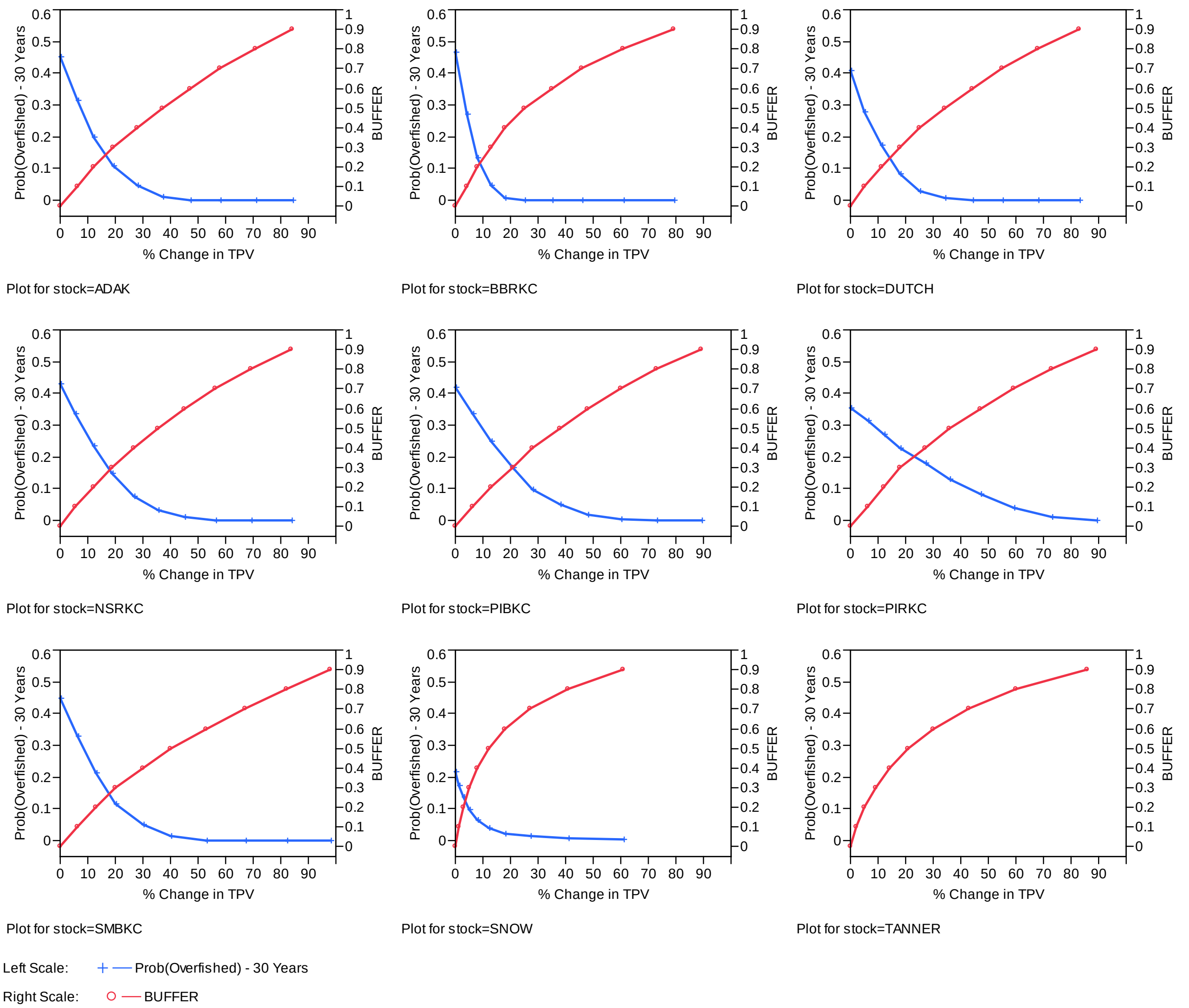


Figure ES-4 ACL buffer size and estimated probability over 30 years that BSAI crab stocks will decline below the MSST overfished limit under ACL alternatives, compared to the estimated percentage change in total present value of crab production associated with reduced catch rates.

Action 2: Rebuilding Plan for Snow Crab stock

The purpose of this proposed action is to rebuild the snow crab stock. Several alternatives are considered under Action 2, which are framed in terms of the time frames necessary to rebuild the stock.

Alternative 1: No Action [preferred]

This is the no action alternative and would maintain the existing rebuilding plan. In October 2010, the Council recommended no action to modify the rebuilding plan. The Council recognized that the NS1 Guidelines impose a constraint on total removals of the lesser of the F associated with the existing rebuilding plan or 75% F_{OFL}, and that this along with the State of Alaska's rebuilding harvest strategy will remain in effect until the stock is rebuilt. The SSC indicated that Alternative 1 was adequate to rebuild the snow crab stock, based on the stock assessment and this analysis. The Council also recognized that snow crab is not overfished and the current stock assessment estimates that snow crab biomass is approximately 96% of B_{MSY}, the level at which the stock would be considered rebuilt. In addition, the

Council considered the results of the 2010 assessment indicating that, retrospectively, the mature male biomass had never dropped below the MSST.

Alternative 2: Set target rebuilding time frame (T_{TARGET}) based on the minimum number of years necessary to rebuild the stock.

This alternative would set T_{TARGET} based on minimum number of years necessary to rebuild the stock, under the current assessment of the snow crab stock, if all sources of fishing-related mortality are set to zero.[11]

For example, the current estimate of the minimum number of years to recover to the biomass level estimated to produce maximum sustainable yield (noted as B_{MSY}) for one year (i.e. under assumption of a catch corresponding to 75% of F_{OFL} through 2010/11 and implementing F=0 beginning in the 2011/12 fishing year) is 2012/13. The minimum number of years is the same with very low levels of removals (equivalent to estimated bycatch mortality in other fisheries).

Alternative 3 and Alternative 4: Set T_{TARGET} above the minimum number of years (between 1 above the minimum and T_{END}).

Under these alternatives, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{TARGET} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{TARGET} would be the year in which the probability of rebuilding is 50%.

The timeframes associated with the alternatives are the following:

Alternative 3: 3 years to rebuild (T_{TARGET} = time of mating 2013/14)
Alternative 4: 4 years to rebuild (T_{TARGET} = time of mating 2014/15)

In addition to these alternatives, options are considered that would increase the probability of rebuilding by the agreed T_{TARGET}. Increasing probability of rebuilding for a given T_{TARGET} is achieved through either extending the time frame for rebuilding (option 1) or through directed fishery harvest constraints (options 2 and 3).

Under these options, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{TARGET} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{TARGET} would be the year in which the probability of rebuilding is 50%.

Options to increase probability of rebuilding:

- option 1: increase probability of rebuilding to 70% by increasing time frame to T_{END} to 8 years.
- option 2: increase probability of rebuilding to 75% by T_{TARGET}.
- option 3: increase probability of rebuilding to 90% by T_{TARGET}.

Under option 1, the probability of rebuilding would be increased to 70% by extending the time frame for T_{END} while retaining the maximum fishing mortality constraint of 75% F_{OFL} for 3 additional years from the Alternative 4. Under options 2 and 3, the time frame to rebuild cannot be extended to increase the

[11] Recovery by the minimum T_{TARGET} could occur with low levels of catch although this would decrease the probability of rebuilding by T_{END}.

probability of rebuilding higher than under option 1 thus these options would require a more constraining maximum fishing mortality rate than the 75% F_{OFL} assumed under the other alternatives and option 1.

Option for defining stock as 'rebuilt' as one-year above B_{MSY} - preferred

This option provides for a definition of the snow crab stock being 'rebuilt' as the first year that the estimated biomass is above B_{MSY} rather than the second consecutive year as currently defined. The Council identified this option as its preferred alternative for defining 'rebuilt' under the rebuilding plan. The SSC recommended that a threshold of one year above B_{MSY} is a appropriate for crab stocks with a stock assessment model. The summary of year-ending target dates under the range of alternatives and options in Table ES-6 assume the one year definition. Additional timeframes for rebuilding under the current two years above B_{MSY} definition are shown in chapter 4.

Summary of impacts of Action 2

For snow crab, this analysis considered the ACLs and rebuilding strategies simultaneously. First, the probability of rebuilding under different P* and buffer values was estimated. The earliest year the stock would be expected to rebuild under F=0 is estimated to be 2012/13 (Alternative 2), while the latest year the stock would be expected to rebuild is 2014/15, fishing at the maximum permissible $F=0.75F_{OFL}$ (Alternative 4). The time frames and the relative probability of rebuilding for each alternative and option are summarized below for the 2009 stock assessment model (Table ES-6). The probability of rebuilding assumes the definition of rebuilt in which calculated biomass must be above the B_{MSY} estimate for one year before the stock is considered 'rebuilt'. Additional results for the current definition of rebuilt (second consecutive year above the B_{MSY} estimate) are shown in chapter 4 of this analysis.

Table ES-6 The relative probability of rebuilding, year-end date in crab fishing year for rebuilding (one year above B_{MSY} definition), and resulting buffer value necessary to rebuild in this time frame for each alternative.

Alternative	Probability of rebuilding	T_{TARGET} year-ending date	Buffer value of F_{OFL} [12]
Alternative 1 (no action)	0.646(50% probability)	2014/15	25%
Alternative 2 (T_{MIN})	0.508(50% probability)	2012/13	100%
Alternative 3	0.5(50% probability)	2013/14	58%
Alternative 3-Option 2	0.751 (75% probability)	2013/14	85%
Alternative 3-Option 3	0.91 (90% probability)	2013/14	97%
Alternative 4 (T_{END})	0.646 (50% probability)	2014/15	25%
Alternative 4-Option 2	0.756 (75% probability)	2014/15	53%
Alternative 4-Option 3	0.91 (90% probability)	2014/15	78%
Alternative 4-Option 1	0.864 (70% probability)	2019/20	25%

For all options, the values for the probability of rebuilding for each year of the rebuilding period and the associated rebuild fishing mortality rate would be calculated annually using the most recent assessment of the snow crab stock, as recommended by the SSC. The CPT, SSC, and Council will annually review progress towards rebuilding and recommend adjustments to the fishing mortality rates on which management decisions are based consistent with the intent of the chosen alternative and progress towards rebuilding. If rebuilding to B_{MSY} does not occur by T_{END}, then the maximum F will be the *rebuilding F*, the F of the final year, or 75% of F_{OFL}, whichever is lower.

[12] This buffer value will vary annually to remain on the trajectory for rebuilding by the target date (and target probability level).

Summary of impacts on other marine resources and cumulative effects (Actions 1 and 2)

Effects of the crab fisheries, as prosecuted under the Crab Rationalization Program, on the physical and biological environment (including effects on benthic species and habitat, essential fish habitat, the ecosystem, endangered species, marine mammals, and sea birds) are fully analyzed in Chapter 4 of the Crab EIS. That analysis is incorporated by reference. The Crab EIS concludes that for all of the components of the environment analyzed, the direct and indirect effects of the crab fisheries are insignificant based on the best available scientific information. Due to the nature of this action, using ACLs and AMs to prevent overfishing, the crab fisheries are not predicted to have additional impacts beyond those identified in the Crab EIS. No new significant information is available that would change these determinations in the Crab EIS. New information on the crab stocks, crab fisheries, and the interrelationship crab and the ecosystem, including changes in the marine environment, is annually updated and published in the SAFE report. New information relevant to this action is provided in this EA.

Changes in interactions with other fish species, marine mammals, seabirds, and the ecosystem are linked to changes in target crab fishery efforts. As described above, overall fishing effort in the crab fishery is expected to remain the same or to decrease under Actions 1 and 2. The harvest levels for all crab species, under any alternative, would remain the same or would be constrained. Further, no changes to the distribution of crab fisheries are anticipated under the proposed actions. To the extent that crab fishing effort is reduced, and consequently adverse interactions with incidental catch species though bycatch or disturbance are also reduced, there could be some benefit to these species. Any effects on incidental catch species, however, should not be significant under either Action 1 or 2 with any associated alternative and option.

The effects of the two proposed actions on marine mammals, seabirds, and their habitat are considered insignificant and are not expected to alter the current rates of interaction beyond those already evaluated because overall fishing effort in the crab fishery is expected to remain the same or to decrease. The proposed actions and alternatives would not affected the spatial and temporal concentration effects by these fisheries, vessel traffic, gear moving through the water column, or underwater sound production which could affect marine mammal foraging behavior. The effects of these Alternatives on seabirds are considered insignificant and are not expected to affect current rates of interaction. No changes in the indirect effects of fisheries on prey (forage fish) abundance and availability, benthic habitat as utilized by seabirds, and processing of waste and offal, all of which could affect seabirds, are expected under these actions and alternatives.

The cumulative effects section of this analysis describes additional past, present, or reasonably foreseeable future actions. The reasonably foreseeable future actions are the following:

- Tanner crab rebuilding plan;
- Pribilof Island blue king crab rebuilding plan;
- Revisions to the Crab Rationalization Program; and
- Management measures to address crab bycatch in the groundfish fisheries.

The Tanner crab and Pribilof Island blue king crab rebuilding plans are currently under development by the Council and NMFS, and include alternatives that could further constrain the catch of those crab stocks. The analyses for the rebuilding plans will follow the Council's adoption of a preferred alternative on ACLs and will take into account any reductions in harvest levels attributable to the implementation of ACLs in the discussion of impacts.

Currently, there are no hard caps on crab bycatch in the groundfish fisheries, although area closures with associated catch limits are utilized to reduce bycatch. AMs are a required provision of the MSA in conjunction with provisions for ACL requirements. The intent of AMs are to further protect a crab stock from overfishing by providing for a transparent response mechanism in the event that the established ACLs are exceeded. Without further Council action, any exceedance of the ACL cause by crab bycatch in the groundfish fisheries will be accounted for by reducing harvest in the directed crab fisheries. In June 2010, the Council initiated an analysis of crab bycatch caps and time area closure to control crab bycatch in BSAI groundfish fisheries.

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
ABC	Acceptable Biological Catch
ACL	Annual Catch Limit
ADF&G	Alaska Department of Fish and Game
AFA	American Fisheries Act
AFSC	Alaska Fisheries Science Center
AIGKC	Aleutian Islands golden king crab
AM	Accountability Measure
AP	advisory panel
B	biomass
Board	Board of Fisheries
BBRKC	Bristol Bay red king crab
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	Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs
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
MMB	mature male biomass
MSA	Magnuson-Stevens Fishery Conservation and Management Act
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)
NS1	National Standard 1
OFL	overfishing level
OY	optimum yield
PIBKC	Pribilof Island blue king crab
PIRKC	Pribilof Island red king crab
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
SMBKC	St. Matthew blue king crab
SOA	State of Alaska
SPR or S-R	spawner per recruit
SSC	Scientific and Statistical Committee
State	State of Alaska
TAC	total allowable catch
TMB	total mature biomass
TPV	total present value
U.S.	United States
USFWS	United States Fish and Wildlife Service
WAI	Western Aleutian Islands

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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 or NPFMC) under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act or MSA). The Secretary of Commerce (Secretary) first approved the FMP on June 2, 1989.

The FMP establishes a state/federal cooperative management regime that defers many aspects of 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.

There are two proposed actions contained in this analysis. The first proposed action would establish annual catch limits (ACLs) and accountability measures (AMs) to meet Magnuson-Stevens Act requirements. ACLs would be established based upon acceptable biological catch (ABC) control rules which account for the uncertainty in the overfishing level (OFL) point estimate and any other scientific uncertainty. To meet the ACL requirements, the Council considered alternatives that establish ABCs and ACLs such that ACL = ABC. The ABC control would be used for the annual calculation of the maximum ABC. Annually, the Scientific and Statistical Committee (SSC) would recommend ABCs for crab stocks at or below the maximum ABC.

The second proposed action is a revised rebuilding plan for the eastern Bering Sea snow crab stock. On September 24, 2009, the NMFS Alaska Region notified the Council that the snow crab stock would not be rebuilt by the end of the rebuilding time frame of 2009/10, and that a revised rebuilding plan must be developed for that stock and implemented within two years of that notification.

Both actions must be implemented prior to the start of the 2011/12 crab fishing year. They are considered together in this analysis as the implementation timing is identical and the actions themselves are related in the interplay between rebuilding plan catch constraints and ACL catch constraints for the snow crab stock. For the remaining nine BSAI crab stocks for which rebuilding provisions are not considered in this analysis, only Action 1 (establishment of ACLs) applies.

Additionally, Pribilof Islands blue king crab remains overfished. The current rebuilding plan has not achieved adequate progress to rebuild the stock by 2014. The Pribilof Islands blue king crab fishery has remained closed since 1999 and bycatch mortality in 2008/09 was below the overfishing level. To comply with section 304(e)(7) the Magnuson-Stevens Act, the Council is preparing an amended Pribilof Islands blue king crab rebuilding plan. This rebuilding plan will be analyzed in a separate document because the primary rebuilding alternatives address bycatch in groundfish fisheries.

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 federal implementing regulations and, therefore, the Regulatory Flexibility Act does not apply, and review under Executive Order 12866 is not required.

1.1 Purpose and Need

The purpose of these proposed actions is to reduce the risk of overfishing and maintain healthy BSAI crab stocks that will provide optimum yield over the long term, in compliance with the Magnuson-Stevens Act and the NS1 Guidelines.

Action 1

The proposed action is to amend the FMP to specify the method by which the Council will establish ACLs and AMs to meet the requirements of the revised Magnuson-Stevens Act, as detailed in section 1.2. The FMP would set forth an ABC control rule that accounts for the uncertainty in the OFL point estimate and other specified sources of scientific uncertainty. ACLs would be set equal to the ABC. To meet the MSA requirements, the SSC would annually recommend the ABC for each crab stock.

The Council approved the following problem statement for this analysis in October 2010.

On January 16, 2009, NMFS issued final guidelines for National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). They provide guidance on how to comply with new annual catch limit (ACL) and accountability measure (AM) requirements for ending overfishing of fisheries managed by federal fishery management plans. Annual catch limits are amounts of fish allowed to be caught in a year. A legal review of the BSAI King and Tanner Crab FMP found there were inadequacies in the FMP texts that need to be addressed. Several work groups (e.g., ABC/ACT Control Rules, Vulnerability Evaluations) have been created to produce reports on how to carry out the more technical components of the NS1 Guidelines. Statutory deadlines require compliance with the MSA by the start of the 2011 fisheries although these reports have not been finalized.

This action is necessary to facilitate compliance with requirements of the MSA to end and prevent overfishing, rebuild overfished stocks and achieve optimum yield. This action also recognizes and maintains the unique joint state-federal cooperative management structure of the BSAI King and Tanner FMP.

Action 2

The purpose of this proposed action is to rebuild the snow crab stock in compliance with section 304(e)(3) of the Magnuson-Stevens Act. Snow crab mature male biomass (MMB) was below B_{MSY} in 2008/09 and preliminary analysis indicates that it remained below B_{MSY} in 2009/10, the last year of the ten-year rebuilding period specified in the FMP. Therefore, this stock did not rebuild within the rebuilding period. This action is designed to meet the requirement under section 304(e)(4) of the Magnuson- Stevens Act: to rebuild the stock in as short a time as possible while accounting for the needs of fishing communities and the status and biology of the snow crab stock.

1.2 Magnuson-Stevens Act and National Standard Guidelines

The Magnuson-Stevens Act sets forth ten national standards for fishery conservation and management. 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."

16 U.S.C. 1851(a)(1). The specification of OY and the conservation and management measures to achieve it must prevent overfishing. NMFS published National Standard Guidelines (50 CFR 600.310-600.355) to provide comprehensive guidance for the development of FMPs and FMP amendments that comply with the Magnuson-Stevens Act national standards.

On January 12, 2007, the President signed into law the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA, Public Law 109-479), which amended the Magnuson-Stevens Act. The MSRA includes provisions intended to prevent overfishing by requiring that FMPs establish a mechanism for specifying ACLs 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. ACLs and AMs were required by fishing year 2010 if overfishing was occurring in a fishery, and they are required for all other fisheries by fishing year 2011. Since overfishing is not occurring for any crab stock, all crab fisheries must have ACL and AM mechanisms by the 2011/12 crab fishing year. The MSRA includes a requirement for the SSC to recommend ABC levels to the Council, and provides that ACLs may not exceed the fishing levels recommended by the SSC. The MSRA also amended section 304(e)(3) of the Magnuson-Stevens Act, which now requires the Council and Secretary to develop and implement a rebuilding plan within two years of receiving notification from the Secretary that a stock is overfished, approaching an overfished condition, or has not made adequate progress towards rebuilding.

On January 16, 2009, NMFS published a final rule to amend the National Standard 1 Guidelines (NS1 Guidelines) to provide guidance on how to comply with the new ACLs and AMs to end overfishing of fisheries managed under fishery management plans (74 FR 3178; 50 CFR 600.310). The NS1 Guidelines clarify the relationship between ACLs, ABCs, OFLs, MSY, OY, and other applicable reference points. The proposed Alternatives 2, 3, and 4 under Action 1 were developed according to these amended guidelines.

These changes to the Magnuson-Stevens Act and the NS1 Guidelines prompted the Council, with extensive involvement of the Crab Plan Team (CPT), and in consultation with NMFS Alaska Region and NOAA General Counsel, to consider amending the Council's FMP. At the outset of this consultative process, the Council developed action plans that targeted areas where the FMP appeared non-compliant with the new requirements.[13] The alternatives currently under consideration were developed specifically in order to satisfy the new legal requirements imposed by these amendments to the Magnuson-Stevens Act while preserving the existing co-management regime of the FMP to the extent possible.

The provisions of the Magnuson-Stevens Act, as amended in 2007, establish, either expressly or by logical extension, five basic requirements that relate to the FMP and require some action to amend the FMP.[14] These five requirements may be paraphrased as follows:

(1) The FMP must provide for the specification of ACLs that will prevent overfishing;

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[13] See http://www.alaskafisheries.noaa.gov/npfmc/current_issues/ACL/ACLactionsCrabFMP509.pdf.

[14] NS1 Guidelines provide guidance to Councils about how to satisfy the obligations newly imposed under the 2007 amendments to the Magnuson-Stevens Act. Pursuant to the Magnuson-Stevens Act, the National Standard Guidelines are advisory. 16 U.S.C. 1851(b). Nonetheless, the NS1 Guidelines reflect mandates imposed by the Act and present "the Secretary's interpretation of the national standards so that [the Councils] will have an understanding of the basis on which FMPs will be reviewed" for consistency with legal requirements. 50 CFR 600.305(a)(2). The Guidelines employ the word "must" "to denote an obligation to act; it is used primarily when referring to requirements of the Magnuson-Stevens Act, the logical extension thereof, or of other applicable law." 50 CFR 600.305(c)(1) (emphasis added).[14] This document identifies several of the obligations under the Magnuson-Stevens Act that are denoted in the NS1 Guidelines as steps that "must" be taken.

(2) The FMP must establish measures that will ensure adherence to ACLs, which, at a minimum, address any overages that may occur;
(3) The Council must establish an ABC control rule based on the scientific advice of its SSC, and which accounts for relevant sources of scientific uncertainty, and the FMP must describe the ABC control rule;
(4) The Council's SSC must provide the Council with periodic recommendations for specifying the ABC for each fishery; and
(5) The FMP must describe the MSY and assess and specify the OY for the fishery.

These five requirements and the statutory and regulatory underpinnings for each of them are addressed below. The five general requirements relate to express statutory mandates and provisions of the Guidelines that employ the term "must" to address "obligation[s] to act" based on the requirements of the Magnuson-Stevens Act and "the logical extensions thereof," as determined by NMFS (50 CFR 600.305(c)(1)).

1. The FMP must establish a mechanism for specifying ACLs that will prevent overfishing.

As amended, the Magnuson-Stevens Act, ***at section 303(a)(15)***, provides that

> "***Any fishery management plan which is prepared by any Council, or by the Secretary, with respect to any fishery, shall . . . 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***." 16 U.S.C. 1853(a)(15).

The FMP must provide for the annual establishment of catch limits that have legal effect and that will prevent overfishing.

The NS1 Guidelines (74 FR 3204; 50 CFR 600.310) elaborate on how to determine, substantively, that catch limits are set at levels "***such that overfishing does not occur in the fishery***." In short, the Guidelines establish a framework which ensures that catch limits are scientifically based and, whenever possible, that the catch limit can be expected to prevent overfishing (i.e., it is likely that a total catch equal to the catch limit will not result in actual overfishing). The Guidelines state that the FMP must describe "***Mechanisms for specifying [annual catch limits (ACLs)] . . . in relationship to the [acceptable biological catch (ABC)] . . . .***" 50 CFR 600.310(c)(4). The ***"ACL cannot exceed the ABC . . . ."*** 50 CFR 600.310(f)(5). Where it is possible to assess the probability that a catch equal to the ABC will result in overfishing, ***"[t]his probability that overfishing will occur cannot exceed 50 percent and should be a lower value***." 50 CFR 600.310(f)(4). Provided that there is an ABC control rule which meets the requirements identified above, establishing an ACL at or below the ABC should ensure that the limit is established at a level that can be expected to prevent overfishing from occurring in a given year, as required by ***section 303(a)(15)*** of the Magnuson-Stevens Act, 16 U.S.C. 1853(a)(15).

Thus, the Guidelines rely on a process for establishing a scientifically based ABC amount to ensure that catch limits are scientifically based and do not lead to inadvertent overfishing. As described below, the Magnuson-Stevens Act expressly prescribes a role for the Council's SSC in recommending ABC amounts, and by implication, mandates the specification of ABC amounts for each stock in the fishery.

2. The FMP must establish measures to ensure adherence to ACLs, including, at a minimum, measures to address any overages that occur.

The NS1 Guidelines also provide further detail regarding the statutory requirement to establish "***measures to ensure accountability***" with ACLs, ***section 303(a)(15) of the Magnuson-Stevens Act***, 16 U.S.C. 1853(a)(15). When an ACL has been exceeded, accountability measures "***must be triggered and implemented as soon as possible to correct the operational issue that caused the ACL overage as well as any biological consequences to the stock or stock complex resulting from the overage when it is known***." 50 CFR 600.310(g)(3). This provision of the Guidelines echoes the legislative history of the 2007 amendments to the Magnuson-Stevens Act regarding the mandate to establish "***measures to ensure accountability***" with ACLs. *See* S. Rep. No. 109-229 (April 4, 2006) ("the Committee determined that, to ensure compliance with the 1996 amendments, S. 2012 needed to require that: . . . (2) any catch in excess of [the annual catch] limit (overages) should be deducted from the following year's catch limit through appropriate management measures."). In sum, FMPs must establish accountability measures that address the causes and consequences of overages of ACLs.

3. The FMP must contain an ABC control rule for each stock in the fishery, which accounts for relevant scientific uncertainty, including the uncertainty in the estimate of the overfishing level.

The NS1 Guidelines state that the FMPs must describe an ABC control rule for each stock in the fishery and prescribes two substantive aspects of the control rule. "***For all stocks and stock complexes that are 'in the fishery' . . ., the Councils must evaluate and describe [an ABC control rule] in their FMPs and amend the FMPs, if necessary, to align their management objectives to end or prevent overfishing . . . .***" 50 CFR 600.310(c)(3); *see also* 50 CFR 600.310(f) ("***The following features (see paragraphs (f)(1) through (f)(5) of this section) of acceptable biological catch and annual catch limits apply to stocks and stock complexes in the fishery..***"); *see also* 50 CFR 600.310(f)(4) ("***For stocks and stock complexes required to have an ABC, each Council must establish an ABC control rule based on scientific advice from its SSC***.").[15] In addition, where it is possible to assess the probability that a catch equal to the ABC will result in overfishing, ***"[t]his probability that overfishing will occur cannot exceed 50 percent and should be a lower value."*** *Id*. Finally, the ABC control rule "***must articulate how the ABC will be set compared to the OFL based on . . . the scientific uncertainty in the estimate of OFL and any other scientific uncertainty***." *Id*.

4. The Council's SSC must recommend ABC amounts for stocks in the fishery.

Two procedural requirements introduced by the 2007 amendments to the Magnuson-Stevens Act relate to the process for establishing ACLs. First, the Magnuson-Stevens Act, at ***section 302(g)(1)(B)***, now expressly requires the Council's SSC to provide recommendations for ABC for the Council's managed fisheries.

> ***"Each scientific and statistical committee shall provide its Council ongoing scientific advice for fishery management decisions, including recommendations for acceptable biological catch . . . ."*** 16 U.S.C. 1852(g)(1)(B).

Additionally, for the ACLs specified for each fishery via the mechanism established in the Council's FMP, ***section 302(h)(6) of the Magnuson-Stevens Act states that***

> ***"Each Council shall, in accordance with the provisions of this Act… develop annual catch limits for each of its managed fisheries that may not exceed the fishing level recommendations of its scientific and statistical committee or the peer review process established under subsection (g) . . . ."*** 16 U.S.C. 1852(h)(6).

[15] The obligation to establish an ABC control rule is implicit in, and logically derives from, the express statutory requirement for the SSC to recommend an ABC to the Council, 16 U.S.C. 1852(g)(1)(B).

While the meaning of "fishing level recommendations" is not precisely clear on its face, this provision is best construed as precluding the Council from specifying an ACLs that exceeds the ABC recommended by the SSC pursuant to section 302(g)(1)(B) of the Magnuson-Stevens Act, 16 U.S.C. § 1852(g)(1)(B).

NMFS has indicated that this provision's reference to a "fishing level recommendation" is best construed as the ABC recommended by the SSC. "Of the several required SSC recommendations (Magnuson-Stevens Act 302(g)(1)(B)), the ABC is most directly applicable as the constraint on the Council's ACL." 74 FR 3189; January 16, 2009; *see* 50 CFR 600.310(b)(2)(v)(D) ("***The SSC recommendation that is most relevant to ACLs is ABC, as both ACL and ABC are levels of annual catch***."); *see also* 74 FR 3189 ("the ABC is the appropriate constraint on ACL because it is the annualized result of applying that control rule"). The legislative history of the 2007 amendments supports NMFS's construction. *See* S. Rep. No. 109-229 at *3 ("The following major recommendations of the Commission for the reauthorization of the Magnuson-Stevens Act were a catalyst for moving the legislation forward and were incorporated into S. 2012: Require the Councils to make management decisions based on the findings of their scientific and statistical committees (SSCs). . . . Require each Council to set harvest limits at or below the allowable biological catch determined by its SSC.").

NOAA General Counsel provided the Council with a requested legal memorandum in April 2010,[16] which set forth these procedural requirements and explained their application in the context of an FMP that delegates to the State of Alaska the function of setting the TAC for the fishery. The legal memorandum concluded the SSC must provide ABC recommendations to the Council, as prescribed by the Magnuson-Stevens Act, and that such recommendations would constrain the applicable ACL, irrespective of whether the State of Alaska or the Council ultimately specifies such limits.

Thus, substantively, the FMPs must include a mechanism for establishing ACLs that will prevent overfishing, along with measures to ensure accountability. In addition, procedurally, the SSC must recommend amounts of ABC for the stocks in the fishery on an ongoing (e.g., annual) basis, and the ACL may not exceed the SSC's fishing level recommendations.

These procedural steps are set forth in mandatory terms in the Magnuson-Stevens Act. They represent a chosen means to further Congress's goal— to ensure that scientifically based catch limits are established. *See, e.g.*, S. Rep. No. 109-229 at *7 ("After numerous meetings and discussions with the Councils, industry, and conservation groups, the Committee determined that, to ensure compliance with the 1996 amendments, S. 2012 needed to require that: (1) scientifically established annual catch limits be set and adhered to in each managed fishery"); *id*. at *3 (quoted above).

5. The FMP must describe the MSY and assess and specify the OY for the fishery.

The NS1 Guidelines require that each FMP include an estimate of MSY and specify the OY from the fishery. "***Each FMP must include an estimate of MSY for the stocks and stock complexes in the fishery, as described in paragraph (d)(2) of this section***." 50 CFR 600.310(e)(1). "***An FMP must contain an assessment and specification of OY, including a summary of information utilized in making such specification, consistent with the requirements of section 303(a)(3) of the Magnuson-Stevens Act***." 50 CFR 600.310(e)(3)(ii).

[16] Lisa Lindeman, Alaska Regional Counsel, Memorandum for the North Pacific Fishery Management Council re: Role of Scientific and Statistical Committee in Annual Catch Limit Determinations in Fishery Management Plans in which Total Allowable Catch Setting is deferred to the State of Alaska (April 8, 2010).

1.3 Scope of Analysis

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 2004, Crab EIS), which is available on the NMFS Alaska Region web site.[17] Additional information concerning the crab fisheries and management under the Crab Rationalization Program, and impacts of these on the human environment are contained in that document.

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.

The Crab EIS analyzes the impacts of the crab fisheries on the human environment. Effects of the crab fisheries and the Crab Rationalization Program on the physical and biological environment (including effects on benthic species and habitat, essential fish habitat, the ecosystem, endangered species, marine mammals, and sea birds) are fully analyzed in Chapter 4 of the Crab EIS. That analysis is incorporated by reference. The Crab EIS concludes that for all of the components of the environment analyzed, the direct and indirect effects of the crab fisheries and the Crab Rationalization Program are insignificant based on the best available scientific information.

This EA tiers off of the Crab EIS to focus the analysis on the issues ripe for decision and eliminate repetitive discussions. The proposed actions would establish ACLs for the crab stocks under the FMP and a rebuilding plan for snow crab. This EA details the specific impacts of the proposed actions on each managed crab stock. Chapter 14 analyzes the impacts of the alternatives on other marine resources and Chapter 15 analyzes the cumulative effects.

In addition to the factors discussed in the Crab EIS, this action specifically concerns the annual establishment of ACLs using a tier system approach to establish status determination criteria for the crab stocks under the FMP. Relevant and recent information on each crab stock is contained in this EA 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 or environmental analyses incorporating by reference the general discussions and concentrating solely on the issues specific to the statement subsequently prepared." This section of the CEQ regulations further notes that tiering is

[17] http://www.alaskafisheries.noaa.gov/sustainablefisheries/crab/eis/default.htm

appropriate "when the sequence of statements or analyses 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 EA prepared for Amendment 24 (NMFS 2008). Amendment 24 amended the FMP to establish overfishing definitions that contain objective and measurable criteria for each managed crab stock. The amendment also removed twelve state-managed crab stocks from the FMP. The EA provides an evaluation of the environmental, social, and economic impacts of alternative overfishing definitions and removing specific stocks from the FMP. The EA is available on the NMFS Alaska Region web site.[18]

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.[19] The SAFE Reports contain the status of the crab stocks, and the annual stocks assessments for all ten stocks.

[18] http://www.alaskafisheries.noaa.gov/analyses/amd24/KTC24finalea0508.pdf.
[19] http://www.alaskafisheries.noaa.gov/npfmc/SAFE/SAFE.htm or http://www.alaskafisheries.noaa.gov/npfmc/membership/planteams/ CPT/CRABSAFE09.pdf.

2 Description of Alternatives

This chapter provides an overview of the actions and associated alternatives and options under consideration in this analysis as well as those considered but not carried forward for further analysis at this time. There are two actions under consideration in this analysis; Action 1 - ACLs and AMs for all 10 BSAI crab stocks and Action 2 - Rebuilding plan for the EBS snow crab stock.

2.1 Action 1: Establish ACLs and AMs for 10 Crab stocks

This action addresses the statutory requirements described in chapter 1 to establish ACLs and AMs for the ten crab stocks under the FMP. Four alternatives are considered under this action: Alternative 1- status quo (the no action alternative); Alternative 2- constant buffer approach; Alternative 3- variable buffer approach; and Alternative 4- blended approach by tier. A range of options are contained under Alternatives 2 and 3.

2.1.1 Alternative 1- Status quo

Alternative 1 would continue the current practice of annually establishing OFLs for the 10 BSAI crab stocks and does not establish ABCs or ACLs below these values. The SSC annually reviews crab stock status and recommends tiers and model parameters. The State establishes directed harvest levels (TACs or GHLs) for each stock at or below the OFL. The SSC does not review the harvest control rules for setting TACs/GHLs.

In June 2010, the Council identified status quo as their preliminary preferred alternative and requested that staff describe how current State management could be used in satisfying the new required provisions of the Magnuson-Stevens Act and NS1 Guidelines. The EA was revised to include a more robust discussion of status quo from which the Council could develop the recommended Alternative 4. Appendix 4 contains a more detailed discussion of the Council's June action.

Flexibility and expertise exercised by the State in managing BSAI crab fisheries is acknowledged in the FMP and is the basis for deferral of management authority to the State. On an annual basis the State conducts a review of current crab stock status trends, biomass estimates, stock distribution, and fishery performance. Evaluation of the scientific uncertainty inherent in each of these estimates is an integral component of State crab management. This vetting process allows the best available scientific information to be integrated into the State's application of its harvest control rules when setting annual TACs/GHLs. Harvest limits are evaluated relative to the OFL for a given stock and are buffered to account for management uncertainty, including bycatch mortality, as well as uncertainty in the biomass estimates. Establishment of a TAC buffered for uncertainty is an accountability measure meant to insure that the stock does not experience overfishing. The State implements other, flexible inseason accountability measures such as closures, time and area restrictions, and gear limits to insure that TAC is not exceeded. Post season data review may trigger additional accountability measures in the following fishing season.

Following approval of Amendment 24 to the FMP in 2008, BSAI crab stocks have had annual stock assessments produced. These assessments provide the Council and the public with information necessary to assess the status of the stocks and are used for annual stock status determination by NMFS. Individual stock assessment chapters are summarized and compiled by the CPT into a SAFE report which is presented to the SSC and Council. The SAFE report is intended to summarize the best available scientific information concerning past, present, and possible future condition of the stocks, marine ecosystem, and fisheries under federal management. The guidelines for FMPs prepared by NMFS require that a SAFE report be prepared and reviewed annually for each FMP.

In addition to providing an assessment of stock status, the SAFE report includes the annually estimated OFL for each stock, the B_{MSY} and MSST estimates for those stocks where this status determination is available, as well as catch in relation to OFL for the previous year to determine whether overfishing occurred. SAFE reports are available on the Council's web site.[20]

Annually, the OFL for each of the 10 BSAI crab stocks is computed using the five-tier system detailed in Table 3-1 and Table 3-2. Table 2-1 shows the 10 crab stocks under the FMP and the tier assignments for the 2011 stock assessment cycle. Stocks are assigned to one of the tiers based on the availability of information for that stock. No crab stocks have sufficient information to be in Tiers 1 or 2. Tier 3 stocks have sufficient information for the stock assessment model to estimate biomass and the biomass level and fishing rate necessary to achieve maximum sustainable yield. Tier 4 stocks have a stock assessment model that estimates biomass using the historical performance of the fishery and information from other stocks as necessary to estimate biological parameters. Tier 5 stocks have no reliable estimates of biomass and only historical catch data is available. Tier assignments and model parameter choices are recommended through the CPT process to the Council's SSC. Each June, the Council's SSC recommends the final tier assignments, stock assessment and model structure, and parameter choices, including whether information is "reliable" for the assessment authors to use for calculating the OFLs based on the five-tier system.

For Tiers 1 through 4, once a stock is assigned to a tier, the stock status level is determined based on recent survey data and assessment models, as available. The stock status level determines the control rule equation used in calculating the F_{OFL}. Three levels of stock status are specified and denoted by "a," "b," and "c" (see Table 3-1). The F_{MSY} control rule reduces the F_{OFL} as biomass declines by stock status level. At stock status level "a," current stock biomass exceeds the B_{MSY} (or the proxy for 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," current biomass is below β * (B_{MSY} or the proxy for $B_{MSY)}$. At stock status level "c," directed fishing is prohibited and an F_{OFL} at or below F_{MSY} (or proxy F_{MSY}) would be determined for all other sources of fishing mortality in the development of the rebuilding plan.

After the most recent survey data are incorporated and the status determinations made, the appropriate control rule is applied to calculate the OFL for the upcoming year. The CPT reviews the status determinations and resulting OFL in September. NMFS then determines the final OFLs prior to the October Council meeting to enable the State to announce TACs (at or below this OFL level such that TAC $\leq$ OFL) by October 1 for the fisheries that open on October 15.

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. Status determination and the resulting OFL control rule application are made in the spring for stocks for which annual summer trawl data are not available. These stocks include all Tier 5 stocks (where the OFL control rule is based upon average catch) as well as those stocks for which there is a summer fishery: Aleutian Islands golden king crab and Norton Sound red king crab.

For Tiers 1 through 4, any overage of an OFL should be reflected in a reduced OFL in the succeeding year, due to consideration of total annual catch in the stock assessment upon which the OFL is based. It is

[20] http://alaskafisheries.noaa.gov/npfmc/SAFE/SAFE.htm

not clear whether this reduced OFL would account for known biological consequences in all circumstances.

Table 2-1 BSAI crab stocks in the FMP and the current tier assignments.

<table>
<tr><th>Tiers</th><th>Stocks currently in these tiers in 2010 assessment cycle</th><th>FMP Crab Stocks (10)</th></tr>
<tr><td>1</td><td>None</td><td rowspan="5">Bristol Bay red king crab (BBRKC)
Snow crab
Tanner crab
St. Matthew blue king crab (SMBKC)
Pribilof Islands red king crab (PIRKC)
Pribilof Islands blue king crab (PIBKC)
Norton Sound red king crab (NSRKC)
Aleutian Islands golden king crab (AIGKC)
Pribilof Islands golden king crab (PIGKC)
Adak red king crab</td></tr>
<tr><td>2</td><td>None</td></tr>
<tr><td>3</td><td>BBRKC, Snow</td></tr>
<tr><td>4</td><td>Tanner, SMBKC, PIRKC, PIBKC,[21] NSRKC,</td></tr>
<tr><td>5</td><td>AIGKC, PIGKC, Adak RKC,</td></tr>
</table>

2.1.1.1 Establishing TAC and GHL under status quo

TAC and GHL levels are a Category 2 measure under the FMP and thus deferred to the State of Alaska. The FMP identifies five factors for the State to consider in TAC-setting: (1) estimates of exploitable biomass, (2) estimates of recruitment, (3) estimates of threshold, (4) estimates of MSY or OY, and (5) market and other economic considerations. The FMP does not expressly require the State to consider or account for uncertainty in the OFL estimate.

The following text reflects information received from ADF&G staff on the process employed in establishing annual harvest limits. Additional documentation from ADF&G for the referenced examples and process described are provided in Appendices 2 and 4.

The process employed by the State to establish annual harvest levels begins with a review of stock status indicators derived from the recent assessments, including estimates of B_{MSY} (or its proxy), MSST, critical biomass threshold, and OFL (including a breakdown of the total OFL into subcomponents – estimates of future retained catch, discard mortality in directed fisheries, and non-target fishery bycatch). The State also relies on guidance provided in the annual stock status notification letter prepared by the NMFS Alaska Region that summarizes stock status relative to overfishing, OFLs for the 10 FMP crab stocks, and special concerns for stocks under rebuilding plans. Annual biomass estimates in MMB provide a projection of stock status at the time of mating while the OFL estimate is a total catch level that may not be exceeded by the sum of all sources of fishing mortality. The OFL subcomponents provide additional information on the total catch OFL calculation for information relative to the directed fishing mortality estimate.

State harvest strategies consist of rules in state regulation for computing TAC from survey and stock assessment data. Harvest strategy elements may include: a stock threshold for opening the fishery, rules for setting exploitation rate on abundance/biomass of mature-sized males, an exploitation rate dependent on stock index estimated from survey data, a cap on legal male exploitation rate, and a minimum TAC for fishery opening. Both state harvest strategy thresholds and stock abundance or biomass estimates for computation of TACs reference stock biomass or abundance at the time of survey.

[21] Note that for Pribilof Islands blue king crab, since the directed fishery is closed, the OFL is set for bycatch only using the Tier 5 control rule (NPFMC 2010).

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

In setting TAC to maintain long-term reproductive potential and ensure that total removals do not exceed OFL, the State considers a range of factors in addition to strict application of the harvest control rules (see Appendix 3 for the approved harvest strategies for applicable stocks[22]). The following list represents a compilation of the factors considered during State evaluation of stock status and TAC-setting:

Survey considerations

- Timing of survey relative to norms
- Net mensuration data, trawl performance or irregularities, if not accounted for in the assessment model
- Stock distribution relative to norms and registration area boundaries
- Presence or absence of "hot spot" stations, their location and influence on populations estimates
- Precision of survey estimates
- Independent ADF&G pot survey data

Fishery considerations

- Present/recent distribution of fishery relative to historic distribution of fishery
- Fishery performance relative to preseason expectations (or past fishery performance)
- Size/shell condition frequency of retained catch relative to surveyed population
- Fishery selectivity
    - High-grading
    - Bycatch patterns (magnitude, sex/size/maturity composition, spatial distribution in directed and non-target fisheries
    - Potential for bycatch mortality
    - Area fished relative to survey distribution
- Monitoring tools, e.g., percentage observer coverage or port sampling
- Closed waters/refugia

Population dynamics/stock structure considerations

- Size frequency distribution (to achieve a stock comprised of various size/age classes)
- Potential for future recruitment to legal and mature-size classes (consideration of environmental conditions on stock)
- Shell condition
- Average weight at time of fishery and survey
- Cohort strength

[22]Note that harvest control rules are not directly comparable to OFL control rules as OFL control rules use MMB as the biomass measure while State harvest control rules vary by stock in the use of benchmarks, such as total mature biomass (snow crab), surveyed mature female biomass (Tanner crab), effective spawning biomass (Bristol Bay red king crab), mature male biomass (St. Matthew blue king crab), abundance of legal males (Norton Sound red king crab), and estimated spawning biomass (Pribilof Islands blue king crab). There are no state harvest control rules for Pribilof Islands red king crab, Adak red king crab, or Pribilof Islands golden king crab.

- Presence or absence of disease
- Indices of reproductive capacity
- Proportion of females mated and clutch size
- Adequacy of male-female ratio; present male-female ratio relative to historic patterns

Not all of these factors apply to every stock nor are all factors relevant each year. Each variable may be weighted independently based on stock-specific considerations, and there may be interactions among several of these factors. Full consideration of the range of stock status indices includes both qualitative discussion and quantitative response applied during TAC setting. Many of the factors listed above may be expressed quantitatively; specific examples of quantitative response include adjustments to biomass estimates to account for the influence on a stock estimate of an unusually large catch at a single trawl survey station, adjustment to TAC because of changes in fishery selectivity (both for size and shell condition), and adjustment to TAC to account for closed waters and resultant loss of exploitable stock.

Specific qualitative considerations include knowledge that early survey timing may bias abundance estimates downward if molting has not been completed when the survey occurs, consideration of how current year size-frequency distribution may influence future recruitment, and consideration of how to best evaluate and incorporate available data sources including pot and trawl surveys and observer data.

Harvest limits for each stock are evaluated relative to the OFL and are buffered to account for management uncertainty, including bycatch mortality (in the various groundfish fisheries and directed crab fisheries), as well as uncertainty in the biomass and OFL estimates themselves. For some Tier 4 and 5 stocks where uncertainty in the OFL estimate is high and biomass estimates may be unavailable or unreliable, the State relies on observer, pot survey, and fishery information to set conservative TACs.

Evaluation of pot survey size-frequency distribution and commercial fishery performance data influenced the State to close the Adak red king crab fishery for five years. The Adak red king crab OFL is based on average catch during years when a liberal harvest policy was applied and there is no reliable biomass information for this stock to move it to a higher information tier (and thus have stock status determination based upon biomass). The State applies a similar policy for the Aleutian Islands golden king crab fishery where extensive fishery-dependent data and limited survey data are available, but biomass estimates are lacking. The OFL is based on average catch, and the State sets TAC substantially below the total catch OFL.

Pribilof red and blue king crab stock biomass estimates are highly dependent on survey catches from one or two trawl survey stations. Recent abundance estimates for red king crab have been adequate to allow for a small fishery, but uncertainty in the biomass and OFL estimates and knowledge that previous commercial fisheries prosecuted at similar biomass levels performed poorly has led the State to close the commercial fishery. This decision was also influenced by a desire to limit bycatch mortality of blue king crab, a stock for which fishery and pot survey information have shown distributional overlap with red king crab and which have been closed to directed fishing since 1998. The Pribilof Island blue king crab stock has been under a rebuilding plan since 2003. A revised rebuilding plan is being prepared for this stock due to inadequate progress towards rebuilding

For some stocks, notably EBS Tanner crab and Aleutian Islands golden king crab, the State recognizes stock structure at a finer spatial scale in setting TAC than is currently assessed at the OFL level. The State sets TAC based on specific spatial components of these stocks while the OFL itself is applied at a broader geographic scale.

For stocks with biomass estimates, the use of mature male biomass for stock status determination may not fully capture the reproductive potential of the stock. Specific measures in State regulation to address the uncertainty that mature male biomass is an adequate measure of reproductive potential and that overfishing only pertains to fishing mortality of mature males include:

- Escape mechanisms and gear configuration restrictions in all fisheries to reduce bycatch of females and sublegal or immature males;
- Tanner crab closure area and gear restrictions to reduce bycatch of female and sublegal male Bristol Bay red king crab;
- Closure area around St. Matthew Island to protect egg-bearing female blue king crabs;
- Mature female biomass is used to define, or is a component of, the fishery threshold and is a determinant of mature male exploitation rate for Bristol Bay red king crab, Pribilof blue king crab, eastern Bering Sea Tanner crab, and eastern Bering Sea snow crab.

A considerable source of management uncertainty is the magnitude of crab bycatch mortality that will occur in a given year. Directed fishery bycatch mortality is controlled for and managed, in part, through measures in regulation addressing fishery selectivity (either size, sex, or spatial) of mature/legal males including:

- Use of “exploited legal males” in the EBS snow crab harvest strategy and “exploitable legal male abundance” in the EBS Tanner crab harvest strategy. These measures of abundance acknowledge industry preference for new-shell crabs and discount for the proportion of the population that is determined to be in old-shell condition;
- Distribution of TAC for EBS Tanner crab east and west of 166°W longitude based on population structure and fishery patterns.

It is more difficult to account for the amount of crab bycatch mortality that will occur in the various groundfish fisheries. Several closure areas designed to protect crab have been established in groundfish fisheries, but crab bycatch limits are in place for only a few groundfish fisheries and these limits are not restrictive enough to act as an upper bound on non-target fishery removals when setting TAC. The State has addressed this uncertainty by basing annual estimates of crab bycatch mortality in groundfish fisheries on the highest observed values from recent fishing seasons.

2.1.2 Overview of Alternatives 2, 3, and 4

Alternatives 2, 3, and 4 were designed to explicitly address the requirements of the MSA and NS1 Guidelines, as detailed in section 1.2. These alternatives specify the ABC control rule and the process by which the SSC will annually recommend the ABC to the Council, and the accountability measures that are enacted if the ACLs are annually exceeded. Three approaches are considered for the specification of the ABC control rule; a constant buffer approach, a variable buffer approach, and a blended approach that applies either a constant buffer or a variable buffer by tier.

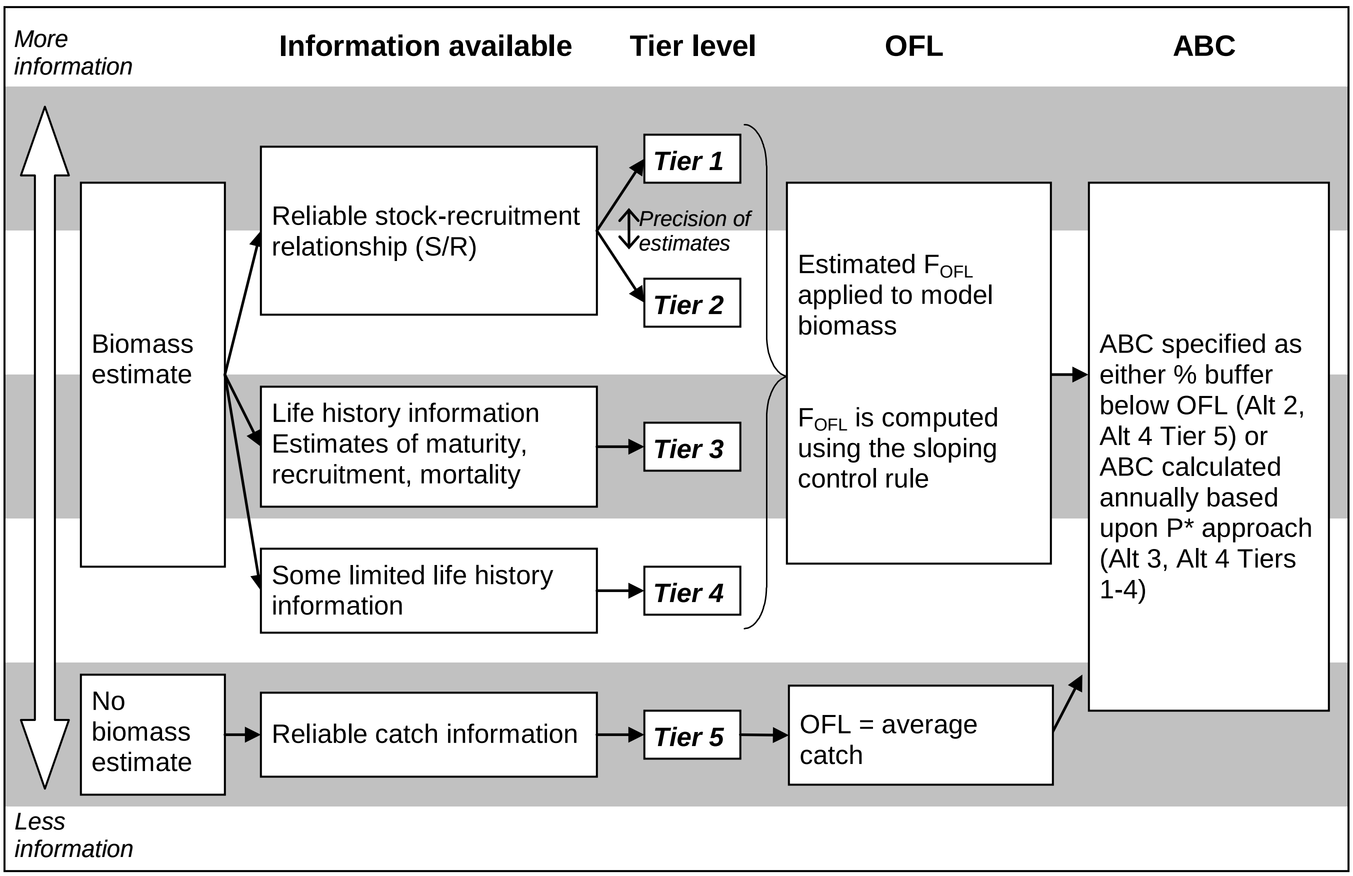
Alternative 2 is a constant buffer approach to establish an ABC at or below the OFL. Once selected, that buffer value does not change over time. Alternative 3 also employs a buffer to establish an ABC at or below the OFL, but this buffer is not fixed and can vary annually depending upon the annually assessed extent of uncertainty. Alternative 4 employs a variable buffer for stocks in Tiers 1 through 4 and a constant buffer for stocks in Tier 5. The analysis of each alternative provides an estimate of the relative risk of overfishing to enable understanding of this relative risk of each ABC control rule. The analysis employs an impact analysis for each alternative and each approach that considers the extent of scientific uncertainty in the OFL and any other specified scientific uncertainty.

Currently, the F_{OFL} for each stock is annually estimated using the Tier system under the FMP. A schematic of the current Tier system is provided in Figure 2-1 with indication of how the ABC will be included by tier. The F_{OFL} is applied to the most recent abundance estimate to calculate the OFL. From this annually-estimated OFL, a corresponding ABC would be calculated. The Tier system in the FMP would be amended to explicitly provide for ABC specification in addition to the current OFL control rules.

Under each alternative, the SSC may recommend an ABC less than the maximum ABC calculated by application of the ABC control rule, but it must provide the rationale for this recommendation. The process would begin with the stock assessment authors' recommended ABCs (at or less than the maximum ABC), followed by CPT review and recommendations by the CPT to the SSC and the final ABC recommendation by the SSC to the Council.

Under these alternatives, the TAC/GHLs must be set sufficiently below the ACL so that total catch will not exceed the ACL. The FMP defers the determinations of TACs and GHLs to the State following the criteria in the FMP. Under these alternatives, determinations of TACs and GHLs will continue to be set by the State, however, the requirement to set TACs and GHLs at a level to prevent exceeding the ACL would be an additional consideration in setting TAC/GHL.

Figure 2-1 Schematic of the current OFL Tier system and proposed ABC setting



The alternatives differ in the annual consideration of uncertainty in the ABC control rule specification, which is an important consideration for a range of stocks with varying levels of scientific uncertainty. For example, consider two hypothetical stocks with differing levels of stock information (Figure 2-2). The OFL point estimate for these two stocks is identical. However, the relative uncertainty surrounding the OFL is considerably higher for the stock with less precise information than for the one with more precise information. Under a constant buffer approach (Figure 2-2A), an ABC value set at 86% of the OFL (i.e., a buffer of 14%) results in a different relative risk of overfishing (conveyed by P*) should total catch equal ABC. Thus, the same buffer value employed to set ABC as a percentage of OFL is riskier for stocks with high levels of uncertainty than for stocks with low levels of uncertainty. This analysis provides an estimate of risk for each buffer, but the risk would not be considered annually in the ABC setting process because the buffer values would be fixed.

Under a variable buffer (or P*) approach (Figure 2-2B), consideration of risk is the primary decision point in specifying the P* value, with the resulting buffer value calculated annually based on the probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. A constant P* (here set at P* = 0.25 or a 25% risk of overfishing should total catch equal ABC) results in different buffer values for the two stocks even though they have the same OFL. Thus, a larger buffer value is necessary for the stock for which less precise information is available to maintain the same risk of overfishing. As information for a stock improves, a constant P* may result in gradually decreasing buffers over time.

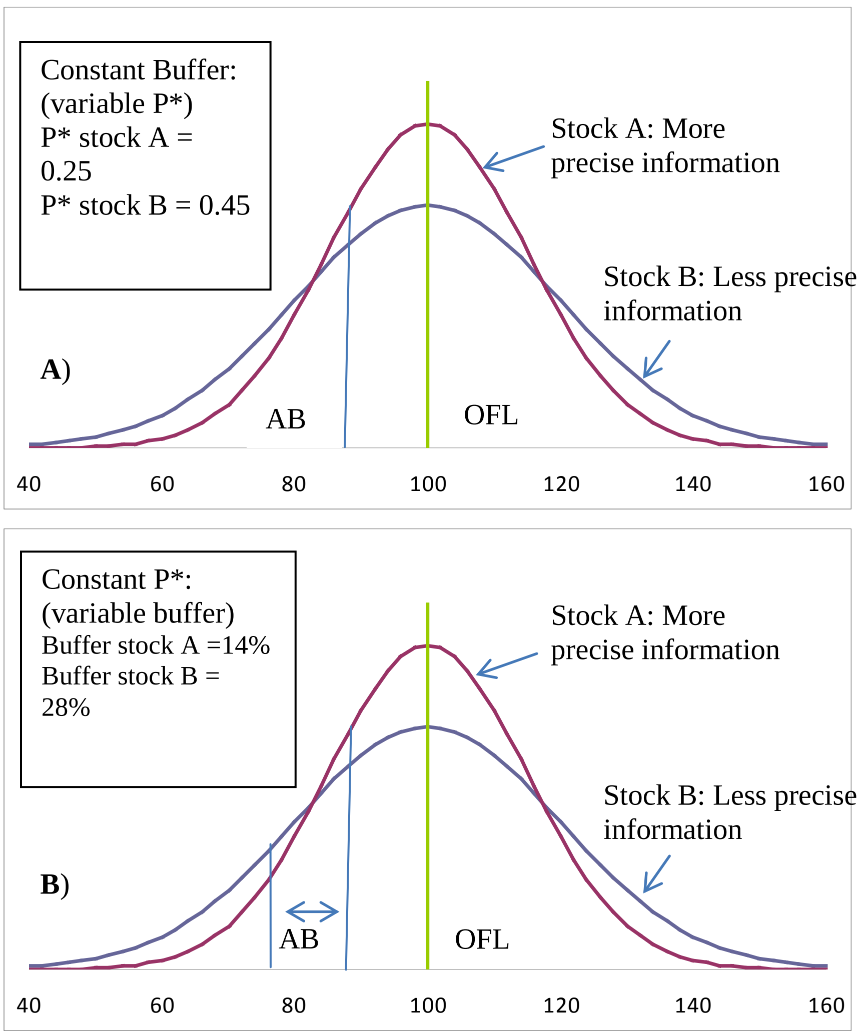


Figure 2-2 **Schematic of ABC control rule approaches. Two stocks are considered in both panels with the same point estimate of the OFL but different levels of information available and hence a different level of uncertainty around that point estimate. The top panel (A) shows a constant buffer approach for both stocks with different resulting P*s for each stock while the lower panel (B) shows a constant P* approach resulting in different buffer levels for each stock.**

2.1.3 Alternative 2- Establish ABC control rule using constant buffer approach

Alternative 2 would establish an ABC control rule for crab stocks to annually calculate the maximum ABC below the annual OFL using a fixed buffer. The ACL would be set equal to the ABC. The maximum ABC for each stock would be set to the product of 1-x (where x is a constant pre-specified buffer less than 1) and the OFL. Directed harvest levels (TAC/GHL) would continue to be specified by the State, subject to the condition that all catch (directed plus non-directed) must be less than the annually specified ABC to avoid annually exceeding the ACL. The SSC would annually set the ABC value for each stock.

Alternative 2 would specify in the FMP the buffer value(s) and the stock(s) or tier(s) to which the specified buffer value(s) will apply. Buffer values under consideration in this alternative include the following[23]:

Option 1:	ABC = OFL (no buffer)
Option 2:	ABC = 90% of OFL (10% buffer)
Option 3:	ABC = 80% of OFL (20% buffer)
Option 4:	ABC = 70% of OFL (30% buffer)
Option 5:	ABC = 60% of OFL (40% buffer)
Option 6:	ABC = 50% of OFL (50% buffer)
Option 7:	ABC = 40% of OFL (60% buffer)
Option 8:	ABC = 30% of OFL (70% buffer)
Option 9:	ABC = 20% of OFL (80% buffer)
Option 10:	ABC = 10% of OFL (90% buffer)

ABC specification under the constant buffer approach would involve fixed values incorporated into the Tier system (by stock or by tier) for calculating the maximum ABC in relation to the annually estimated OFL. The Tier system, which currently specifies an OFL control rule by tier (see Figure 2-1), would be modified to include an ABC control rule written in the form of ABC = xOFL. The buffer value, once selected, would be fixed at that level and x would not vary annually regardless of changes in information in the annual stock assessment. Any modification of the fixed buffer value would necessitate an FMP amendment.

The P* corresponding to the fixed buffer value (for a buffer of $y\%$, x would be $1-y/100$) is calculated only for this analysis to inform the choice of an appropriate buffer. The P* (should it be calculated periodically) corresponding to a given buffer may decrease over time as improved information is available in the stock assessment, but this would not modify the selected buffer value. The P* associated with a range of buffer values is provided in this analysis to indicate the relative risk of overfishing that corresponds to a selected buffer value under a constant buffer approach. By definition, unless there is a skewed distribution in the estimates of OFL, P* = 0.5 for buffer values = 0. No additional annual analyses would be provided of the annual P* corresponding to these selected buffer values. The selected buffer value remains fixed regardless of the uncertainty in the OFL estimate.

2.1.4 Alternative 3- Establish ABC control rule using variable buffer (P*) approach

Alternative 3 would specify in the FMP the ABC control rule for crab stocks and the P* value(s) and the stock(s) or tier(s) to which the P* value(s) will apply. The ACL would be set equal to the ABC. The maximum ABC would be established based upon a pre-specified percentile of the distribution for

[23] Note that other buffer values may be selected within these ranges. ABC reflects the maximum ABC resulting from application of the control rule.

estimates of the OFL. This method directly accounts for the annually assessed scientific uncertainty regarding the estimate of the OFL. This method establishes a variable buffer between the ABC and the point estimate of the OFL, in order to prevent the ABC from exceeding the "true" OFL. The probability of the ABC exceeding the "true" OFL (noted as OFL') is equal to a specified P* value, (P(ABC>OFL')).[24]

A range of P* values are provided to indicate the current buffer value by stock corresponding to the relative risk of overfishing (characterized by the P* value). Once the P* value is selected, the ABC would be annually established below the annual OFL using the buffer which corresponds to the selected P* and taking account of the annual assessed extent of scientific uncertainty. The stock-specific percentage buffer values would vary over time depending on the assessed extent of scientific uncertainty. Lower uncertainty in the OFL estimate over time would lead to a decrease in the buffer value for the same P* value (and thus a higher ABC value). Directed harvest levels (TAC/GHL) would continue to be specified by the State of Alaska as a category 2 measure. This category 2 measure would be subject to the condition that all catch (directed plus non-directed) must be less than the annually specified ABC to avoid annually exceeding the ACL. The SSC will annually recommend an ABC value for each stock.

Alternative 3 would specify in the FMP the buffer value(s) and the stock(s) or tier(s) to which the specified buffer value(s) will apply. P* values under consideration in this alternative include the following[25]:

Option 1: P* = 0.5
Option 2: P* = 0.4
Option 3: P* = 0.3
Option 4: P* = 0.2
Option 5: P* = 0.1

Actual ABC values corresponding to the P* options, based upon calculation of the appropriate buffer value below OFL by stock, are listed in the individual chapters of impacts of the alternatives by stock.

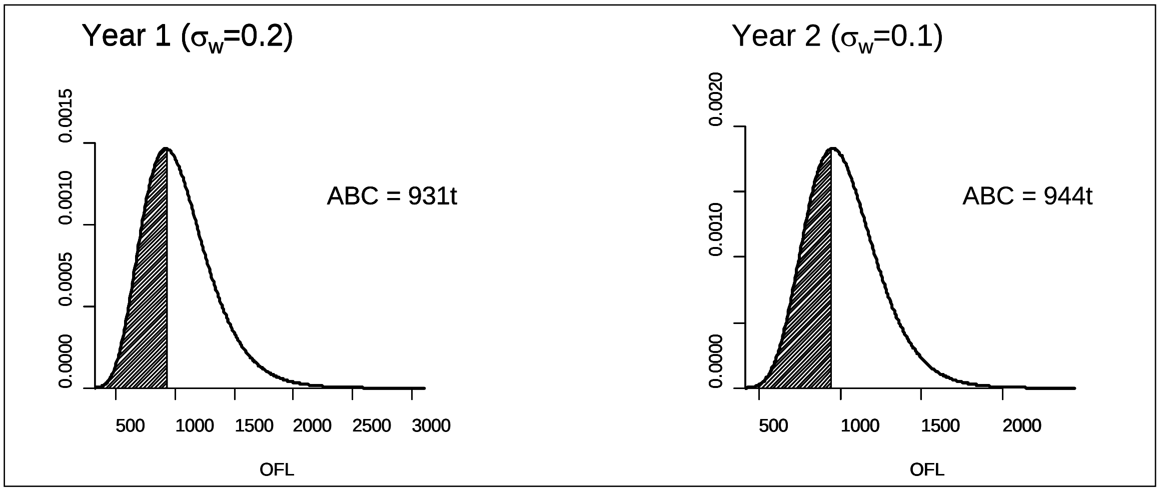
ABC specification under the P* approach would require that the annual stock assessment process include quantification of the uncertainty associated with the OFL. Currently, the F_{OFL} for each stock is annually estimated using the tier system under the FMP (Figure 2-1). The F_{OFL} is then applied to abundance estimates to calculate the OFL. From this annually-estimated OFL, a corresponding ABC must be calculated. For a given P*, assessment authors, the CPT, and SSC would determine the amount by which the point estimate of the OFL needs to be reduced to account for scientific uncertainty so that the estimated probability of exceeding the true but unknown overfishing limit (of which the OFL is an estimate) would not exceed the selected P* (should catch equal that ABC).

For example, if the Council chose that P* for BBRKC is no greater than 0.4 (or a 40% probability of overfishing if the total catch for BBRKC is equal to the ABC) then the stock assessment must annually calculate the ABC values corresponding to P* of 0.4 and that calculation will be reviewed by the CPT and SSC. A variety of ways exist to calculate the uncertainty associated with the OFL, depending on data availability and analytical techniques, and account will be taken of the agreed level of additional uncertainty. The simplest possible formulation for the maximum ABC for year *y*, ABC_y, would be $ABC_y = OFL_y \exp(x{*}CV(OFL_y))$ where *x* is a factor which determines how much the OFL needs to be reduced

[24] Further information on the background rationale and utility of P* as a reference value for risk is contained in chapter 3.
[25] Note that other P* values may be selected within these ranges.

to achieve the given P*, and CV(OFL_y) is the coefficient of variation of the OFL.[26] This will result in the difference between the ABC and the OFL changing over time as the assessed level of uncertainty (e.g. CV(OFL_y)) changes owing to changes in the amount of available data, improvements in models, etc. As information in the assessment improves, the difference between the ABC and OFL for any given P* should get smaller because the amount of uncertainty will be smaller (and hence CV(OFL_y) is smaller; (Figure 2-3). While the difference between the ABC and OFL will vary annually, changes to the selected P* (and hence the value for *x*) would necessitate an FMP amendment.

Figure 2-3 Distribution around a hypothetical OFL where the best estimate is equivalent to 1000 in each year and the only change between year 1 and year 2 is the decrease in the relative within-assessment uncertainty σ_w in year 2 resulting in a higher ABC for the same OFL.



This analysis does not consider of the implications of future changes in relative (within and additional) uncertainty. However, the current OFL Tier system is designed to allow for improved information and more precise management as assessment information improves and stocks move to lower tiers. Consideration of the impacts of future changes in uncertainty is an important consideration in the decision of which alternative to select despite the fact that the analysis is not structured to allow for projecting this.

2.1.5 Alternative 4 - Preferred Alternative

The Council took final action to recommend the preferred alternative in October 2010. The Council's preferred alternative blends Alternatives 2 and 3 and recommends establishment of a set of ABC control rules within the current Tier system for crab stocks. For stocks in Tiers 1 through 4, the control rule for the preferred alternative follows a P* approach which implies a variable buffer between OFL and ABC. For stocks in Tier 5, a constant 10% buffer is used. Annually, the ABC control rule would be used to calculate the maximum ABC in the stock assessment. The SSC would recommend an annual ABC for each stock.

The full October 2010 Council motion for Actions 1 is the following:

The Council adopts the purpose and need statement as amended and the following preferred alternatives for final action, as specified below.

Action 1: Establish Annual Catch Limits (ACLs) for 10 Crab stocks

[26] Actually the standard deviation of the logarithm, but the difference between this quantity and the CV is minor in most cases.

On January 16, 2009, NMFS issued final guidelines for National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). They provide guidance on how to comply with new annual catch limit (ACL) and accountability measure (AM) requirements for ending overfishing of fisheries managed by federal fishery management plans. Annual catch limits are amounts of fish allowed to be caught in a year. A legal review of the BSAI King and Tanner Crab FMP found there were inadequacies in the FMP texts that need to be addressed. Several work groups (e.g., ABC/ACT Control Rules, Vulnerability Evaluations) have been created to produce reports on how to carry out the more technical components of the NS1 guidelines. Statutory deadlines require compliance with the MSA by the start of the 2011 fisheries although these reports have not been finalized.

This action is necessary to facilitate compliance with requirements of the MSA to end and prevent overfishing, rebuild overfished stocks and achieve optimum yield. This action also recognizes and maintains the unique joint state-federal cooperative management structure of the BSAI King and Tanner FMP.

Alternative 2- Establish ABC control rule using constant buffer approach
Option 2: ABC = 90% of OFL (10% buffer) for all Tier 5 stocks.

Alternative 3- Establish ABC control rule using variable buffer (P*) approach
Option 1: P* = 0.49 for all Tier 1, 2, 3, and 4 stocks.

Under Alternative 3 buffers between the OFL and ABC for individual stocks will be based on a P* of 0.49 and the within-model scientific uncertainty in the OFL point estimate (σ_w) for each stock. Additional buffering to account for outside-of-model scientific uncertainty in the OFL point estimate will be accomplished by the State of Alaska as a Category 2 measure, which provides for federal oversight under the FMP, during the annual TAC/GHL specification process.

Factors that influence estimates of scientific uncertainty are currently considered by the State in TAC setting and are time-sensitive. It will not be possible for the CPT and SSC to make recommendations that incorporate all scientific uncertainty based on the best and most timely information available, as is recognized in defining the State's role under the FMP.

The Council encourages the CPT and SSC to identify factors influencing scientific uncertainty that could be incorporated in the ABC control rule, and which are best reserved for State consideration on an annual basis in TAC setting. Less time-sensitive factors could be reviewed during the normal crab assessment cycle (i.e., May CPT and June SSC).

In adopting this preferred alternative the Council requests the CPT and SSC continue work to improve understanding of scientific uncertainty in the estimation of crab OFLs and to ensure that crab stock assessment models and OFLs are risk-neutral. The Council requests that crab assessment and management staff work to evaluate all sources of uncertainty in assessments, develop methods to accurately quantify uncertainty, and to provide for SSC review.

Accountability Measures
The annual TAC for each crab stock will be established by the State of Alaska at a level sufficiently below the ACL so that the sum of State considerations of scientific and management uncertainty in the OFL estimate; the estimated discard mortality in directed crab, groundfish, and scallop fisheries as well as the directed crab fishery removals; and management uncertainty in bycatch estimates does not exceed the ACL. Anytime an ACL is exceeded the overage will be accounted for through a downward adjustment to the TAC for that species during the fishing season following the overage.

Options for modifying the NPFMC review process
Option 1: SSC recommends ABC levels annually at October Council meeting (delayed TAC-setting).

Optimum Yield specification: FMP will be amended to read "OY range 0 to < OFL catch".

2.1.5.1 Rationale for the preferred alternative

For stocks in Tiers 1 through 4, the Council recommended the control rule that follows a P* approach, which implies a variable buffer between OFL and ABC. Alternative 4 specifies P* = 0.49. For stocks in Tier 5, the Council recommended a constant buffer of 10% below the OFL. Modification to the P* value or the constant buffer for establishing the maximum ABC would require an FMP amendment. While the SSC recommended a P* approach for stocks in all tiers because it is "more directly responsive to changes in our understanding of uncertainty" (June 2010 SSC minutes), they did note that the Council may not be comfortable with a P* approach for data-poor stocks. In deciding whether to use a P* or buffer approach by tier, consideration was given to ensure that the implied buffer increases as information decreases. This was noted by the SSC in their June 2010 minutes "…such an approach would have to be carefully designed to ensure that the implied buffer increases with tier level to reflect higher levels of uncertainty for data poor stocks and provide a continued incentive to move stocks into higher tiers." Thus, the buffer value for Tier 5 is higher than those resulting from a P* approach for Tiers 1 through 4.

In recommending Alternative 4, the Council recognized that a P* of 0.49 meets the NS 1 guidelines requirements because it provides for a probability of overfishing that is less than 50% and it incorporates appropriate scientific uncertainty in the ABC-setting process. In addition, by taking this approach, the Council acknowledges that the precautionary approach that is currently employed by the State in setting TAC/GHL will further reduce the risk of realizing overfishing at this P* level, by incorporating variable scientific information that cannot be quantified in a control rule.

Under Alternative 4, scientific uncertainty is to be considered in characterizing the probability distribution (probability density function or pdf) of the OFL for each stock. This probability distribution for the OFL accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. However, Alternative 4 does not prescribe the approach for quantifying all out-of-model uncertainty that was used to analyze the impacts of Alternative 3. Alternative 4 relies on the State TAC/GHL-setting process to address the additional uncertainty while requesting that the CPT and SSC continue to work to understand and quantify those sources of uncertainty in the OFL point estimate for incorporation into the ACB control rule.

The Council recognized that some scientific uncertainty is not applicable to the OFL setting process and is better addressed through the State TAC/GHL setting process. Alternative 4 relies on the State to incorporate additional buffering to account for uncertainty as a Category 2 measure in the annual TAC/GHL specification process. The Council directed the CPT and SSC to identify (1) factors influencing scientific uncertainty that could be incorporated into the ABC control rule, and (2) factors influencing scientific uncertainty that are best reserved for State consideration on an annual basis in TAC/GHL setting. Annually, the CPT and the SSC would evaluate and make recommendations, as necessary, on the specification of the probability distribution of the OFL, the methods to appropriately quantify uncertainty in the ABC control rule, and the factors influencing scientific uncertainty that the State will account for on an annual basis in TAC setting. The end result will be to incorporate some additional outside of model uncertainty into the ABC control rule where possible while continuing to consider time-sensitive aspects of uncertainty in the TAC/GHL-setting process. The State also has the flexibility to use the expertise of its managers and biologists to be more conservative than existing harvest strategies as necessary to prevent overfishing and meet State management goals and federal requirements.

Many factors that influence estimates of scientific uncertainty are currently considered by the State in TAC setting and are time-sensitive. The Council recognized that it would not be possible for the CPT and SSC to make scientific recommendations regarding the incorporation of these factors in the ABC control rule. A listing of some of these factors is included in section 2.1.1.1. Understanding how to account for these factors should be based on the best and most timely information available, and the Council recognized that the most appropriate method to do so is through the existing State TAC/GHL setting process. This choice by the Council recognized the State's role and expertise in crab research and management under the FMP.

The crab stock assessment process prevents taking into account some timely information. In other words, the SSC and CPT recommend model parameters in May and June, before the most recent survey data is available, and the assessments are effectively fixed at that time. When new information comes in from the current year's survey, it is incorporated, but there is no opportunity to re-evaluate the assessment, and determine whether new information (from the survey or prosecution of the fishery) should be accounted for in some manner. Also, the crab assessments are inherently limited in their focus (i.e., on MMB) and in their use of data, and therefore do not account for information that the State considers in TAC-setting, but that may have no intrinsic effect on the assessment outcome.

The Council's intent in crafting this preferred alternative was to meet MSA requirements while maintaining the shared management regime of the FMP that makes use of existing State resources to achieve National Standard 1 goals, rather than implement new management measures that could limit the flexibility to incorporate information that provides a more complete, detailed, or up-to-date understanding of the status of the stock (i.e., the best available scientific information).

In recommending this alternative, the Council indicated that this action confirms their current risk strategy as it relates to crab management under shared management FMP but does not preclude the Council from continuing to evaluate the impact of this risk strategy on crab stocks and to potentially modify this approach in the future should information indicate that it is necessary.

For Tier 5 stocks, the ABC control rule will be established as ABC = 0.9*OFL resulting in an ABC 10% below the OFL. No additional consideration of uncertainty is required in the annual assessment under this approach because the uncertainty is incorporated in the size of the buffer. In selecting a fixed buffer approach for Tier 5 stocks, the Council recognized that a fixed buffer was more appropriate than a P* approach because the OFL estimate for Tier 5 stocks is based on average catch. There is little inter-annual variability that would necessitate the use of a P*, thus a buffer of 10% adequately mitigates the risk.

2.1.6 Accountability Measures

The Magnuson-Stevens Act requires that FMPs include AMs to prevent ACLs from being exceeded and to correct for overages of the ACL if they do occur. Accountability measures to prevent TACs and GHLs from being exceeded, and to account for and minimize bycatch, are currently used in crab fisheries management and will continue to be used to prevent ACLs from being exceeded. These accountability measures include: individual fishing quotas and the measure implemented under the Crab Rationalization Program to ensure that individual fishing quotas are not exceeded, measures to minimize crab bycatch in directed crab fisheries, and monitoring and catch accounting measures.

AMs in the harvest specification process include the downward adjustments to ACL in the fishing season after an ACL has been exceeded. As an accountability measure, the total catch estimate used in the stock assessment will include any amount of harvest that may have exceeded the ACL in the previous fishing season. For stocks managed under Tiers 1 through 4, this would result in a lower maximum ABC in the subsequent fishing season, all else being equal, because maximum ABC varies directly with biomass. For Tier 5 stocks, the information used to establish the ABC is insufficient to discern the existence or extent of biological consequences caused by an overage in the preceding fishing season. Consequently, the subsequent fishing season's maximum ABC will not necessarily decrease. However, when the ACL for a Tier 5 stock has been exceeded, the SSC may recommend a decrease in the ABC for the subsequent fishing season as an accountability measure.

Given that the State sets the TAC, Alternative 4 also includes accountability measures for the State to exercise in the annual TAC-setting process. First, Alternative 4 would require that the State establish the annual TAC for each crab stock at a level sufficiently below the ACL so that the sum of the total catch (including all bycatch mortality and any uncertainty in bycatch estimates) and the State's assessment of additional uncertainty in the OFL estimate will not exceed the ACL. Additional uncertainty includes (1) management uncertainty (i.e., uncertainty in the ability of managers to constrain catch, including bycatch, so the ACL is not exceeded, and uncertainty in quantifying the true catch amount) and (2) scientific uncertainty identified and not already accounted for in the ABC. At the end of the fishing year, the total catch is calculated and compared to the ACL.

Second, if an ACL is exceeded, the FMP would require that the State implement accountability measures to account for any biological consequences to the stock resulting from the overage through a downward adjustment to the TAC or GHL for that species in the following fishing season. Note that this is in additional to the downward adjustment to the ABC in the ABC-setting process discussed previously. This accountability measure would be under the FMP's category 2, which means that the State has the discretion under the FMP to determine the most appropriate method to account for any catch above the ACL in setting the TAC or GHL for the subsequent fishing season.

Overages in the directed fishery are unlikely due to management precision, but overages due to bycatch in directed and non-directed fisheries has potential to drive total catch over the ACL. The directed crab fisheries are predominantly IFQ fisheries with observer coverage and a requirement for complete offloads and, as such, there is high precision in the catch estimates in accordance with that allotted under the IFQs. Overages on the directed fishery are rare. The structure of the IFQ fishery allows for flexibility in transferring quota between individuals to cover overages, and overages are discouraged through enforcement penalties. Those overages that do occur could be accounted for through potential downward adjustment to TAC during the fishing season following the overage. Therefore the current management measures on the directed fishery are sufficient to ensure that the directed fishery would not cause the catch to annually exceed a specified ACL.

For the non-rationalized stocks, Norton Sound red king crab is managed by ADF&G using a superexclusive registration area so access to the fishery is limited to a small, local fleet. Fisheries for the other non-rationalized stocks are not currently active and if ADF&G were to open a fishery, they would be opened by commissioner's permit. This means that a fishery participant has to apply for a permit to participate in the fishery and, if ADF&G issues a permit, it would contain small pot limits, vessel size limits, observer requirements, and associated measures to control and account for catch. Therefore overages in the non-rationalized fisheries are also rare and the potential for overages is factored into the GHL setting process.

The Council recognized that these accountability measures place the burden of accountability only on the directed crab fishery. Bycatch of crab species in directed crab, and groundfish fisheries however is not constrained. In the scallop fishery there are absolute limits on the total amount of Tanner crab, Bristol Bay red king crab, and snow crab that can be taken in the Bering Sea. There are no equivalent limits in the crab and groundfish fisheries. Crab bycatch and associated mortality in the directed crab fisheries are accounted for in the stock assessment process and estimates of bycatch mortality from the directed fishery are considered when setting TAC. Bycatch trends and changes in retention practices (such as potential high-grading) are closely monitored in the IFQ crab fisheries.

Measures to minimize crab bycatch in the groundfish fisheries include prohibited species catch limits and area closures. In the groundfish fisheries, there are trawl fishery bycatch limits for Bristol Bay red king crab, Tanner crab, and snow crab that when reached trigger time and area closures. Bycatch of these species can continue outside of the fishery-specific closure however. There are no limits established in the groundfish fisheries for any other crab stock, nor any limits on fixed gear fisheries.

The Council has initiated a comprehensive analysis of crab bycatch in the BSAI groundfish fisheries to assess these existing crab protection measures and to determine whether changes or additional measures are necessary to further minimize crab bycatch in the groundfish fisheries. This analysis will likely be available within the next year for review by the Council; thus current accountability measures should be considered as an interim step until additional measures are reviewed and recommended by the Council.

In June 2010, the Council initiated an analysis to evaluate appropriate bycatch limits and time/area closures by crab stock on groundfish fisheries. Limits in these fisheries by crab stock would effectively ensure that if the directed fishery TAC was set sufficiently below the ACL to account for both the estimate of bycatch in the directed crab fisheries as well as the sum of the bycatch limits in the groundfish fisheries, that the bycatch by groundfish fisheries would not drive the catch over the annually estimated ACL. Currently there is a risk that groundfish bycatch of crab species could potentially drive the annual catch to exceed the ACL. The Council will consider an analysis of crab bycatch limits in groundfish fisheries and may take action in late 2011 for implementation potentially in the 2013 fishing season. The Council's motion with draft alternatives for analysis is available on the Council web site.[27]

Until any additional action is taken to manage the annual bycatch of crab species, if the ACL is exceeded in any given year the accountability measure would be for some reduction in the directed fishery catch in the subsequent year in order to account for the biological consequences of the overage and to buffer against the possibility of exceeding the ACL in the following year.

2.1.7 Options for modifying the OFL and ABC setting process

As noted in section 1.2, one of the requirements of the MSA and NS1 Guidelines for ACL measures is that the SSC recommend the ABC levels for each BSAI crab stock on an annual basis in conjunction with the annual assessment process and ACL specification. TACs must be set below the ACLs. The current crab review process does not allow for the SSC to set the ABC before the State set the TACs. Under the current process, the SSC reviews draft stock assessments in June for the following stocks: EBS snow, EBS Tanner, Bristol Bay red king crab, Pribilof Islands blue king crab, Pribilof Islands red king crab, and St. Matthew blue king crab. The purpose of reviewing stock assessments at that time is to recommend tiers for each stock, review model parameters and model-specific issues for inclusion in the final assessment which also incorporates the results of the summer EBS trawl survey.[28] The review of the stock assessments at that time does not involve the SSC making recommendations on ABCs for these stocks. Because the most recent abundance data from summer trawl surveys is not available at that time, any recommendations on ABCs for these stocks made at that time could not utilize the best and most recent scientific information available at the time the State establishes TACs.

[27] http://alaskafisheries.noaa.gov/npfmc/current_issues/bycatch/crab_bycatch_motion_June_11.pdf.
[28] The SSC review follows the CPT annual review in May. The CPT provides its report and recommendation to the SSC in conjunction with their review in June.

Final assessments for those stocks are available in late September and include the proposed OFLs. The CPT reviews the OFLs in September. However, the timing of the current process for OFL determination, the resulting TAC determination, individual fishing quota (IFQ) issuance, and the opening of the fishing season on October 15, does not allow for the SSC to recommend the final OFL at their annual October meeting.[29] As a result, after the September Crab Plan Team meetings, the AFSC sets the OFLs consistent with the FMP and forwards the OFLs for each stock to the State of Alaska prior to its setting the TAC or GHL for that stock's upcoming crab fishing season. The SSC then reviews the OFL in October and provides any recommendations for the next assessment cycle. Likewise, the timing of the current process would not allow the SSC to recommend ABC levels at the annual October meeting.

Two stocks, Norton Sound red king crab and Aleutian Islands golden king crab, have summer fisheries and thus their final assessments are reviewed in June by the SSC with OFLs recommended at that time. The final two stocks, Pribilof Island golden king crab and Adak red king crab, have OFLs based only on average catch information and thus OFLs are not dependant on data available from the summer trawl surveys. OFLs for those stocks are currently recommended by the SSC in June. SSC recommendations of ABCs for all of these stocks would also occur in June.

In order to modify this process to allow for the SSC to recommend the ABC for the remaining crab stocks before the TAC is set, four options are considered:

Option 1: SSC recommends ABC levels annually at October Council meeting
(delayed TAC-setting)-**preferred**

The Council recommended Option 1 as part of Alternative 4. Under Option 1, the SSC would annually set the ABCs for most crab stocks at the October meeting. TAC/GHL-setting by the State would be delayed until after the SSC has sets the ABCs. With this new process, it would no longer be necessary for the AFSC to set the OFLs and forward them to the State before the October SSC meeting. The ABCs would be set for Tier 5 stocks, Norton Sound red king crab, and Aleutian Islands golden king crab at the June meeting. This approach would be the least disruptive to the current process for stock assessment and TAC/GHL setting because it allows for the use of the most recent survey and fishery data. Use of the most recent survey data is critical in assessing crab stocks because survey estimates can be highly variable from one year to the next, therefore it is very important to retain the ability to incorporate the most recent data into stock assessments and to use consistent data in both the stock assessment and TAC-setting processes.

Option 2: SSC recommends ABC levels annually prior to October
(shift timing of October Council meeting)

Under this option, the SSC would recommend the ABC levels in conjunction with the regularly scheduled Council meeting. However to meet the timing needs established for TAC-setting and IFQ issuance, the Council meeting would need to be shifted to occur earlier in the fall. In order to do this, the stock assessments would need to be completed by early September to allow for a CPT review and recommendations on OFL and ABC levels prior to the SSC meeting. It may not be feasible given scheduling constraints to move the timing of the Council meeting itself. This option would also constrain the already compressed time frame for stock assessments.

Option 3: SSC recommends ABC levels annually prior to October
(convene special SSC meeting prior to TAC-setting)

[29] For more information on this process, relative timing constraints for data available from the summer survey, and the rationale for the current process as amended under Amendment 24 to the FMP, see NMFS 2008.

Under this option, the SSC would recommend the ABC levels at a separate meeting prior to the regularly scheduled Council meeting. As with option 2, in order to do this, the stock assessments would need to be completed by early September to allow for a CPT review and recommendations on OFL and ABC levels prior to the SSC meeting. It may not be feasible given scheduling constraints to conduct an additional SSC meeting at that time. This option would also constrain the already compressed time frame for stock assessments.

Possibilities for hosting a separate SSC meeting could be to have an in-person meeting, a teleconferenced meeting or a web-based (with teleconference) meeting of the SSC. A web-based joint groundfish plan team meeting has recently been held (May 6, 2010) to have a short, half-day session to review model proposals. A similar type meeting could be considered under this option to minimize costs and disruptions of hosting this additional meeting. Irrespective of how the meeting is held (in-person, teleconference-only, web-based with teleconferencing), the meeting would be open to the public.

Under all three options the SSC would continue to review and comment on model parameterization and tier levels in June, and at that time would recommend both OFL and ABC levels for the Norton Sound red king crab stock, Aleutian Island golden king crab stock and for any stocks annually in Tier 5. For the remaining stocks, the SSC would recommend OFLs and ABCs following the updated stock assessments in the fall based upon one of the three options as noted above.

Option 4: SSC recommends ABC levels annually in June

Option 4 would establish a process whereby the SSC would annually recommend the ABCs for each stock in June. The process of OFL and ABC determination varies depending on a stock's tier (and subsequent information availability). Each spring, the CPT would recommend the placement of stocks into Tiers (1, 2, 3, 4, or 5), stock status level (a, b, or c), the resulting F_{OFL} (see the tier system in chapter 3, Table 3-1) and the recommended ABC based on whichever approach (Alternative 2 or 3) the Council selects, to the SSC and Council, based on the work of the assessment authors.

The SSC commented in June that they felt that "option 3, which requires an additional SSC meeting, either in person or via teleconference, may not be viable due to scheduling difficulties. With regard to option 4, setting OFL[30] in June may be a viable option for some stocks but should not be used as a general approach for all stocks because of the lack of recent summer survey information in the determination of stock status." (June 2010 SSC minutes).

Under any of the options the ABC recommendation for Tier 5 stocks and Norton Sound red king crab, Aleutian Islands golden king crab will occur at the June meeting. The Council should decide upon a timing option (Tiers 1 through 4) and whether they would like to have some additional stocks assessed for the June recommendation timing (e.g., if St. Matthew blue king crab should be considered for that time frame).

For stocks in Tiers 1 through 3, the F_{OFL} is applied to model estimates of exploitable abundance to derive the OFL and then uses the calculated OFL (based on whichever process is selected for ABC control rules) to derive the ABC. 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, ABCs, and MSSTs.

[30] Note that this would entail setting OFL and ABC (not just OFL).

Absent a change in State policy (regarding their current harvest strategies), the State would set TACs for the fall fisheries based on the summer survey abundance estimates, constrained by the ABCs. Once the catch and bycatch data are available, overfishing would be determined by comparing the actual catches with the OFL and ACL (from the previous year). Two main issues are raised in considering Option 4 which have implications for the resulting ABC for crab stocks in the following year (for the annually surveyed stocks). The first issue relates to the observed fluctuations in area-swept estimates from one year to the next, which are noted in each assessment. For those stocks without an assessment model, these interannual variations in survey abundance estimates can have a profound effect on biomass estimates and stock status determinations. The second issue is related to one-year projection errors and is described in more details with examples for two stocks below.

2.1.7.1 Issues raised with option 4

An important criterion for comparing the timing of ACL determinations is relative one-year projection errors. 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 2009. Biomasses estimated in terminal years are used in OFL and ACL determination. Biomasses estimated in 2009 are considered as baseline estimates and should be more reliable than those in terminal years because more data are available in 2009, the most recent year's assessment for this report.

Table 2-2 illustrates the relative terminal estimates and one year ahead projections for results for MMB and legal males from the stock assessment model for St. Mathew blue king crab from 1998 to 2009 as well as the relative error to the estimates in 2009 (Table 2-3). Relative one-year projection errors ranged from -5.6% to 70.1% for legal male abundance and from -14.4% to 66.5% for MMB when compared to abundances and biomasses estimated in 2009. This means that during the 10-year period, in any given year the one-year projection would have either underestimated legal male biomass by up to 5.6% or overestimated the abundance of legal males by up to 70.1%. Relative errors of projected to observed biomasses estimated in 2009 were generally larger than errors based on terminal year estimates. The absolute mean of relative errors during these 10 years is 19.9% for the terminal year assessments and 25.9% for the one-year projections for the mature male biomass. These mean errors for legal males are 21.3% and 25.4%, respectively for the terminal year assessments and the one-year projections (Table 2-3). Therefore, the relative errors for the terminal assessments are about 4.1% to 6.0% points less than the one-year projections. If Option 4 is adopted, the abundance and biomass estimates are in average about 4.1% to 6% points less precise than the terminal year estimates under the current approach.

Table 2-2 Comparison of terminal year estimate and one year ahead projection for St. Matthew blue king crab assessment 1998 to 2009.

	MMB (million lbs)			*Legals (millions of crab)*		
	Terminal year estimate	Projection	2009 estimate	Terminal year estimate	Projection	2009 estimate
1998			3.391			2.147
1999	2.895		2.655	0.560		0.504
2000	3.202	3.099	3.075	0.616	0.589	0.568
2001	4.925	3.404	3.516	0.893	0.649	0.636
2002	5.397	5.829	3.770	0.966	1.047	0.651
2003	5.562	6.231	3.743	1.006	1.127	0.662
2004	4.466	6.593	3.980	0.806	1.139	0.700
2005	4.268	4.526	4.169	0.815	0.871	0.782
2006	5.588	4.517	5.275	0.982	0.847	0.898
2007	9.173	6.863	7.138	1.407	1.154	1.180
2008	9.702	12.996	9.278	1.577	2.008	1.509
2009		12.54	12.732	1.973	2.007	1.973

Table 2-4 illustrates the relative one-year model projection errors from 1998 to 2009 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 2009 SAFE report (NPFMC 2009a). Constant natural mortality of 0.18yr and constant molting probabilities for males over time were used in the updated model.

Table 2-3 Comparison of relative error in 2009 of one year ahead projection for St. Matthew blue king crab assessment 1998-2009.

	MMB		*Legals*	
	Estimates	Projection	Estimates	Projection
1998				
1999	0.090		0.111	
2000	0.041	0.008	0.085	0.037
2001	0.401	-0.032	0.404	0.021
2002	0.431	0.546	0.485	0.609
2003	0.486	0.665	0.519	0.701
2004	0.122	0.657	0.152	0.628
2005	0.024	0.086	0.042	0.114
2006	0.059	-0.144	0.094	-0.056
2007	0.285	-0.039	0.193	-0.022
2008	0.046	0.401	0.045	0.331
2009		-0.015		0.017
Abs. mean	0.199	0.259	0.213	0.254

Compared to Bristol Bay red king crab baseline biomass estimates (made in 2009) errors ranged from 24.9% to 32.4% for MMB, from 28.0% to 23.2% for legal male abundance. This means that during the

10-year period, in any given year the one-year projection would have either underestimated the legal male abundance by up to 28.0% or overestimated the legal male biomass by up to 23.2% (Table 2-4). The absolute mean of relative errors during these 10 years is 14.4% for the terminal year assessments and 16.4 for the one-year projections for the mature male biomass.

Table 2-4 Comparison of terminal estimate and one year ahead projection for MMB and legal male biomass from the assessment model for Bristol Bay red king crab.

	MMB (million lbs)			*Legals (millions of crab)*		
	Terminal year estimate	Projection	2009 estimate	Terminal year estimate	Projection	2009 estimate
1998			52.530			7.949
1999	71.55985		62.767	10.461		9.261
2000	68.53069	64.1942	63.418	11.641	12.403	10.755
2001	51.1274	58.87224	61.876	9.003	11.378	10.537
2002	51.60801	51.49337	68.532	8.135	8.559	10.329
2003	47.2605	50.92899	67.014	8.705	8.746	11.510
2004	63.66509	45.62467	63.326	11.038	7.981	11.087
2005	70.84996	75.12252	66.679	11.014	10.995	10.758
2006	91.01344	82.30518	74.720	13.684	12.573	11.664
2007	89.27619	101.1723	76.412	14.391	15.948	12.943
2008	92.69336	107.1777	87.826	14.151	16.028	13.584
2009		99.11542	95.169		16.488	15.626

Table 2-5 Comparison of relative error in 2009 of one year ahead projection for Bristol Bay red king crab assessment 1998 to 2009.

	MMB		*Legals*	
	Estimates	Projection	Estimates	Projection
1998				
1999	0.140		0.130	
2000	0.081	0.012	0.082	0.153
2001	-0.174	-0.049	-0.146	0.080
2002	-0.247	-0.249	-0.212	-0.171
2003	-0.295	-0.240	-0.244	-0.240
2004	0.005	-0.280	-0.004	-0.280
2005	0.063	0.127	0.024	0.022
2006	0.218	0.102	0.173	0.078
2007	0.168	0.324	0.112	0.232
2008	0.055	0.220	0.042	0.180
2009		0.041		0.055
Abs. mean	0.145	0.164	0.117	0.149

2.1.8 Optimum Yield definition

Alternative 4 includes a housekeeping amendment to specify the OY range for crab stocks under the FMP. Modification to the OY range was analyzed under Amendment 24 (NPFMC. 2008), however the specification for OY was omitted from the amendment text for Chapter 6 of the FMP. The current specification for OY under the FMP should read "OY range 0 to < OFL catch." The Council considered modifying this definition to read "OY range 0 to <ACL" as the previous definition reflected the OFL catch as the total annual catch while the ACL action clarifies that the ACL is overall annual total catch limit.

For crab stocks, the OFL is the annualized maximum sustainable yield (MSY) and is derived through the annual assessment process, under the framework of the tier system. Recognizing the relatively volatile reproductive potential of crab stocks, the cooperative management structure of the FMP, and the past practice of restricting or even prohibiting directed harvests of some stocks out of ecological considerations, this optimum yield range is intended to facilitate the achievement of the biological objectives and economic and social objectives of the FMP (see sections 7.2.1 and 7.2.2) under a variety of future biological and ecological conditions. It enables the State to determine the appropriate TAC levels below the OFL to prevent overfishing or address other biological concerns that may affect the reproductive potential of a stock but that are not reflected in the OFL itself. It enables the State to establish TACs at levels that maximize harvests, and associated economic and social benefits, when biological and ecological conditions warrant doing so.

2.2 Comparison of Action 1 alternatives

This section provides a comparison of alternatives under Action 1.

2.2.1 Consideration of uncertainty

The treatment of uncertainty is a critical aspect in this analysis. The NS1 Guidelines state that the ABC control rule must articulate how ABC will be set compared to the OFL based on the scientific knowledge about the stock of stock complex and the scientific uncertainty in the estimate of the OFL and any other scientific uncertainty (50 CFR 600.310(f)(4)). NMFS has described the characterization of the uncertainty in the OFL as a scientific decision.[31] The policy decision lies in determining the appropriate level of risk of overfishing, by selecting between buffers or P* values in the ABC control rule. The ABC control rule encompasses both the policy decision for the buffer or P* value and the annual consideration of scientific uncertainty.

Alternative 2, 3, and 4 would establish the ABC control rule that reflects the scientific knowledge about the stock and the scientific uncertainty in the estimate of the OFL and any other specified scientific uncertainty. However, each alternative uses a different approach to incorporating scientific uncertainty in the ABC control rule. For Alternative 2, this EA includes an evaluation of the relative uncertainty in the OFL and the risk of overfishing when harvest is at different ABC levels using the same process as for Alternative 3. However, under Alternative 2, once the ABC control rule is specified under a constant

[31] Comments on the proposed NS1 Guidelines stated that "accounting for scientific uncertainty is a matter of policy, not science and therefore should be delegated to the Council." The agency's response disagreed with the position voiced in this comment: "NMFS believes that determining the level of scientific uncertainty is not a matter of policy and is a technical matter best determined by stock assessment scientists as reviewed by peer reviewed processes and SSCs. Determining the acceptable level of risk of overfishing that results from scientific uncertainty is the policy issue." 74 FR 3192, January 16, 2009. (Comment 42 and Response).

buffer approach, no annual assessment of uncertainty would be conducted or utilized in the control rule. This is also how uncertainty would be treated under Alternative 4 for stocks in Tier 5 with a 10% buffer between the ABC and OFL. The annual ABC recommendations by the SSC may differ from the application of the ABC control rule based on consideration of scientific uncertainty. However, the SSC must explain why a recommendation differs from the application of the ABC control rule.[32]

For Alternatives 3 and 4, the annual estimation of the uncertainty in the OFL is implicit in the ABC control rule under the P* approach. Under these alternatives, stock assessment authors would annually calculate the probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty. Two aspects to uncertainty are considered: within-assessment uncertainty and additional uncertainty. Under Alternative 3, scientific uncertainty would be annually assessed and incorporated into the ABC control rule using a process that estimates a value for the with-in model uncertainty and quantifies all additional uncertainty as a fixed value that represents either high, medium, or low levels of additional uncertainty (this process is described below).

Under Alternative 4, with-in model uncertainty would be incorporated in the same way as Alternative 3, however, Alternative 4 has a more detailed approach for addressing additional uncertainty. In Alternative 4, the Council directed the CPT and SSC to identify factors influencing scientific uncertainty that should be incorporated in the ABC control rule, and which factors are best reserved for State consideration on an annual basis in TAC setting. This way, additional scientific uncertainty that is not applicable to the OFL setting process would be accounted for through the State TAC/GHL setting process. At this point, it is not possible to predict how this additional scientific uncertainty will be specified, quantified, or incorporated into the ABC control rule. Annually, the CPT and the SSC would evaluate and make recommendations, as necessary, on the specification of the probability distribution of the OFL, the methods to appropriately quantify uncertainty in the ABC control rule, and the factors influencing scientific uncertainty that the State will account for on an annual basis in TAC setting. The Council also requested the CPT and SSC continue work to improve understanding of scientific uncertainty in the estimation of crab OFLs and to ensure that crab stock assessment models and OFLs are risk-neutral. The Council expects that crab assessment and management staff will continue to work to evaluate all sources of uncertainty in assessments, develop methods to accurately quantify uncertainty, and to provide for SSC review. The end result will be to incorporate some additional outside of model uncertainty into the ABC control rule where possible while continuing to consider other aspects of uncertainty in the TAC-setting process.

This approach relies on the State's TAC-setting process to address additional uncertainty recognizing that many factors that influence estimates of scientific uncertainty are currently considered by the State and are time-sensitive. This is consistent with the State's role in conducting and analyzing scientific data on crab and in establishing TACs/GHLs under the FMP. The Council recognized that it would not be possible for the CPT and SSC to make scientific recommendations regarding the incorporation of many types of scientific uncertainty in the ABC control rule. The State also has the flexibility to use the expertise of its managers and biologists to be more conservative than existing harvest strategies as necessary to prevent overfishing and address scientific uncertainty.

The crab stock assessment process prevents taking into account some timely information. In other words, the SSC and CPT recommend model parameters in May and June, before the most recent survey data is available, and the assessments are effectively fixed at that time. When new information comes in from the current year's survey, it is incorporated, but there is no opportunity to re-evaluate the assessment, and

[32] "The SSC must recommend the ABC to the Council. An SSC may recommend an ABC that differs from the result of the ABC control rule calculation, based on factors such as data uncertainty, recruitment variability, declining trends in population variables, and other factors, but must explain why." 50 CFR 600.310(f)(3).

determine whether new information (from the survey or prosecution of the fishery) should be accounted for in some manner. Also, the crab assessments are inherently limited in their focus (i.e., on MMB) and in their use of data, and therefore do not account for information that the State considers in TAC-setting, but that may have no intrinsic effect on the assessment outcome.

Stock-specific OFL distributions are contained in each chapter and indicate the relative uncertainty characterized within the assessment itself due, for example, to the ability of the population dynamics model to mimic the observed length-frequency and survey biomass data. However as noted in each chapter, this characterization of uncertainty may not be sufficient to adequately capture the true uncertainty of the stock's OFL. For this reason a qualitative section is included in each chapter which outlines the additional sources of uncertainty that are not captured in the assessment itself but should still be considered when assessing the true uncertainty associated with the estimate of the OFL. The sources listed for each stock are restricted to calculation of OFL in the short-term and do not consider issues such as changes over time in productivity and habitat loss. Additional uncertainty has a substantial impact on the size of the resulting buffer value.

This analysis uses a procedure for calculating the total uncertainty in the OFL estimate that was developed through a lengthy analytical and peer-review process involving iterative review by the CPT and SSC between 2009 and 2010. The total uncertainty involved two components: the within-assessment uncertainty (denoted σ_w) and the additional assessment uncertainty (denoted σ_b). The relationship between the total uncertainty and the two components is calculated as $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$. Fundamental to capturing the total uncertainty is that the within-model assessment uncertainty alone is insufficient to characterize the true uncertainty in the stock-specific OFLs.[33] A full description of the analytical process resulting in the approach to characterize additional uncertainty is contained in section 3.2.4 and reflected in CPT and SSC minutes. SSC minutes relative to this topic from June 2009 to October 2010 are included as Appendix 1.

2.2.1.1 Within assessment uncertainty

The extent of uncertainty regarding the OFL "within" the assessment is quantified by the standard deviation of the logarithm of the estimate of mature male biomass at the time of mating (MMB) for the last year of the assessment (σ_w) as described in section 3.2.4. However, this value does not capture the

[33] "The SSC recommends that the initial default values be evaluated annually by the assessment authors, CPT, and SSC and that the CPT further develop a process and criteria for how to determine the most appropriate levels for σ_b. This process should draw on State and federal expertise in evaluating different sources of scientific uncertainty to ensure that the best available information is used… Consideration of scientific uncertainty in the level of OFL is appropriately applied through the specification of σ_w and σ_b. The SSC feels that the public process established by the Council for reviewing stock assessments through the plan teams and the SSC provides the best forum for determining the appropriate level of scientific uncertainty in OFL for the purposes of establishing Annual Catch Limits." (October 2010 SSC minutes). "The SSC believes that some approach to incorporating additional uncertainty in OFL beyond within-model uncertainty is warranted." (December 2009 SSC minutes) "The SSC agrees that the analyses should attempt to account for additional uncertainty, as long as a consistent approach is used across stocks…" (February 2010 SSC minutes). "The SSC supports the CPT approach to classifying stocks into those with relatively low, intermediate, and high levels of additional uncertainty." (April 2010 SSC minutes). "...the SSC endorsed the inclusion of a low, medium, and high levels of additional uncertainty to reflect sources of uncertainty that are not accounted for within the stock assessments….values for the additional uncertainty (sigma b) have to be chosen by the SSC and will become defaults under the P* approach. However the default values should be evaluated annually by the assessment authors, CPT and SSC to reflect our evolving understanding of the true magnitude of uncertainty in the OFL….the SSC accepted the May 2010 CPT recommendation to use values of 0.2, 0.3 and 0.4 for stocks with low, medium, and high levels of additional uncertainty.."(June SSC minutes).

true extent of uncertainty regarding the OFL from the assessment because the assessment does not consider all of the sources of uncertainty. In particular, most assessments pre-specify (do not estimate) some of the parameters which have a large impact on the estimate of the OFL (such as natural mortality, M, survey catchability, q, and the fishing mortality at which MSY is achieved, F_{MSY}). Some measure of additional uncertainty needs to be characterized in order to best approximate the "true" uncertainty in the assessment and thus establish ABC levels which are reflective of the "true" OFL. The method used to do this for this analysis was to add a σ_b value to σ_w.

The stocks with the most precise estimates of within-assessment uncertainty (σ_w) are the following: Bristol Bay red king crab, EBS snow crab, St, Matthew blue king crab, Norton Sound red king crab, AI golden king crab, and Tanner crab. However, of these, the OFL for some stocks (St. Matthew blue king crab, Tanner crab, Norton Sound red king crab and AI golden king crab) should be based on higher (assumed) levels of additional uncertainty than for the Tier 3 stocks, despite the low uncertainty associated with the estimate of the OFL from the assessment itself. It is not possible to estimate the extent of uncertainty associated the OFL for Tier 5 stocks in a manner similar to stocks in Tiers 1 through 4 due to lack of reliable biomass estimates. Thus a different characterization of uncertainty was employed for Tier 5 stocks, as described in section 3.3.5

2.2.1.2 Additional uncertainty (outside of estimated assessment)

For all stocks, the SSC and CPT recommend that some additional uncertainty should be allowed for when computing ABCs. Many assumptions are made in estimating the OFL. For several stocks, fixed values are assumed for parameters such as natural mortality, survey selectivity, and the biomass that would support maximum sustained yields. Making these assumptions introduces uncertainty into the estimate of OFL, which is often not reflected in the calculation of "within assessment uncertainty". Further discussion on the necessity of accounting for additional uncertainty to characterize the total uncertainty in the OFL estimate (outside of the within model uncertainty) is contained in chapter 3. The impacts of accounting for these levels of additional uncertainty compared to only employing the buffer resulting from the within-assessment variability can be substantial.

Direct measures to quantify this additional uncertainty were evaluated (see chapter 3), but a fully justifiable and defensible analytical means of calculating the extent of "additional" uncertainty could not be identified. The additional uncertainty is clearly larger than zero however, given that zero additional uncertainty indicates that assumptions about F_{MSY}, survey catchability (q) and natural mortality (M) are perfectly specified and precise. Currently, estimates of F_{MSY} and B_{MSY} are not available for any crab stocks and proxy values are estimated, while population modeling parameters such as M and q are pre-specified without consideration of the errors associated with that assumed value.

Therefore, this analysis uses constant values for σ_b to represent low, medium, and high levels of additional uncertainty. Results are also presented for a value of 0 (no additional uncertainty). Results for each stock are therefore shown for a range of levels for the extent of "additional" uncertainty based on values for σ_b of 0 (no additional uncertainty), 0.2, 0.3, 0.4, and 0.6. For this analysis, the values in Table 2-6 are used as the default values for σ_b in estimating the annual ABC calculations under the P* approach. Projection results are only shown for the selected σ_b value. Table 2-6 also summarizes the qualitative sources of additional uncertainty for each crab stock. As discussed in chapter 3, this range of values considered for σ_b were selected as constants with no specific analytical basis, but they are in the general range of calculated "additional uncertainty" for BSAI and GOA groundfish stocks as well as for fish stocks in other regions. The narratives for each stock outline the uncertainties considered most important for that stock and which level of additional uncertainty seems most applicable to that stock relative to information available amongst BSAI crab stocks.

A section characterizing additional uncertainty will be included in each stock assessment following the outline of the sections included for each stock in this EA. Changes to stock assessments and new information employed will be characterized each year to assess if there is a need to incorporate a non-zero value for σ_b to account for specified sources of outside of model uncertainty in the ABC control rule. The SSC and CPT will review stock assessment authors' recommended method of accounting for specified sources of outside of model uncertainty, and utilize the accepted approach for a given stock in a given year in recommending an ABC to the Council, provided that any recommendation to depart from the strict application of the ABC control rule is adequately explained.

Table 2-6 Factors considered in assigning additional uncertainty for all stocks and recommended additional variance employed in analysis

Stock	Factors considered in estimating additional uncertainty						
	Model CV estimate on MMB	Key population dynamics parameters pre-specified	Survey Q fixed	Basis for F_{MSY}	Uncertainty in B_{MSY} estimation	Additional considerations	Recommended additional variance (σ_b)
Bristol Bay red king crab	0.05	Yes	Yes	Yes	Yes		0.2
EBS snow crab	0.086	Some	No	Yes	Yes		0.2
Tanner crab	0.01 (estimated unreliable-not used) 0.140 (survey)	Yes	Yes	Yes	Considerable	Model under development	0.3
Pribilof Island red king crab	0.574 (survey data) 0.180 (model)	Yes (M)	Yes	Yes	Considerable	Model under development; CV on MMB range from 0.0357-0.0786 since 1995	0.4
Pribilof Island blue king crab	0.713 (survey data) 0.271 (model)	Yes (M)	Yes	Yes	Considerable	Model under development	0.4
St. Matthew blue king crab	0.160	Yes	Yes	Yes	Considerable	Uncertainty in trawl survey distribution	0.3
Norton Sound red king crab	0.110	Yes	Yes	Yes	Considerable	No bycatch estimates, periodic surveys only	0.4
Aleutian Island golden king crab	0.021 (Dutch) 0.027 (Adak)	Yes	Yes	Yes	Yes	Model under development, no trawl survey data	0.3
Pribilof Island golden king crab	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	Tier 5 fishery with no effort on 150,000-lb GHL during 2006–2009	0.4
Adak (AI) red king crab	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	N/A – Tier 5	Fishery closed due to stock concerns	0.4

2.2.2 Impacts of ACL Alternatives

The analysis characterizes the effects of the different alternatives on short-term harvests and long-term stock biomass and rebuilding probability (for EBS snow crab only), as well as the associated short- and long-term biological and economic impacts of the alternatives. The impacts depend on both the size of the buffer (or the associated value for P*) as well as the assumed level of additional uncertainty. These impacts are summarized to provide comparative information on the policy choices of various risk levels for P* and buffer choices.

A summary of the analysis of alternatives is provided below to highlight the distinction between the policy choice of a constant buffer by stock and a variable buffer by stock. Under Alternative 3, the Council would choose a P* value for each stock (or tier) depending upon an understanding of the relative risk of overfishing. Once the P* decision is made, the buffer value associated with that level of risk is calculated annually and results in a buffer level for that particular stock taking into account the additional variance and the annually calculated within assessment variance. As noted previously, as information improves for each assessment, the buffer value calculated will likewise decrease for the same P*, resulting in a gradual decrease in the ratio of the OFL to the ABC over time. Table 2-7 and Table 2-8 provide a summary of the buffer values calculated for a range of P*s for the current fishing year using the values for additional uncertainty shown in Table 2-6. To meet the statutory requirements, the ACL cannot lead to greater than 50% chance of overfishing, thus P* > 0.5 for all stocks is not a viable option.

Table 2-7 Buffer values for 8 stocks for a range of P*s under Alternative 3 using the recommended additional variance levels (σ_b) shown in Table 2-6. Shading indicates P* choices that would result in a 50% chance of overfishing. This table uses the mean to calculate the probability distribution of the OFL. [34]

P*:	0.5	0.4	0.3	0.2	0.1
Stock	Buffer				
Bristol Bay red king crab	0%	6%	11%	17%	24%
EBS snow crab	3%	8%	13%	18%	16%
Tanner crab	18%	34%	49%	NA	NA
Pribilof Island red king crab	30%	68%	73%	100%	100%
St. Matthew blue king crab	0%	0%	6%	16%	28%
Norton Sound red king crab	0%	16%	26%	34%	44%
Dutch Harbor golden king crab	0%	15%	21%	27%	36%
Adak golden king crab	0%	15%	23%	29%	44%

Table 2-8 Buffer values for 8 stocks for a range of P*s under Alternative 3 using the recommended additional variance levels (σ_b) shown in Table 2-6. Shading indicates P* choices that would result in a 50% chance of overfishing. This table uses the median calculate the probability distribution of the OFL.

P*:	0.5	0.4	0.3	0.2	0.1
Stock	Buffer				
Bristol Bay red king crab	0%	5%	10%	16%	23%
EBS snow crab	0%	5%	11%	17%	24%
Tanner crab	0%	8%	16%	24%	35%
Pribilof Island red king crab	0%	16%	31%	45%	60%
St. Matthew blue king crab	0%	8%	16%	25%	35%
Norton Sound red king crab	0%	10%	20%	25%	30%
Dutch Harbor golden king crab	0%	7%	15%	22%	32%
Adak golden king crab	0%	7%	15%	22%	32%

Table 2-9 and Table 2-10 present similar information for Alternative 2. The policy decision is to select an appropriate fixed buffer level by stock (or tier), taking into account the estimated risk of overfishing indicated in the analysis. Once the policy decision is made on the choice of a fixed buffer level (i.e., ABC = x% OFL, where 1-x is the buffer level selected), that buffer level would be used annually for that stock regardless of any modification in information contained in the stock assessment annually. The P*s associated with a range of buffer values calculated for the current fishing year using the recommended

[34] See section 3.2.4.2 for explanation of the impact of a highly skewed OFL distribution, and the use of the median or mean to calculate the probability distribution of the OFL on the resulting buffers for different P* values.

levels of additional variance and the current estimates of variance are summarized in Table 2-6. Again, an alternative that would lead to greater than or equal to a 50% chance of overfishing, thus a zero buffer (equating to a P* ≥ 0.5 for all stocks) is not a viable option.

Table 2-9 P* values for 8 stocks for a range of buffer values under Alternative 2 using the recommended additional variance levels (σ_b) shown in Table 2-6. Shading indicates P* choices that would result in a 50% chance of overfishing. This table uses the mean to calculate the probability distribution of the OFL. [35]

Buffers	0	10%	20%	30%	40%
Stock	P*				
Bristol Bay red king crab	0.50	0.25	0.11	0.04	0
EBS snow crab	0.50	0.36	0.18	0.07	0.01
Tanner crab	>0.50	>0.50	0.49	0.43	0.36
Pribilof Island red king crab	>0.50	>0.50	>0.50	>0.50	0.49
St. Matthew blue king crab	0.50	0.26	0.16	0.09	0.05
Norton Sound red king crab	>0.50	0.48	0.37	0.25	0.15
Dutch Harbor golden king crab	0.50	0.47	0.32	0.16	0.07
Adak golden king crab	0.50	0.45	0.35	0.19	0.10

Table 2-10 P* values for 8 stocks for a range of buffer values under Alternative 2 using the recommended additional variance levels (σ_b) shown in Table 2-6. Shading indicates P* choices that would result in a 50% chance of overfishing. The best estimate is assumed to be the median of the distributions for the OFL for all stocks. This table uses the median calculate the probability distribution of the OFL.

Buffers	0	10%	20%	30%	40%
Stock	P*				
Bristol Bay red king crab	0.50	0.25	0.14	0.04	0.01
EBS snow crab	0.50	0.31	0.15	0.05	0.01
Tanner crab	0.50	0.38	0.25	0.14	0.06
Pribilof Island red king crab	0.50	0.44	0.38	0.31	0.23
St. Matthew blue king crab	0.50	0.26	0.26	0.15	0.07
Norton Sound red king crab	0.50	0.40	0.30	0.20	0.11
Dutch Harbor golden king crab	0.50	0.36	0.23	0.12	0.05
Adak golden king crab	0.50	0.36	0.23	0.12	0.05

Alternative 4 specifies P* = 0.49 (and corresponding buffer which will vary slightly for each stock) for stocks in Tiers 1 through 4. Annually, stock assessment authors would calculate the probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL and any other specified sources of scientific uncertainty. Any additional scientific uncertainty that is not applicable to the OFL setting process would be accounted for through the State TAC/GHL setting process. The Council directed the CPT and SSC to identify factors influencing scientific uncertainty that could be incorporated in the ABC control rule, and which are best reserved for State consideration on an annual basis in TAC setting.

At this point, it is not possible to predict how the additional scientific uncertainty will be specified, quantified, or incorporated into the ABC control rule. Therefore, for this analysis, the estimated buffers resulting from a P* = 0.49, and σ_w to characterize uncertainty, are shown in Table 2-11 in comparison with similar buffer values at a range of P* values between 0.4 and 0.5 with σ_b included in estimating uncertainty. Note that for this comparison table, the median was used to calculate the probability

[35] See section 3.2.4.2 for explanation of the impact of a highly skewed OFL distribution and the use of the median or mean to calculate the probability distribution of the OFL on the resulting buffers for different P* values.

distribution of the OFL for all stocks. As discussed in section 3.2.4.2, the choice of using the mean or the median for the probability distribution of OFL has a huge impact on the size of the buffer under different P* values for many the Tier 4 stocks. For comparison, both the mean and the median was used to calculate the probability distribution for Tier 4 stocks in the previous tables (Table 2-7 through Table 2-10). The analysis in the stock-specific chapters uses the mean. The method used to calculate the probability distribution of the OFL would be an annual decision and specified in the stock assessment.

Annually, the CPT and the SSC shall evaluate and make recommendations, as necessary, on the specification of the probability distribution of the OFL, the methods to appropriately quantify uncertainty in the ABC control rule, and the factors influencing scientific uncertainty that the State will account for on an annual basis in TAC setting. The Council also requested the CPT and SSC continue work to improve understanding of scientific uncertainty in the estimation of crab OFLs and to ensure that crab stock assessment models and OFLs are risk-neutral. The Council expects that crab assessment and management staff will continue to work to evaluate all sources of uncertainty in assessments, develop methods to accurately quantify uncertainty, and to provide for SSC review. The end result will be to incorporate some additional outside-of-model uncertainty into the ABC control rule where possible while continuing to consider other aspects of uncertainty in the TAC-setting process.

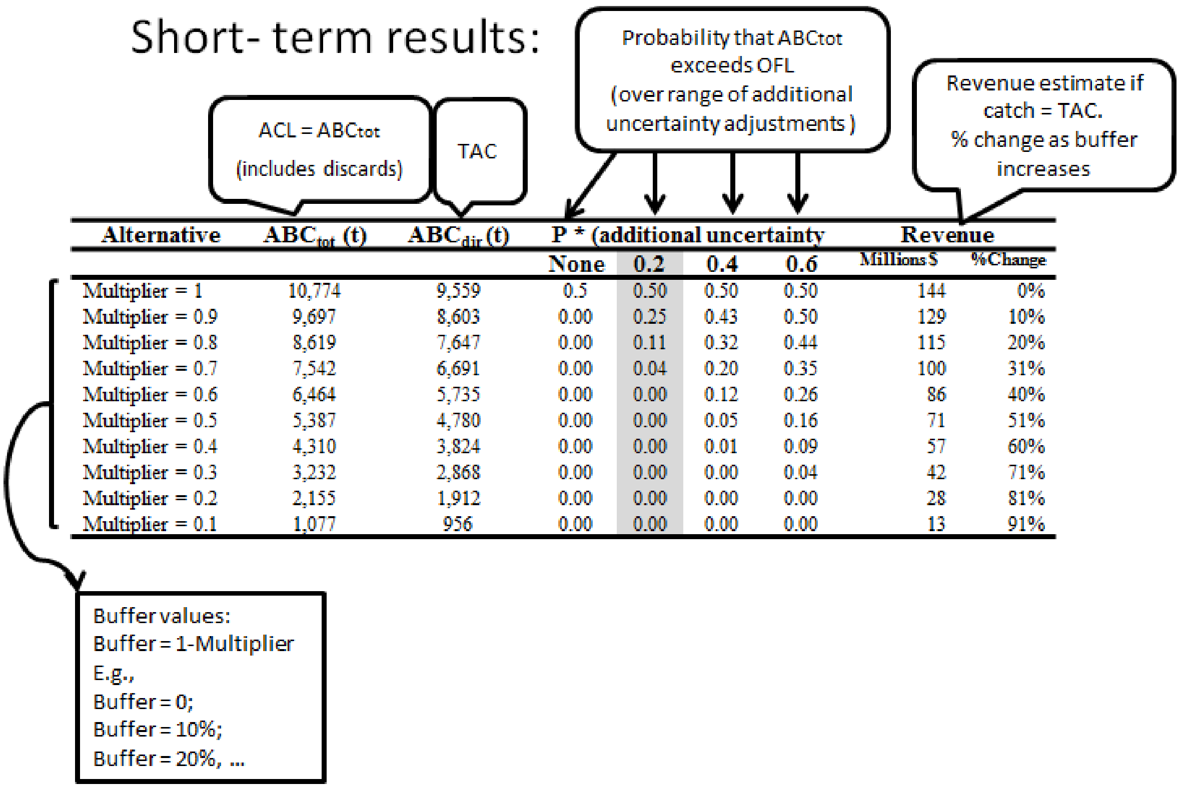
This approach relies on the State's TAC-setting process to address additional uncertainty recognizing that many factors that influence estimates of scientific uncertainty are currently considered by the State and are time-sensitive. This is consistent with the State's role in conducting and analyzing much of the scientific data on crab and in establishing TACs/GHLs under the FMP. The Council recognized that it would not be possible for the CPT and SSC to make scientific recommendations regarding the incorporation of many types of scientific uncertainty in the ABC control rule. The State also has the flexibility to use the expertise of its managers and biologists to be more conservative than existing harvest strategies as necessary to prevent overfishing and comply with federal requirements.

Table 2-11 Estimated P* values between 0.4 and 0.5 with total uncertainty estimated with recommended values for additional uncertainty (σ_b) and with model-estimated (σ_w) uncertainty only. In bold are the buffers resulting from the P* = 0.49 without any additional uncertainty in the ABC control rule. This table uses the median calculate the probability distribution of the OFL.

P*:	0.5	**0.49**	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41	0.40
Stock	Buffer (% reduction of OFL)										
Bristol Bay red king crab											
$\sigma_w + \sigma_b$	0.00%	0.52%	1.03%	1.54%	2.05%	2.56%	3.06%	3.57%	4.08%	4.58%	5.09%
σ_w	0.00%	**0.13%**	0.25%	0.38%	0.50%	0.63%	0.75%	0.88%	1.00%	1.13%	1.26%
EBS snow crab											
$\sigma_w + \sigma_b$	0.00%	0.54%	1.08%	1.62%	2.16%	2.69%	3.23%	3.76%	4.29%	4.82%	5.36%
σ_w	0.00%	**0.21%**	0.43%	0.64%	0.85%	1.06%	1.28%	1.49%	1.70%	1.92%	2.13%
Tanner crab											
$\sigma_w + \sigma_b$	0.00%	0.83%	1.65%	2.46%	3.27%	4.07%	4.88%	5.67%	6.47%	7.26%	8.05%
σ_w	0.00%	**0.35%**	0.70%	1.05%	1.40%	1.74%	2.09%	2.44%	2.79%	3.14%	3.48%
Pribilof Island red king crab											
$\sigma_w + \sigma_b$	0.00%	1.74%	3.45%	5.13%	6.79%	8.42%	10.02%	11.61%	13.17%	14.72%	16.24%
σ_w	0.00%	**1.43%**	2.84%	4.23%	5.60%	6.96%	8.30%	9.63%	10.94%	12.24%	13.53%
St. Matthew blue king crab											
$\sigma_w + \sigma_b$	0.00%	0.85%	1.69%	2.53%	3.36%	4.18%	5.00%	5.82%	6.63%	7.44%	8.25%
σ_w	0.00%	**0.40%**	0.80%	1.20%	1.59%	1.99%	2.39%	2.78%	3.18%	3.58%	3.97%
Norton Sound red king crab											
$\sigma_w + \sigma_b$	0.00%	1.04%	2.06%	3.08%	4.08%	5.08%	6.07%	7.06%	8.04%	9.01%	9.98%
σ_w	0.00%	**0.28%**	0.56%	0.83%	1.11%	1.39%	1.66%	1.94%	2.22%	2.49%	2.77%
Dutch Harbor golden king crab											
$\sigma_w + \sigma_b$	0.00%	0.75%	1.50%	2.24%	2.98%	3.71%	4.44%	5.17%	5.89%	6.61%	7.34%
σ_w	0.00%	**0.05%**	0.11%	0.16%	0.21%	0.26%	0.32%	0.37%	0.42%	0.48%	0.53%
Adak golden king crab											
$\sigma_w + \sigma_b$	0.00%	0.75%	1.50%	2.24%	2.98%	3.71%	4.45%	5.17%	5.90%	6.62%	7.35%
σ_w	0.00%	**0.07%**	0.14%	0.20%	0.27%	0.34%	0.41%	0.48%	0.54%	0.61%	0.68%

2.2.2.1 Short-term harvest constraint

Results in each chapter (chapters 4 through 13) summarize the impact of a range of ACL buffer values on the short-term harvest, i.e. whether the ABC control rule at different buffer values would constrain the State harvest strategy for that stock. The State harvest strategy is used to approximate the TAC level in future years.



Alternative	ABC_{tot} (t)	ABC_{dir} (t)	P * (additional uncertainty				Revenue	
			None	0.2	0.4	0.6	Millions $	%Change
Multiplier = 1	10,774	9,559	0.5	0.50	0.50	0.50	144	0%
Multiplier = 0.9	9,697	8,603	0.00	0.25	0.43	0.50	129	10%
Multiplier = 0.8	8,619	7,647	0.00	0.11	0.32	0.44	115	20%
Multiplier = 0.7	7,542	6,691	0.00	0.04	0.20	0.35	100	31%
Multiplier = 0.6	6,464	5,735	0.00	0.00	0.12	0.26	86	40%
Multiplier = 0.5	5,387	4,780	0.00	0.00	0.05	0.16	71	51%
Multiplier = 0.4	4,310	3,824	0.00	0.00	0.01	0.09	57	60%
Multiplier = 0.3	3,232	2,868	0.00	0.00	0.00	0.04	42	71%
Multiplier = 0.2	2,155	1,912	0.00	0.00	0.00	0.00	28	81%
Multiplier = 0.1	1,077	956	0.00	0.00	0.00	0.00	13	91%

Figure 2-4 Schematic for understanding short-term results in each stock-specific chapter. Shading indicates the recommended level of additional uncertainty. Similar tables of short-term results are found in each chapter (e.g., Tables 6-1, 7-1).

This section describes where in the analysis to locate the stock by stock information in each chapter (chapters 4 through 13). In evaluating short-term results, Figure 2-4 shows an example how to consider the relative impacts of varying levels of uncertainty in evaluating the probability of overfishing. Figure 2-4 gives an overview of how short-term tables in each chapter can be interpreted to identify the implications of any P* value. For comparison, a range of σ_b values (additional uncertainty) values are shown with the SSC's recommended value shaded. The choice of σ_b is a scientific decision; thus results are summarized for the resulting policy choices (P* or constant buffer) by stock thereafter.

The analysis discusses the impacts of a range of ACL buffer values on the short-term harvest, i.e., whether the ABC control rule at different buffer values would constrain the retained catch for that stock. The State harvest strategy was used to calculate approximate TAC for future years, and the retained catch is assumed to equal the TAC. Alternative 4 and buffer values (and corresponding P*s) less that those noted below would have no short-term impacts relative to status quo, except for St. Matthew blue king crab. Buffer values larger that those noted would constrain harvest relative to status quo. From this analysis, the application of the State harvest strategy would result in buffers between catch and the OFL of between 10% and 100% (when the fishery is closed even though the ABB would have allowed catch). These buffers protect against overfishing. The following is a brief summary of the short-term directed harvest constraint for each crab stock:

- For Bristol Bay red king crab, the retained catch would be constrained at buffer values greater than 10% (i.e., a 10% buffer, or ABC established at < 90% of the OFL).

- For snow crab, buffer values greater than 10% would constrain the retained catch based upon the 2009/10 TAC level.
- For Tanner crab, buffer values greater than 40% would constrain the retained catch based upon the 2009/10 TAC.
- For Pribilof Islands red king crab, any buffer (i.e. even at a 0% buffer or ABC established at the OFL) would constrain the State harvest strategy (note that, as described in Chapter 7, this fishery is closed and the State harvest strategy has not been employed for this stock since 1993 given concerns with the potential for bycatch of the Pribilof blue king crab in a directed Pribilof Island red king crab fishery and uncertainty in Pribilof Island red king crab stock abundance levels).
- For Pribilof Islands blue king crab, the directed fishery is closed so there is no short-term impact of any buffer size of the retained catch component of the ABC.
- For St. Matthew blue king crab, the retained catch would be constrained at all buffer values.
- For Norton Sound red king crab, only buffer values greater than 50% would constrain the retained catch.
- For Aleutian Islands golden king crab, only buffers greater than 80% would constrain the retained catch.[36]
- For Pribilof Island golden king crab, buffer values greater than 20% would constrain the retained catch (based on the 2010 GHL amount).
- The Western Aleutian Islands red king crab fishery is currently closed, so buffer values considered do not impact retained catch for this stock.

Appendix 3 describes the assumptions employed in this analysis to characterize the State's TAC-setting process. It was assumed that employing the harvest control rules for TAC-setting by stock was an adequate characterization of how TAC would be set into the future in order to compare this against proposed ABC control rules as harvest constraints. For some stocks this may be a better characterization than for others. For example, for Bristol Bay red king crab this may be a better approximation of TAC-setting as the stock is above B_{MSY} and has had a consistent directed fishery in recent years with the harvest strategy used as a primary decision component in the discussion of how to set TAC for this stock annually (see section 2.1.1.1 for further description of the TAC-setting process). However, for St. Matthew blue king crab, the harvest strategy has not in recent years been a good indication of where the State will set the TAC because application of the harvest strategy alone would have resulted in a TAC greater than the OFL. Thus for this stock, setting the TAC below the OFL is a major consideration in TAC-setting (note that in the end this stock in 2010/11 was not opened to directed fishing). Nevertheless the State of Alaska (SOA) harvest strategy is presented for St. Matthew blue king crab in the projections as a prediction of TAC-setting in the future. For stocks where this assumption of using the harvest strategy is more valid, an approximation can be given to impacts of operating under Alternative 4 where the total catch level is less than the ABC due to State TAC-setting.

In each chapter, where information is available, a breakdown of the OFL components is provided, as shown for Bristol Bay red king crab in Table 2-12. This information is used by ADF&G managers in their TAC-setting process to estimate the amount of buffering necessary to estimate all discards (so as not to exceed the annual OFL level). Additional buffering occurs between the ABC and TAC in TAC-setting to accommodate scientific uncertainty and other factors.

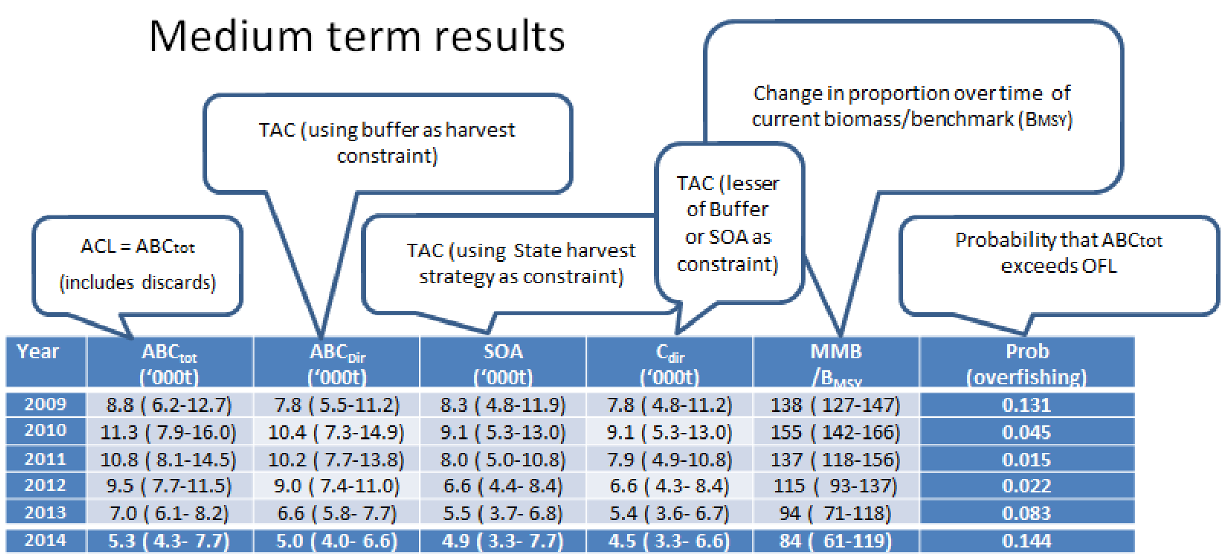
[36] Based on the Tier 4 model estimated output as shown in chapter 11, section 11.2. For Tier 5 results see chapter 11, section 11.4.3.

Table 2-12 Breakdown of the 2009/10 OFL for Bristol Bay red king crab among the sources of mortality included in the OFL Similar tables are found in each chapter (e.g., Tables 6-2, 7-2).

Component	Catch (t)
Directed fishery	9,559
Male discard in the directed fishery	942
Female discard in the direct fishery	152
Bycatch in the trawl fishery	108
Bycatch in the Tanner fishery	13
Total	10,774

2.2.2.2 Medium-term and long-term stock rebuilding

Two additional time frames were considered in the analysis in characterizing results. A medium-term simulation is included for most stocks whereby the first five years of the long-term (30 year) simulation are shown in detail to indicate the impacts of different alternatives over that time frame. Figure 2-5 shows a schematic of the tables included by chapter to understand the implications during the medium-term time frame (2009 to 2014). Each medium-term table shows one alternative scenario. The P* associated with that alternative by year is shown as the probability of overfishing (to the far right in each table). To best understand the results, comparison must be made across tables to evaluate the impact of less constraining and more constraining buffers for each stock and the relative probability of overfishing at that harvest level over that time frame.



Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	8.8 (6.2-12.7)	7.8 (5.5-11.2)	8.3 (4.8-11.9)	7.8 (4.8-11.2)	138 (127-147)	0.131
2010	11.3 (7.9-16.0)	10.4 (7.3-14.9)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	10.8 (8.1-14.5)	10.2 (7.7-13.8)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	9.5 (7.7-11.5)	9.0 (7.4-11.0)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	7.0 (6.1- 8.2)	6.6 (5.8- 7.7)	5.5 (3.7- 6.8)	5.4 (3.6- 6.7)	94 (71-118)	0.083
2014	5.3 (4.3- 7.7)	5.0 (4.0- 6.6)	4.9 (3.3- 7.7)	4.5 (3.3- 6.6)	84 (61-119)	0.144

Figure 2-5 Schematic of medium-term results table for stock-specific impacts by chapter. For this example a buffer value of X% is shown. Tables for each stock show similar results for a range of buffer values.

More constraining buffers (or lower values for P*) decrease the probability that stocks will become overfished in the future. This is shown quantitatively for those stocks for which biomass estimates and projections of stock status are possible. However this is highly dependent upon individual stock status and recruitment assumptions inherent to these models. Additional information by stock should be considered in evaluating long-term implications of these ACL alternatives.

For Alternative 4, the distinction between P* = 0.5 and P* = 0.49, as well as between a zero σ^b or with a σ^b with a value, are indistinguishable analytically. However, in practice, the TAC is the effective catch limit that will be set below the ACL by a considerable amount. Thus, for understanding the impacts of Alternative 4, the results are characterized by using the tables showing ABC = OFL (i.e. multiplier = 1) with the SOA control rule. For most stocks, the imposition of the SOA control rule scenario shows that the harvest control rule provides greater protection against overfishing than fishing at an ABC control rule of P* = 0.49 and any σ^b value considered. In other words, the impacts of Alternative 4 are indistinguishable from the impacts of Alterative 1, status quo, because of the existing TAC-setting process. The exceptions to this are St. Matthew blue king crab, where the TAC calculated from the harvest strategy exceeds the OFL. However, in practice, if the harvest control rule would result in a TAC that exceeds the ACL, ADF&G managers would reduce the TAC to a level that ensures that total catch would not exceed the ACL.

Table 2-13 Summary of the medium-term consequences of a multiplier of 1 for Bristol Bay red king crab. The point estimates are medians and the intervals 90% intervals. The results in the table are based on σ_b = 0.2. Similar tables are found in each chapter (e.g. Tables 6-4, 7-4).

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2009	11.0 (7.8-15.9)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	136 (125-146)	0.198
2010	14.1 (9.8-20.1)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	13.5 (10.1-18.2)	8.0 (5.0-10.8)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	11.8 (9.6-14.5)	6.6 (4.4- 8.4)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	8.8 (7.7-10.3)	5.5 (3.7- 6.8)	5.5 (3.7- 6.8)	5.5 (3.6- 6.8)	94 (71-118)	0.076
2014	6.9 (5.6- 9.8)	5.0 (3.4- 7.6)	5.0 (3.4- 7.6)	5.0 (3.3- 7.6)	85 (59-119)	0.226

Figure 2-6 and Figure 2-7 present a depiction of the tradeoff between risk of reducing the stock below the MSST and the relative cost of implementing ACL measures to reduce risk. For each of the nine BSAI stocks for which stock assessment models and surveys are available, stock simulations under a range of ACL multiplier values ranging from 0 to 1.0 were used to forecast stock biomass, ABC, and directed catch values for the medium (5 years, Figure 2-6) and long-term (30 years, Figure 2-7) period of analysis. Results are presented for all Tier 3 and 4 crab stocks, as well as Western Aleutian Island golden king crab, and are based on stock assessment model forecasts using the recommended additional uncertainty parameter (σ_b) value for each stock, and crab market price forecasts and discounted present value (r=2.7%) of estimated future gross revenues. Medium-term results are not available for the σ_b = 0 scenarios and instead are consistently presented for the range of P* values using the recommended levels of sigma b. Directed catch estimates were combined with probabilistic forecasts of first wholesale market prices for king crab and snow crab to produce estimates of the value of future crab production under ACL alternatives. Detailed methods and results are presented in following chapters, and Figure 2-6 and Figure 2-7 provide a summary those analyses. Results are presented in terms of percentage change in total present value (TPV) resulting from the alternatives relative to expected economic value under a zero buffer, ABC=OFL, and assuming that total catch equals the OFL. This allows equal comparison across fisheries of different scale and value. A zero buffer does not reflect the State of Alaska control rules for TAC setting that reduce catch below the OFL, therefore it does not reflect status quo. Accordingly, these results tend to overstate the change in total present value that would occur under Alternatives 2, 3 and 4. Additional results are presented in each species specific chapter.

The upward sloping curve in each figure shows the relatively linear relationship for most crab stocks between ACL buffer sizes and the forecasted percentage reduction in TPV over the 5- and 30-year period, respectively, although snow and Tanner crab, and to a lesser degree Bristol Bay red king crab, display an increasing incremental reduction in TPV as the multiplier level increases.

The downward sloping curve in each display the tradeoff between risk of the stock becoming overfished and the foregone economic value required. The nonlinearity of the tradeoff is of particular note in the consideration of ACL alternatives. With the exception of Pribilof Island red king crab, most stock projections display a decreasing incremental reduction in probability of the stock becoming overfished as multiplier sizes and catch and revenue reduction increase from 0 to 100%, with relatively large risk reduction from the current baseline at relatively modest economic impact. Model simulations for all stocks (with the exception of Tanner crab, for which the simulation reflects the status of the stock as currently overfished) indicate that the probability of becoming overfished in the next thirty years at the baseline level of zero multiplier is somewhat below 0.5.

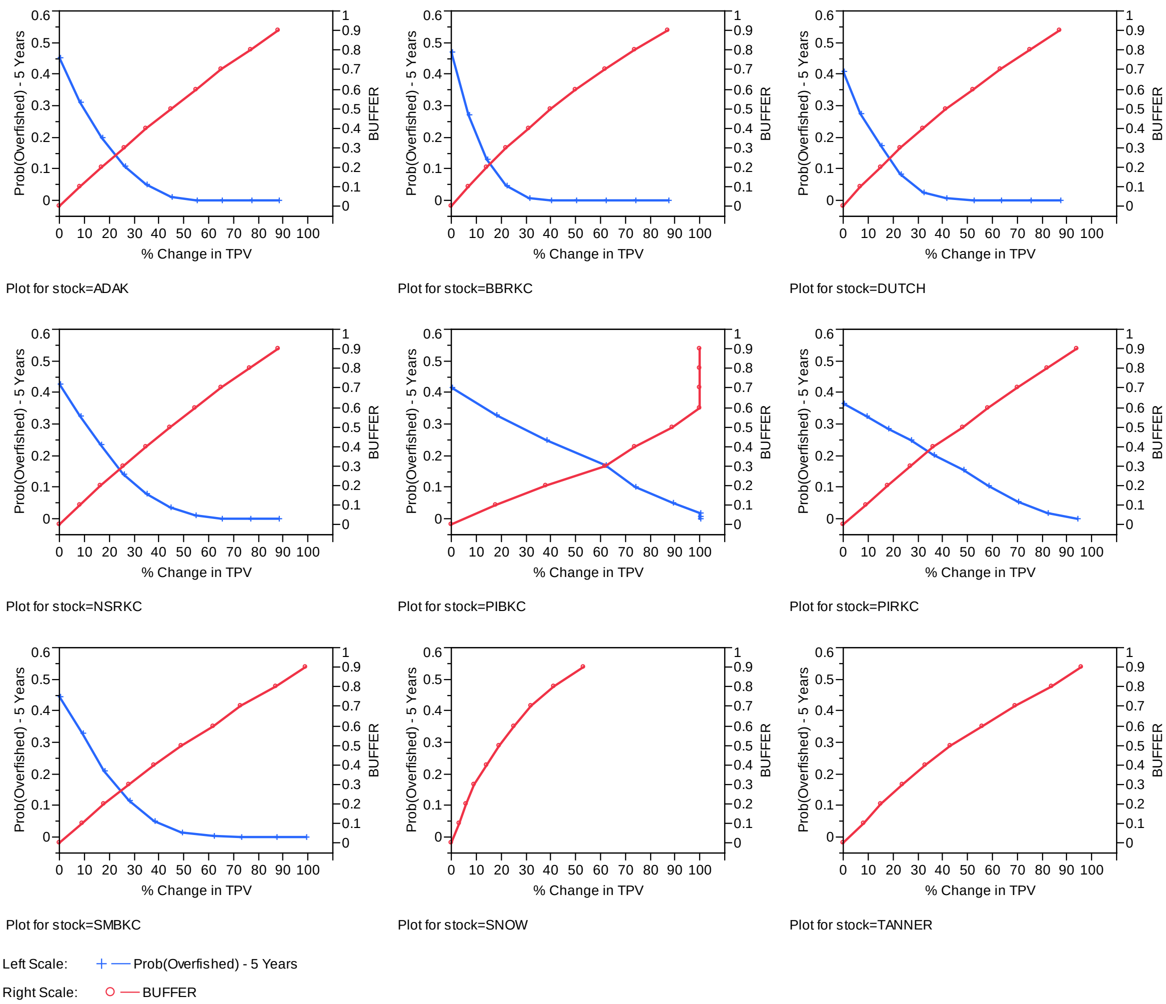


Figure 2-6 **ACL buffer size and estimated probability over 5 years that BSAI crab stocks will decline below the MSST overfished limit under ACL alternatives, compared to the estimated percentage change in total present value of crab production associated with reduced catch rates.**

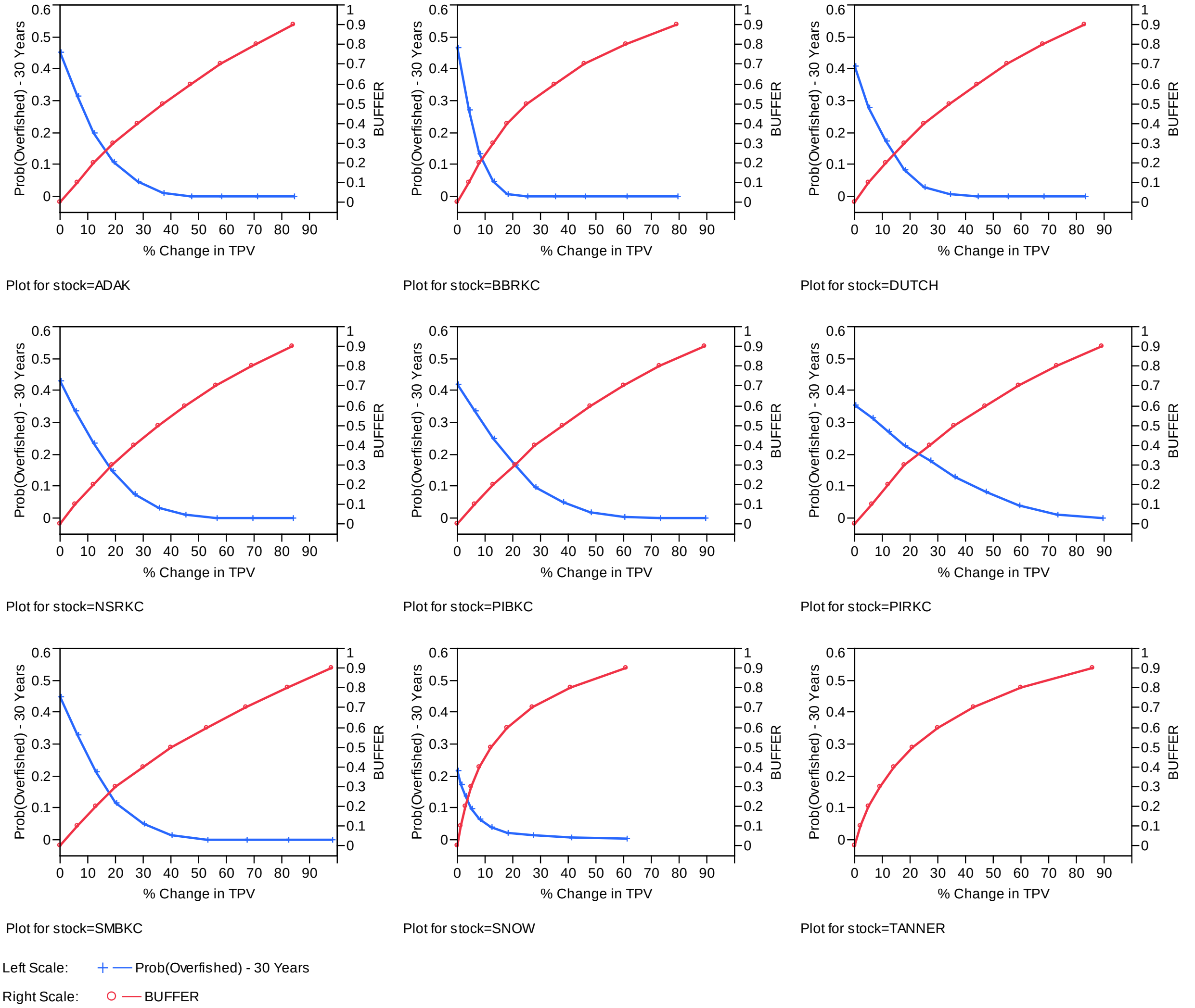


Figure 2-7 ACL buffer size and estimated probability over 30 years that BSAI crab stocks will decline below the MSST overfished limit under ACL alternatives, compared to the estimated percentage change in total present value of crab production associated with reduced catch rates.

For long-term impacts, results can be characterized similarly to the medium-term results. Long-term projections in Table 2-14 show the scenario of including σ_b but with no buffer (i.e. multiplier = 1 or ABC = OFL) and including the SOA control rule to evaluate the impacts on mature male biomass over the 30-year projection. In some cases there is additional information on the distinction in long-term economic gains of $\sigma_b = 0$. Again, for most stocks, the SOA control rule provides greater protection against overfishing and against the stock size declining below the overfished threshold than an ABC control rule of P*=0.49 and any σ_b values considered. In other words, the impacts of Alternative 4 are indistinguishable from the impacts of Alterative 1, status quo.

Table 2-14 Summary of long-term economic impacts of the ACL alternatives for Bristol Bay red king crab. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the five year period 2009 to 2038 (2008 dollars), and differences in revenues relative to a zero buffer constrained by the SOA control rule. Alternatives include fixed buffers (multipliers of 1.0 to 0.4) and P* levels (0.5 to 0.1), for additional uncertainty σ= 0.2. Point estimates are medians and ranges are 90% confidence intervals. Similar tables are found in each chapter (e.g., Tables 6-6, 7-7). Circles indicate the preferred alternative.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
	Multiplier = 1	3206(969,6247)	2259(734,4227)	1429(523,2577)	0	0
	Multiplier = 0.8	3168(959,6181)	2220(719,4138)	1403(511,2535)	2	0
0	Multiplier = 0.6	2939(886,5783)	2030(665,3827)	1273(464,2318)	10	0
	Multiplier = 0.4	2366(699,4630)	1618(516,3054)	994(352,1809)	28	0

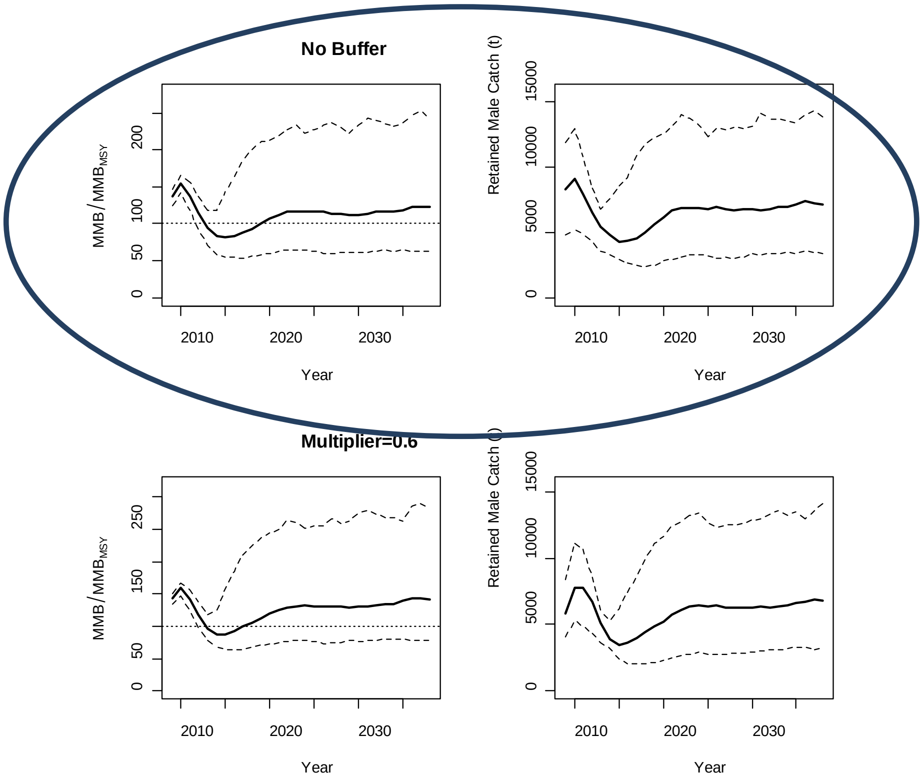


Figure 2-8 **Time-trajectories of mature male biomass at mating relative to B_{35} (the proxy for B_{MSY}) and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the table are based on $\sigma_b = 0.2$. The results in this figure are based on applying the SOA control rule. Similar figures are found in each chapter (e.g., Figure 6-6, 7-6). Circles indicate the preferred alternative.**

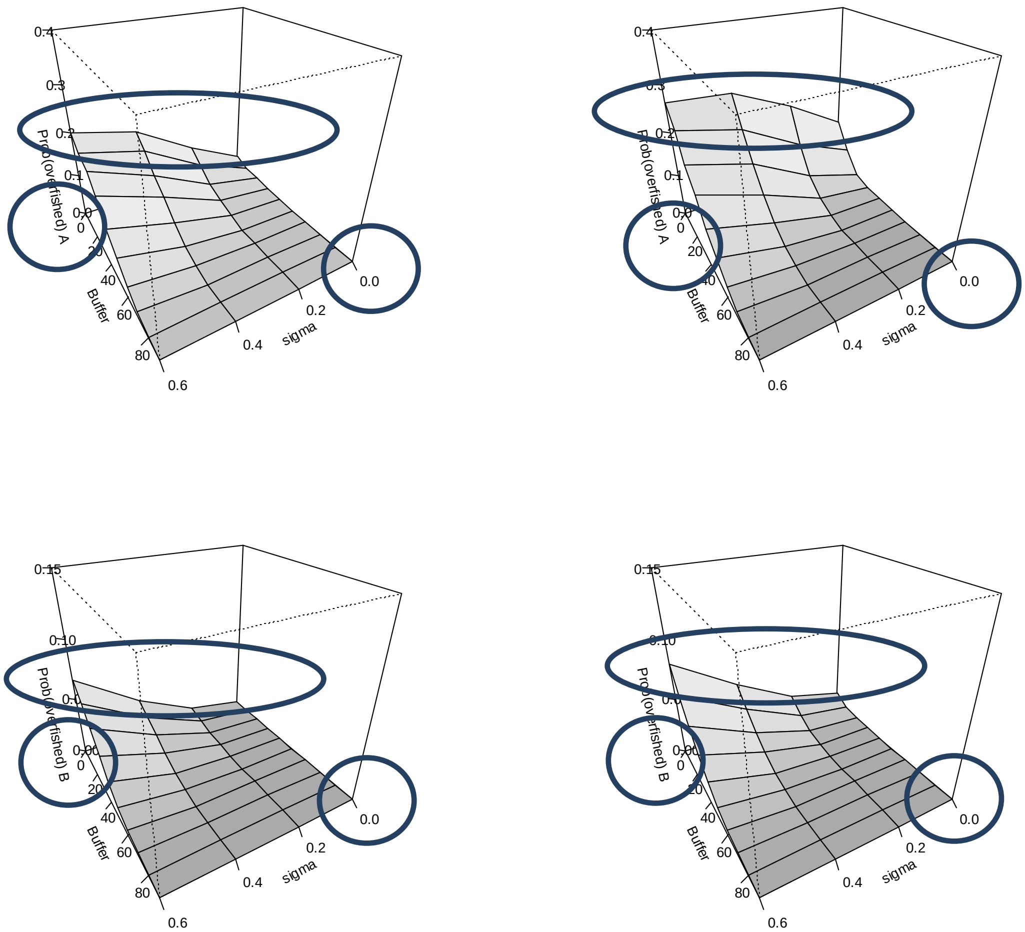


Figure 2-9 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Bristol Bay red king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored. Similar figures are found in each chapter (e.g., Figure 6-7, 7-7). Circles indicate the preferred alternative.**

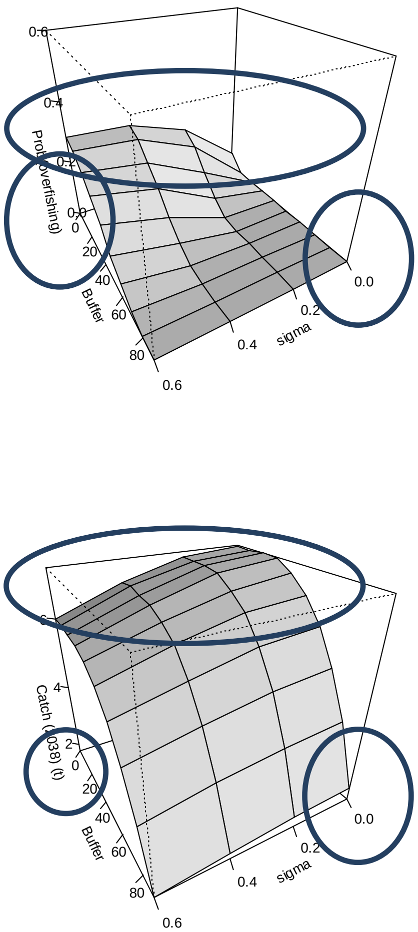


Figure 2-10 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Bristol Bay red king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored. Similar figures are found in each chapter (e.g. Figure 6-8, 7-8).**

For Tier 5 stocks the Council selected a constant buffer approach of 10% (or ABC = 90% of OFL) in Alternative 4. The current Tier 5 stocks are the following: Aleutian Islands golden king crab, Pribilof Islands golden king crab, and western Aleutian Islands red king crab. Of these, AIGKC was evaluated in this analysis as both a Tier 4 and a Tier 5 stock as a model is being developed, and it is anticipated this stock will be moved out of Tier 5 in the 2011/12 assessment cycle. For these three stocks, tables and figures demonstrate the impacts of a 10% buffer and no additional uncertainty in terms of both resulting P* values and relative harvest constraint in the directed fishery (note only AIGKC has a directed fishery and there is no constraint at a 10% buffer). Biological projections are not possible for Tier 5 stocks.

2.3 Action 2: Rebuilding plan for EBS snow crab stock

The alternatives below represent different target years for rebuilding the snow crab stock to the proxy for B_{MSY} with a pre-specified probability no less than 50% (values for T_{target}). Options (applicable to each alternative) establish increased probabilities for rebuilding by T_{target}. Annual fishing mortality rates will be derived based on the chosen T_{target} and associated probability of rebuilding by that target date.

Rebuilding alternatives may be more constraining than the ABC control rule for this stock. The harvest strategy necessary to rebuild the stock under each option below will inform the maximum ACL for this stock. Once the stock is rebuilt, the rebuilding measures will no longer apply.

2.3.1 Alternative 1: No Action [preferred]

This is the no action alternative and would maintain the existing rebuilding plan. In October 2010, the Council recommended no action to modify the harvest strategy under the existing rebuilding plan. The Council recognized that the NS1 Guidelines recommend limiting total removals to the lesser of the F associated with the existing rebuilding plan and 75% F_{OFL}, and that this approach along with the State of Alaska's rebuilding harvest strategy will remain in effect until the stock is rebuilt. Additionally, the State's harvest strategy will constrain directed catch after the stock is rebuilt. The SSC indicated that Alternative 1 was adequate to meet rebuilding goals. The Council also recognized that snow crab is not overfished, and in fact based on the current stock assessment its biomass is approximately 96% of B_{MSY}, the level at which the stock would be considered rebuilt. In addition, the retrospective in the current assessment indicates that historically the mature male biomass never dropped below the MSST.

2.3.2 Alternative 2: Set T_{TARGET} based on minimum number of years necessary to rebuild the stock

This alternative would set T_{TARGET} based on minimum number of years necessary to rebuild the stock, under the current assessment of the snow crab stock, if all sources of fishing-related mortality are set to zero.[37]

For example, the current estimate of the minimum number of years to recover to $B_{35\%}$ for one year (i.e., under assumption of a catch corresponding to 75% of F_{OFL} through 2010/11 and implementing F=0 beginning in the 2011/12 fishing year) is 2012/13. The minimum number of years is the same with very low levels of catch (equivalent to estimated incidental catch in other fisheries).

2.3.3 Alternative 3 to Alternative 4: Set T_{TARGET} above the minimum number of years (between 1 above the minimum and T_{END}).

Under these alternatives, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{TARGET} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{TARGET} would be the year in which the probability of rebuilding is 50%. Additional options under consideration (see section 2.3.4 below) would increase this time frame to 8 years (under option 1).

[37] Recovery by the minimum T_{target} could occur with low levels of catch although this would decrease the probability of rebuilding by T_{end}.

The timeframes associated with the alternatives are the following:
Alternative 3: 3 years to rebuild (T_{TARGET} = time of mating 2013/14)
Alternative 4: 4 years to rebuild (T_{TARGET} = time of mating 2014/15)

2.3.4 Options to increase the probability of rebuilding by the agreed T_{TARGET}

Under these options, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{TARGET} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{TARGET} would be the year in which the probability of rebuilding is 50%.

Options to increase probability of rebuilding:
- option 1: increase probability of rebuilding to 70% by increasing time frame to T_{END} to 8 years.
- option 2: increase probability of rebuilding to 75% by T_{TARGET}.
- option 3: increase probability of rebuilding to 90% by T_{TARGET}.

Under option 1 the probability of rebuilding would be increased to 70% by extending the time frame for T_{END} while retaining the maximum fishing mortality constraint of 75% of F_{OFL} for 3 additional years from the Alternative 4. Under options 2 and 3, the time frame to rebuild cannot be extended to increase the probability of rebuilding higher than under option 1 thus these options would require a more constraining maximum fishing mortality rate than the 75% of F_{OFL} assumed under the other alternatives and option 1.

2.3.5 Option for defining rebuilt as one-year above B_{MSY} [preferred]

This option would define rebuilt as the first year that the estimated biomass is above B_{MSY}, rather than the second consecutive year as currently defined. In June 2010 the Council identified this option as its preliminary preferred direction for defining rebuilt under the revised rebuilding plan. In October, 2010, the Council took final action to recommend this option. The SSC recommended that a threshold of one year above B_{MSY} is a suitable definition of rebuilt for modeled crab stocks.

2.4 Comparison of Action 2 alternatives

ACLs and rebuilding strategies are considered simultaneously for EBS snow crab stock. For this stock, the probability of rebuilding under different P* and buffer values was estimated. For the analysis, rebuilt is defined in two ways, by the current definition of the second consecutive year above B_{MSY} as well as a single year above B_{MSY}. In June, 2010, the Council recommended that the definition of rebuilt be modified to one year above B_{MSY} thus results for the one-year definition under each option for harvest strategy are highlighted below. Additional timeframes for rebuilding under the current two years above B_{MSY} definition are shown in chapter 4.

The upper limit of the buffer examined for rebuilding was 0.75 as prescribed by the NS1 Guidelines for stocks which have failed to rebuild at the end of a rebuilding plan. Note, this is an interim measure until a revised harvest strategy under the rebuilding plan is adopted or when the stock is rebuilt. For snow crab, the earliest year the stock would be expected to rebuild under F=0.0 is estimated to be 2012/13 (Alternative 2), while the latest year the stock would be expected to rebuild is 2014/15, fishing at the maximum permissible $F=0.75F_{OFL}$ (Alternative 4).

The time frames and the relative probability of rebuilding for each alternative and option are summarized below for the current stock assessment model (Table 2-15). The probability of rebuilding assumes the definition of rebuilt in which calculated biomass must be above the B_{MSY} estimate for one year before the stock is considered rebuilt. Additional results for the current definition of rebuilt (second consecutive year above the B_{MSY} estimate) are shown in chapter 4.

Table 2-15 The relative probability of rebuilding, year-end date in crab fishing year for rebuilding (one year above B_{MSY} definition), and resulting buffer value necessary to rebuild in this time frame for each alternative.

Alternative	Probability of rebuilding	T_{TARGET} year-ending date	Buffer value of F_{OFL} [38]
Alternative 1 (no action)	0.646(50% probability)	2014/15	25%
Alternative 2 (T_{MIN})	0.508(50% probability)	2012/13	100%
Alternative 3	0.5(50% probability)	2013/14	58%
Alternative 3-Option 2	0.751 (75% probability)	2013/14	85%
Alternative 3-Option 3	0.91 (90% probability)	2013/14	97%
Alternative 4 (T_{END})	0.646 (50% probability)	2014/15	25%
Alternative 4-Option 2	0.756 (75% probability)	2014/15	53%
Alternative 4-Option 3	0.91 (90% probability)	2014/15	78%
Alternative 4-Option 1	0.864 (70% probability)	2019/20	25%

For all options, the values for the probability of rebuilding for each year of the rebuilding period and the associated rebuild fishing mortality rate would be calculated annually using the best assessment of the EBS snow crab stock, as recommended by the SSC. The CPT, SSC, and Council will annually review progress towards rebuilding and recommend annual adjustments to the fishing mortality rates on which management decisions are based consistent with the intent of the chosen alternative and progress towards rebuilding. If rebuilding to the proxy for B_{MSY} does not occur by T_{end}, then the maximum F will be the *rebuilding F*, the F of the final year, or 75% of F_{OFL}, whichever is lower, until a new rebuilding plan is developed.

2.5 Development of alternatives and alternatives considered and not carried forward for analysis

Development of alternatives for both the ACLs and rebuilding plans involved an iterative approach. Proposed ACL approaches originated from a workshop convened by the NPFMC in 2009 (NPFMC 2009). A range of approaches were then analyzed over the summer of 2009 for both groundfish and crab stocks, with results presented at a joint BSAI/GOA groundfish and CPT meeting held in Seattle in September 2009 (Joint Groundfish/Crab Plan Team Report, 2009). The CPT made recommendations at that time on the proposed approaches for both ACLs and rebuilding plans. Since that time, a workgroup consisting of CPT members, SSC members, stock assessment scientists, NPFMC staff, NMFS AKR staff, and NOAA GC have convened multiple meetings to assess and refine approaches for both ACLs and rebuilding plans. The Council reviewed and approved the current suite of ACL alternatives in October 2009, and the rebuilding plan alternatives in December 2009.

A range of alternative ACL methods were initially proposed at the May 2009 workshop. These included establishing ABC control rules based upon straight application of the groundfish Tier system ABC control rules to crab, use of a decision-theoretic approach to estimate uncertainty in the OFL and use of a P* approach. The groundfish tier system direct application approach and the decision-theoretic approach were not carried forward for analysis. The groundfish tier system approach was not considered to be directly applicable to crab stocks and while an assessment of the relative uncertainty of the tier system

[38] This buffer value will vary annually to remain on the trajectory for rebuilding by the target date (and target probability level).

using the P* and decision-theoretic methods indicated that the ABC control rules under the groundfish tier system are sufficiently conservative to account for uncertainty, a more direct consideration of uncertainty for crab stocks was considered preferable (NPFMC 2009; NPFMC 2010). In addition, as indicated in section 3.2.4.3, modifications will likely be proposed for amending the groundfish Tier system to more explicitly address the guidelines for addressing uncertainty. The decision-theoretic approach was considered to be more complicated and less directly applicable to the NS1 Guidelines and thus was also not carried forward for analysis (Joint Groundfish/Crab Plan Team Report, 2009).

Several analyses were conducted to try to directly calculate a σ_b value for crab stocks. One approach relied on the results of retrospective analyses constructed from all previous assessments of a stock (Punt, 2009). A historical retrospective analysis differs from a standard retrospective analysis (where the data used in the current stock assessment are removed one year at a time and the assessment is repeated) because a historical retrospective analysis captures the impact of additional sources of uncertainty, such changes in fixed values for parameters and in the values for the weights assigned to data sources, that are not considered during a standard retrospective analysis. Unlike Anon (2009), the analyses in that document were not restricted to "full" assessments only because the notion of "full" assessments does not exist for NPFMC crab stocks and because there is much more consistency in authorship of BSAI crab assessments over time. A comparison was done between retrospective results from candidate BSAI crab stock assessment retrospectives and BSAI and GOA groundfish stock assessment. Results for this analysis were unsatisfactory as the σ_b results for crab stocks were much lower than for groundfish stocks for which there is significantly more reliable information. This led to the conclusion that this method was not applicable for BSAI crab stocks given the noted assessment limitations.

Several different recommendations were made for the default σ_b values to be used under the P* approach (and for estimating the impacts in this EA of the constant buffer values). A consistent recommendation was made by the CPT and SSC to categorize stocks into low, medium, and high levels of additional uncertainty based upon understanding of the relative uncertainties associated with the various stock assessments and OFL calculations. Initially the analysts evaluated a range of values of 0.2, 0.4, and 0.6 associated with the interpretation of low, medium and high levels. At the May CPT meeting the CPT re-categorized stocks (moving St. Matthew blue king crab to a 'medium' level from a 'high" level) and recommended that the default values associated with this range of σ_b values should be 0.2, 0.3, and 0.4. The SSC concurred with this recommendation in June 2010 and requested analysts to revise the analysis to reflect these values.

Rebuilding plan alternatives for snow crab initially considered modifications to the *C. opilio* Bycatch Limitation Zone (COBLZ) limit and area closure which applies to groundfish trawl bycatch of snow crab. However, preliminary information presented at the December 2009 Council meeting indicated the insensitivity of snow crab model results to a range of assumed bycatch under the COBLZ limit. Specifically, regardless of assuming bycatch equal to the entire limit (understanding that the overall limit has not been reached for several years), there was no change in the estimated minimum time frame for rebuilding. Thus bycatch in the directed groundfish trawl fisheries and modification to the COBLZ limit and area were not considered necessary components of the rebuilding plan for purposes of rebuilding the EBS snow crab stock. The Council is considering additional restrictions on groundfish bycatch of all BSAI crab species, however, and in June 2010 initiated an analysis to amend the groundfish FMP to limit the overall catch by crab species. At that time the COBLZ limit and area as well as all snow crab bycatch outside of that area and by all gear types will be reconsidered. Groundfish bycatch of crab species could be a contributing cause of a stock exceeding its ACL on an annual basis regardless of the precision of catch against the TAC in the directed fishery.

3 Methodology

3.1 Five-Tier System

The OFL for each of the 10 BSAI crab stocks is computed using the five-tier system detailed in Table 3-1 and Table 3-2. Stocks are assigned to one of the tiers based on the availability of information for that stock and model parameter choices. Tier assignments and model parameter choices are recommended through the CPT process to the Council's SSC. The Council's SSC will recommend final tier assignments, stock assessment and model structure, and parameter choices, including whether information is "reliable" for the assessment authors to use for calculating the OFLs based on the five-tier system. Table 3-4 lists the current assignments of stocks to tiers.

For Tiers 1 through 4, once a stock is assigned to a tier, the stock status level is determined based on recent survey data and assessment models, as available. The stock status level determines the control rule equation used in calculating the F_{OFL}. Three levels of stock status are specified and denoted by "a," "b," and "c" (see Table 3-1). The F_{MSY} control rule reduces the F_{OFL} as biomass declines by stock status level. At stock status level "a," current stock biomass exceeds the B_{MSY} (or the proxy for 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," current biomass is below β * (B_{MSY} or the proxy for $B_{MSY)}$. At stock status level "c," directed fishing is prohibited and an F_{OFL} at or below F_{MSY} (or proxy F_{MSY}) would be determined for all other sources of fishing mortality in the development of the rebuilding plan.

For Tiers 1 through 4, the coefficient α is set at a default value of 0.1, and β set at a default value of 0.25. In Tier 4, a default value of natural mortality rate (M) or an M multiplied by a scalar, γ, where γ can be > 1 or < 1, is used in the calculation of the F_{OFL}. 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.

For the purpose of the analyses of the EA, the TACs and GHLs are assumed to be set using the current State of Alaska (SOA) control rules adopted by the Alaska Board of Fisheries as harvest strategies or fixed harvest levels in SOA regulations: **5 AAC 34.612** for Aleutian Islands golden king crab, **5 AAC 34.816** for Bristol Bay red king crab, **5 AAC 34.915** for Norton Sound red king crab, **5 AAC 34.917** for St. Matthew Island blue king crab, **5 AAC 34.918** for Pribilof Islands blue king crab, **5 AAC 35.508** for Eastern Bering Sea (EBS) Tanner crab, and **5 AAC 35.517** for EBS snow crab (there is no harvest strategy in SOA regulations for the Adak red king crab, Pribilof Islands red king crab, or Pribilof Islands golden king crab stocks; summaries of the management history of those stocks are provided in Bowers et al. (2008)). Appendix 3 outlines have these control rules have been modeled for the purposes of this EA.

3.2 Methods for computing ABCs and ACLs (Action 1)

Alternative 2, 3, and 4 would establish ACLs as a numerical value set to prevent overfishing. For the BSAI crab stocks, the ACL would be set equal to the ABC. The ABC is determined for each stock using an ABC control rule which adjusts the OFL to account for scientific uncertainty.

3.2.1 The Buffer method

The buffer method involves the Council selecting a buffer, *b*, between 0 and 1 for each of the 10 BSAI crab stocks taking account of the amount of scientific uncertainty for each stock, the probability of overfishing, and the socio-economic consequences of buffers lower than one. The ABC would then be calculated annually as:

$$ABC = (1-b) * OFL \qquad (3.1)$$

The difference between the OFL and the ABC is smallest for a buffer of 0 (the OFL equals the ABC) and greatest for a buffer of 1 (the ABC is zero). The value for the buffer for a stock could be changed given new information. However, in general, the buffer for each stock would be unlikely to change over time. If, however, the uncertainty associated with a stock changes over time then the probability of overfishing will change unless the value for *b* is changed.

3.2.2 The P* method

The P* method (Caddy and McGarvey, 1996; Prager *et al*., 2003; Shertzer *et al*., 2008; Hanselman, 2009) is conceptually the same as the buffer method except that the numerical value of the buffer for a stock could potentially change each year to account for changes in the understanding of the scientific uncertainty associated with the stock. The ABC would then be calculated annually as:

$$ABC = (1- b_y) * OFL \qquad (3.2)$$

where b_y is the buffer for year *y*. The value for the annual buffer is calculated from the P* (the probability that the ABC exceeds the true, but unknown, OFL). Given a value for P* (between 0 and 0.5) and a probability distribution for the OFL[39], the ABC (and hence the buffer which is ABC divided by the best estimate of OFL) is computed so that the probability in the left tail of the distribution is P* (see Figure 3-2). The lower the value for P*, the lower the probability that the ABC exceeds the true OFL (i.e. the probability of overfishing is less), but the larger the buffer would be. Figure 3-3a and Figure 3-3b compare P* values of 0.4 and 0.2 and show that the ABC is 13% lower for the smaller choice of P*.

The P* method requires that a distribution for the OFL can be generated which accounts for scientific uncertainty. Section 3.2.3 summarizes how uncertainty is typically characterized in BSAI crab stock assessments. The amount of uncertainty impacts the buffer along with the choice of P*. Figure 3-3c and Figure 3-3d show how the ABC is impacted when uncertainty (as measured by the standard deviation of the distribution) is increased by 25% and P*=0.3.

3.2.3 Sources of uncertainty

The aim of the ABC control rule is to account for scientific uncertainty in the calculation of the OFL. There are many sources of scientific uncertainty, some of which can be quantified using the data collected from a fishery through the use of assessment methods and other methods of data analysis, while other sources cannot. In this EA, the former sources (e.g. observation error associated with survey indices and catch and survey-length samples) are referred to a "within" uncertainty because they can be quantified "within" the stock assessment. However, this within model uncertainty does not capture the true extent of uncertainty. Some measure of additional uncertainty needs to be characterized and incorporated into the ABC control rule or elsewhere in the TAC-setting system in order to best approximate the 'true' uncertainty in the assessment and thus establish ABC levels which are reflective of the 'true' uncertainty of the OFL and TACs that will prevent overfishing.

[39] A variety of statistical techniques (e.g. Bayesian sampling, bootstrapping or asymptotic methods) could be used to determine this distribution. The particular technique for each stock will be chosen by the Crab Plan Team taking account of the nature of the data available and the computational demands of the calculations.

In contrast, the "additional" uncertainty pertains to sources of uncertainty which cannot be quantified using stock assessment models. There are many of these sources of uncertainty. However, those most pertinent to the calculation of OFLs are:

(a) errors in definitions for the proxies for F_{MSY} and B_{MSY} for those stocks for which estimates of F_{MSY} and B_{MSY} are not available (currently all BSAI crab stocks);
(b) errors associated with the values for the parameters of population models which are pre-specified rather than being estimated by maximizing the likelihood function or by sampling from Bayesian posterior distributions (such as natural mortality, M, and survey catchability, q);
(c) the choice of appropriate methodology (e.g. how survey data are summarized for inclusion in assessments); and
(d) the choice of which data sources are included in assessments.

3.2.4 Calculating P* using constant values of external variance

For this analysis, the extent of uncertainty regarding the OFL "within" the assessment is quantified by the standard deviation of the logarithm of the estimate of mature male biomass at the time of mating (MMB) for the last year of the assessment (denoted σ_w). The "within" uncertainty is quantified by 800 draws from Bayesian posterior distributions computed by applying the Markov chain Monte Carlo (MCMC) algorithm with 5,000,000 or 10,000,000 cycles (thinning the chain every 5,000th or 10,000th cycle and implementing a burn-in of 20% of the chain).

Direct measures to quantify this additional uncertainty were evaluated, but a fully justifiable and defensible analytical means of calculating and quantifying the extent of "additional" uncertainty could not be identified (although the additional uncertainty is clearly larger than zero). For this analysis, additional uncertainty is denoted as σ_b and constant values for σ_b are used in this analysis to represent low, medium, and high levels of additional uncertainty. Results are also presented for a value of 0 (no additional uncertainty). Results for each stock are therefore shown for four levels for the extent of "additional" uncertainty based on values for σ_b: of 0 (no additional uncertainty), 0.2, 0.3 and 0.4. The narratives for each stock outline the uncertainties considered most important for that stock and which of the four levels of additional uncertainty seem most applicable to that stock relative to information available amongst BSAI crab stocks, and projection results are only shown for the selected choice for σ_b.

For this analysis, the relationship between the total uncertainty and the two components is calculated as $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$. Using a stock-specific estimate of the amount of uncertainty captured within the assessment, σ_w, a table was constructed using the equation $\exp[\Phi^{-1}(P^*)\sigma_{tot}]$ where $\sigma_{tot} = \sqrt{\sigma_b^2 + \sigma_w^2}$, which provides buffers which result from each of the σ_b and P* values (Table 3-3). A similar table is constructed for each stock to calculate the appropriate buffer associated with the selected P* and σ_b value.

Using the σ_b values in Table 2-6, in conjunction with the assessment estimated σ_w, results in the σ_{total} values for all stocks used in this analysis and shown in Table 3-7. Values for σ_w may change annually due to changes to the assessment. Values for σ_b were analyzed as constant values. σ_{total} will vary as a result of modifications in either of these two parameters.

The range of values considered for σ_b were selected as constants with no specific analytical basis, but they are in the general range of calculated "additional uncertainty" for BSAI and GOA groundfish stocks as well as for fish stocks in other regions. For groundfish stocks in the BSAI and GOA, evaluations considering a range of appropriate uncertainty based upon model biomass and survey CV were used to best approximate the overall known variance. In the analysis of the groundfish stocks, CV on the arithmetic scale was used instead of σ_b. The CV on the arithmetic scale is very similar to σ_b which is on the log-scale. The CV of ending year spawning stock biomass was computed from the Hessian matrix by dividing the Hessian standard deviation of ending year spawning biomass by the estimate of ending year spawning biomass. The CV of the survey biomass estimates is computed as the mean CV of the last three survey CVs. This was one of multiple potential methods to determine a useful survey CV, but the intention of this method was to use recent information, but protect from using one outlier CV to determine the buffer. Stocks that were considered in this evaluation were intended to span from well-studied data-rich stocks such as EBS pollock to more data-poor stocks such as many minor rockfish species (Table 3-5). This analysis suggested that using survey CVs was more robust than using model CVs because they better approximated the relative amount of uncertainty between data-rich and data-poor stocks than did model CVs.

Considering a σ_b based on the ending year of spawning biomass led to ranges of values for these stocks of 0.04-0.4 (with the end points based upon Alaska sablefish and GOA rougheye respectively) while using the average of the last three years survey biomass estimates yielded values for σ_b of 0.09 - 0.51 (endpoints from GOA Arrowtooth and GOA harlequin rockfish respectively; Table 3-5).

Additional uncertainty was estimated for groundfish and coastal pelagics stocks for the Pacific Fishery Management Council based on changes over time in assessment outcomes (Table 3-6). The level of overall uncertainty for the OFL for Tier 1 (data-rich) stocks will be taken to be the maximum of 0.367 (the average value over all of the stocks in Table 3-6) and the extent of uncertainty regarding the OFL captured within the assessment. The Pacific Council is also considering accounting for the variation between models selected as “base” and as the “low” and “high” states of nature for each assessment (the “low” and “high” states of nature are intended to be models which are half as likely as the “base” model) when selecting buffers to OFLs, but this has yet to be agreed upon. The Pacific Fishery Management Council has established values for the uncertainty of the OFL for groundfish stocks classified as being in Tier 2 (data moderate) and Tier 3 (data-poor; OFL based on historical catch) stocks to be 0.72 and 1.44 respectively.

3.2.4.1 Sensitivity analysis of impacts of additional uncertainty

Simulations were conducted for a range of constants for each stock to assess the sensitivity of the resulting P* and buffer values to the extent of additional uncertainty. For comparison across stocks for Alternative 3 (variable buffer), Table 3-8 shows the difference in the size of the buffer at the same P* value (here P* = 0.4, or a 40% chance of exceeding the true but unknown OFL should catch = ABC established at the buffer value indicated) with increasing incorporation of additional uncertainty from the default (σ_b = 0) among-assessment estimated uncertainty.

The Council in June requested that staff include σ_b = 0.1 as an option in the analysis. The range of σ_b values considered for sensitivity analysis includes 0.1 and results shown for all stocks can be interpolated to determine the effect of this value by averaging the results for σ_b and 0 and 0.2. Note that the lowest level of σ_b for purposes of this analysis is for the Tier 3 stocks (Bristol Bay red king crab and EBS snow crab). The recommended σ_b for each stock is shown by the shading in Table 3-8 and Table 3-9.

Similarly, for comparison across stocks for Alternative 2 (constant buffer), Table 3-10 shows the difference in the P* value for a constant buffer (here buffer =10% for all stocks i.e., the ABC = 90% of the OFL) with increasing incorporation of additional uncertainty from the default (σ_b =0) within-assessment estimated uncertainty. Due to issues with skewness in the pdf of the OFL (see Section 3.2.4.2) results are presented both for the "best estimate" (mean or median depending upon the individual assessment assumptions) as well as the 'median" only for each set of results (i.e. the comparison in results between Table 3-10 and Table 3-11 as well as all summary tables in chapter 2).

3.2.4.2 Probability distribution of OFL - Impact of skewness

The probability distributions for the OFL for the Tier 4 stocks are not symmetric. Tier 4 stocks are managed based only on the most recent estimate of abundance (unlike Tier 3 stocks which involve a time-series of estimates). Thus, the high degree of between-station survey variability affects the probabilities that a survey-only based estimate of ABC will be below the OFL. For Tier 4 stocks, where the use of median or mean can result in large differences in the buffer between OFL and ABC for the same P* value, the SSC's review of the probability distribution of the OFL would include a recommendation on the appropriate method to calculate the distribution. For this analysis, results for both the median and the mean are presented in the Executive Summary and Chapter 2, however, for the analysis in the stock specific chapters, the mean was used to calculate the probability distribution for the OFL.

The distributions for the OFL for Tanner crab and Pribilof Island red king crab are skewed to the right. This arises because these animals have a patchy spatial distribution which affects the variability of density estimates among trawl survey stations. That is, high densities of crab occur at relatively few stations while most other stations show densities that tend to be considerably lower. The statistical distribution of estimates from individual stations is often best described as being "lognormal." A characteristic of this distribution is that the expected buffer value increases with greater variability, while the median value (where 50% of the stations are above and below) remains constant (Figure 3-1). Therefore, for these asymmetrical distributions, using the mean results in higher buffer values than using the median. This is an issue when it relates to which (mean or median) is employed in the calculation of the OFL, and the probability distribution of the OFL. The mean is the same as the median for normal distributions. However, skewness can result in an OFL that may be lower than the mean for right-skewed (e.g. log-normal) distributions. Using the mean (or median) exclusively over all stocks would provide consistent results.

For St. Matthew blue king crab however, the opposite situation occurs leading to results showing that ABC increasing from the point estimate (by which P* = 0.5 was calculated), at lower P* values (e.g. P* 0.4 and 0.3).

3.2.4.3 Comparison of accounting for uncertainty in the ABC control rule for Crab and Groundfish Tier systems

The Council in April 2010 requested that staff clarify the treatment of uncertainty in establishing the ABC control rule under the proposed crab ACL analysis versus the existing treatment of uncertainty in establishing ABCs in the BSAI and GOA groundfish tier systems. The current treatment of uncertainty was found to be sufficiently conservative under the existing Tier systems for GOA and BSAI groundfish. The groundfish Tier system explicitly specifies both OFL and ABC control rules. For example, the buffers resulting from application of the Tier system for BSAI groundfish in 2010 result in the following buffer amounts for several BSAI groundfish stocks for a range of tiers (Table 3-12). Below is an excerpt from the groundfish ACL analysis (NMFS/NPFMC 2010) which noted that current treatment of scientific uncertainty in the groundfish Tier system was sufficiently conservative at this time to meet the intent of the NS1 Guidelines.

Annual Harvest Specification Process and Incorporation of Uncertainty[40]

Regulations at 50 CFR part 679 address management of groundfish in the BSAI and GOA. These regulations describe the annual process of specifying OFL, ABC, and TAC levels for target species and other species. Under § 679.20(a), a TAC must be specified for each target species category and for the combined other species category. TACs for the target species may be split or combined by the Council to establish new quota categories through the annual specifications process, as recommended by its scientific advisors; a plan amendment is not required. The Council, however, is not authorized under § 679.20 to split or combine the species in the other species category. Before the Council can specify a TAC for a single species or species group within the other species category, it first must move this species from the other species category to the target species category in the FMPs. Once a species or species group is categorized as a target species in the FMPs, the Council must specify a separate OFL, ABC, and TAC for the species or species group in the annual groundfish specifications process, or combine this new target species with some other target species to form a target species group. Annual specifications for 2010 are listed for the BSAI in Table 10 and for the GOA in Table 11.

The control rule used for setting specifications for target groundfish is intended to account for scientific uncertainty in two ways. First, the control rule is structured explicitly in terms of the type of information available, which is related qualitatively to the amount of scientific uncertainty. Second, the size of the buffer between the maximum fishing mortality rate (maxF) and ABC in Tier 1 of the ABC control rule and F and OFL in Tier 1 of the OFL control rule varies directly with the amount of scientific uncertainty. For the information levels associated with the remaining tiers, relating the buffer between maxF/ABC and F/OFL to the amount of scientific uncertainty is more difficult because the amount of scientific uncertainty is harder to quantify, so buffers of fixed size are used instead.

The probability that the specified ABC exceeds the "true" OFL (i.e., the OFL that would be specified if all scientific uncertainty were eliminated) was evaluated for a variety of stocks in Tiers 1, 3, 5, and 6. The SSC has determined that the range of resulting probabilities provide sufficient protection against overfishing, at least for the time being. It is anticipated that research regarding estimation of these probabilities will continue. This research may result in a future amendment proposal that prescribes the buffer between ABC and OFL explicitly in terms of the amount of scientific uncertainty (presently, Tier 1 prescribes the buffer explicitly in terms of the amount of scientific uncertainty, but the other tiers do not).

3.3 Methods for evaluating the ACL alternatives for red, golden, and blue king crab

Determining the likely impacts of the alternatives is possible on a stock by stock and tier by tier basis due to the structure of the alternatives. Results are characterized for the short-, medium-, and long-term time frames to understand the immediate implications on the actual ABC value as well as the medium-term implications on harvest constraints and the long-term biological and economic implications. Summary figures are provided for each stock to indicate the risk-assessment choices in selecting an appropriate P* value (or to determine the likely risk of overfishing at various buffer values).

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[40] From Section 1.4.2.1.1 of NMFS/NPFMC 2010. Environmental Assessment for Amendment 96 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area and Amendment 87 to the Fishery Management Plan for Groundfish of the Gulf of Alaska to Comply with Annual Catch Limit Requirements. North Pacific Fishery Management Council, Anchorage, AK 99501.

3.3.1 Tiers 3-4

Stocks in Tiers 3 and 4 are characterized as those for which a reliable survey index is available or for which an assessment is available which provides estimates of mature male biomass. Estimates of F_{MSY} and B_{MSY} are not available for these stocks, so status determination depends on proxies. Stock assessments are available for stocks in Tier 3 and for these stocks it is possible to reliably estimate $F_{35\%}$ (the rate of fishing mortality which reduces the mature male biomass (at the time of mating)-per-recruit to 35% of the unfished mature male biomass (at the time of mating)-per-recruit). The proxy for B_{MSY} for Tier 3 is computed multiplying the average recruitment over a range of years recommended first by the CPT and finally by the SSC by the mature male biomass (at the time of mating)-per-recruit corresponding to $F_{35\%}$.

Stock assessments may or not be available for stocks in Tier 4. The defining characteristic of Tier 4 stocks is that it is not possible to estimate $F_{35\%}$ (or the estimates has not been accepted by the CPT/SSC). The proxy for F_{MSY} is γM for these stocks, where at present γ equals 1 for all Tier 4 stocks. The proxy for B_{MSY} for Tier 4 stocks is the average mature male biomass (at the time of mating) over a range of years recommended by the CPT / SSC.

The focus for the evaluation of the alternatives for the stocks in Tiers 3 and 4 relates to the impact of lack of precision, i.e. this evaluation assumes that on average[41] the assessment is correct and assumptions regarding proxies for F_{MSY} are also correct.

Although the ideal is for the OFL to apply to the total catch (retained catches of males and females in the directed fishery and bycatch in other fisheries), this ideal had yet to be achieved for all BSAI crab stocks. The narrative for each stock outlines which components of the population are covered by the OFL. Nevertheless, the methodology employed to evaluate the alternatives is the same for all stocks, irrespective of which components covered by the OFL.

3.3.1.1 Short-term implications for Tiers 3-4

The short-term implications of the alternatives are evaluated by calculating the ABC for the most recent year (2009 or 2009/10 depending on the stock and the structure of the stock assessment) using Equations 3.1 and 3.2. The ABC values for each stock includes removals due to several sources so the value corresponding to the retained catch by the directed fishery is listed as well as the breakdown of the OFL among the various sources of mortality accounted for in the OFL. The retained catch by the directed fishery is most comparable with the output from the SOA control rule.

The value of P* is reported for each buffer value (and choice for the extent of additional uncertainty) and the buffer corresponding to each choice of P* is also reported. This provides a basis to explore how these two quantities relate for each stock. The relationships between P* and buffer will differ due to differences among stocks in the uncertainty of the last estimate of MMB (σ_b, see Table 3-3).

3.3.1.2 Medium- and long-term implications for Tiers 3-4

The medium- and long-term implications are evaluated by projecting each stock ahead 30 years[42] under the assumptions that the catch equals the lower of the ABC and the total catch corresponding to the TAC

[41] In the sense of multiple “replicates” of each stock.

computed using the SOA control rule (this is equivalent to assuming that the TAC is set equal to the component of the ABC which is estimated to consist of legal male crab caught by the directed fishery), and that the catch equals to the ABC. If there is no SOA control rule, the catch is set to the ABC. The medium-term implications are evaluated using the results of projections for the first six years of the projection period while the long-term implications consider the implications of the entire 30-year projection period. Results are shown when the SOA is accounted for and when it is ignored. The results with the SOA control rule illustrate the likely biological and economic impacts of the alternatives under the current TAC-setting process, while the results without the SOA control rule illustrate the maximum biological and economic impacts attributable to the ACL alternatives exclusive of the SOA control rule because catches will be higher when the SOA control rule is not applied.

The medium- and long-term implications of the different buffers and choices for P* are quantified in terms of their impact on stock status (measured in terms of mature male biomass at the time of mating relative to $B_{35\%}$ ($B_{35\%}$ can be computed, albeit roughly, for all modeled stocks), the probability of overfishing (.e. total catch > *OFL'*) and the probability of the stock becoming overfished, $B < 0.5B_{35}$) as well as economic impacts (see Section 3.5 for description of methods and sources of uncertainty associated with forecasts of economic impacts of alternatives). The probability that the TAC is constrained by the ABC control rule is computed by the SOA control rule (expressed as the probability that the output from the SOA control rule exceeds the component of the ABC which is estimated to the retained in the directed fishery) is also reported.

The projections account for uncertainty related to: (a) the values for the parameters of the population dynamics model used to model the stock, (b) the recruitment to the modeled population for each future year, and (c) the stock assessment models used for population size estimation. The results in this EA are based on the Beverton-Holt form of the stock-recruitment relationship because (a) the fits of the Beverton-Holt model are not appreciably different from that of the Ricker model (see Figure 3-4), and (b) preliminary results suggested that the results of projections do not differ appreciably between these forms of the stock-recruitment relationship. These sources of uncertainty reflect the scientific uncertainty which the buffer between the OFL and ABC (and hence ACL) is meant to account for.

The algorithm used is as follows (see also Figure 3-5):

1) Fit the stock assessment model to the data for the stock to obtain the "best estimates" of parameters of the model.
2) Apply the Markov chain Monte Carlo (MCMC) method to obtain a set of 800 equally likely sets of parameter vectors from the posterior distribution for these parameters. This step quantifies source (a) outlined above.
3) For each draw from the posterior distribution:
    a. Calculate $F_{35\%}$ and set F_{MSY} to $F_{35\%}$ (Tier 3 stocks) or set F_{MSY} to M (Tier 4 stocks).
    b. Find the value for the steepness of the stock-recruitment relationship so that MSY occurs at F_{MSY} (either $F_{35\%}$ or M depending on which Tier the stock is in).
    c. Set R_0 (the virgin recruitment) so that B_{MSY} occurs at the proxy for B_{MSY} selected by the CPT/SSC if full-selection fishing mortality on legal male crab in the directed fishery equals F_{MSY}
    d. Calculate the extent of variability (quantified using a standard deviation, i.e. σ_R) between the actual recruitment estimates and the values predicted by the stock-recruitment relationship for the years corresponding to B_{MSY}.

[42] 30 years is sufficiently long so the resource equilibrates close to the proxy for B_{MSY} under deterministic conditions (no fluctuations in recruitment about the assumed stock-recruitment relationship).

4) Set the value for F_{OFL} used when setting the OFL to the median of the values for $F_{35\%}$ (or M) across the draws from the posterior (i.e., the projections are undertaken under the assumption that the proxy for F_{MSY} is correct on average when setting OFLs).
5) Set the value for σ_R used when generating future recruitment to the median of the values for σ_R across the draws from the posterior. Set σ_R to 1.5 if the value for the calculated σ_R is unrealistically high for exploited marine population (larger than 1.5).
6) For each draw from the posterior distribution and choice of a buffer:
    a. Generate an assessment bias, κ, based on a normal distribution with mean zero and standard deviation σ_b[43].
    b. For each year of the thirty-year projection period:
        i. Compute the true OFL (the OFL based on the parameters generated from the posterior distribution).
        ii. Generate the data on which the ACL will be based by generating a random variable ε_y from $N(0;\sigma_w^2)$[44] which represents the annual deviation in the assessment result from the true value and then multiplying all of the population-related information needed to set the ABC (mature male biomass at mating, numbers-at-length) by $\exp(\kappa+\varepsilon_y-\sigma_b^2/2-\sigma_w^2/2)$ to generate the data used when setting the ABC[45]. Specifically, the generated numbers by length used to calculate the OFL relate to the true numbers at length according to the equation:
$$N_{l,y}^{s,GEN} = N_{l,y}^{s,TRUE}\exp(\kappa+\varepsilon_y-\sigma_b^2/2-\sigma_w^2/2)$$
        iii. Compute the OFL based on the data generated at step ii) and multiply it by the (1-*b*) to compute the ABC (and hence the catch). Note that this calculation depends on whether it is assumed that OFLs are based on stock assessment results or survey data alone.
        iv. Apply the SOA control rule if the catch is to be constrained by the SOA control. If the output from the SOA control rule is larger than the retained-directed component of the ABC, the catch (ACL) equals the ABC otherwise the catch equals the output from the SOA control rule multiplied by the ratio of the ABC to the retained-directed component of the ABC.
        v. Project the population ahead one year and generate the recruitment for the next year.

The analyses are unable to predict the extent to which the uncertainty in terminal biomass will change over time (the next 30 years) nor whether estimates of the extent of uncertainty not captured by the assessment will change over time. These parameters are therefore not updated as part of the analyses. In addition, the analyses are predicted on the assumption that SOA control rules are not changed over the next 30 years.

Models for AI golden king crab, PI blue king crab, and PI red king crab, have been developed to evaluate the alternatives for purposes of this analysis. However, these models have not yet been accepted by the CPT and SSC as the basis for management advice. Also, the model for St Matthew blue king crab has been modified from that accepted by the CPT and SSC to account for discard by trawl and fixed-gear fisheries.

[43] This source of uncertainty reflects the "additional uncertainty" not captured within the assessment.

[44] The value for σ_w is set to the standard deviation of the logarithm of the estimate of mature male biomass at mating in the last year of the assessment (see Table 3-4).

[45] The data used when setting the ABC thus differ from the true values due to a random component which is common across years and a random component which varies among years,

The uncertainty associated with the long-term projections is necessarily higher than that associated with the medium-term projections given that the 30-year projections rely to a much greater extent on assumptions regarding the form of the stock-recruitment relationship, which is very uncertain for all BSAI crab stocks. This is particularly the case for stocks such as Pribilof Islands blue and red king crab for which the fits of the assumed stock-recruitment relationship are very poor. In general, therefore, the relative differences between the outcomes for the long-term projections are more robust than the predictions in absolute terms.

The results of the medium- and long-term projections are shown in the form of (pointwise) time-trajectories of, for example, mature male biomass relative to $B_{35\%}$. These time-trajectories are summarized in the form of medians and 90% intervals (e.g. Figure 3-6a). However, the lines on Figure 3-6a do not represent individual realizations. Rather these are summaries of realizations (see Figure 3-6b for the results of ten of the 800 simulations on which Figure 3-6a is based). The inter-annual variation in MMB (and catch) for the individual simulations is much larger than the pointwise intervals.

3.3.2 Tier 5

Three BSAI FMP crab stocks are currently classified as Tier 5 stocks (NPFMC 2010):

- Western Aleutian ("Adak") red king crab (WAIRKC)
- Aleutian Islands golden king crab (AIGKC)
- Pribilof Islands golden king crab (PIGKC).

Note that the AIGKC stock is anticipated to be re-classified as a Tier 4 stock, pending adoption of a stock-assessment model that has been developed for the stock (NPFMC 2009, p. 23), and ACLs are also examined for AIGKC stock in the analyses for Tier 4 stocks using the stock-assessment model in its current state of development.

The OFL for each of the Tier 5 stocks "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" (NPFMC 2009, p. 3):

> 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 (NPFMC 2009, p. 5).

Due to insufficient history and confidentiality of data on discards and bycatch, the OFL for the Tier 5 stocks has been defined in terms of the retained catch only. The provision that the time period chosen to compute the average catch be chosen to "provide the appropriate risk aversion for stock conservation" (in addition to it being "from a time period determined to be representative of the production potential of the stock") is presumably superseded by the implementation of ACLs. In practice, the Tier 5 OFLs have been set according the SSC's advise that the OFL serve as "appropriate proxy for the long-term average production potential" and that "risk aversion is more appropriately applied when setting harvest level" (June 2008 SSC minutes, p. 15).

3.3.2.1 Short-term implications for Tier 5

The short-term implications of the alternatives are evaluated by calculating the buffer applied to the OFL and the resulting ABC for the most recent year (2010 or 2009/10, depending on the stock) using Equations 3.1 and 3.2. The buffer corresponding to each choice of P* (and choice for the extent of additional uncertainty) and the value of P* (for each alternative considered to account for the extent of additional uncertainty) for each buffer value is reported here.

The ABCs for each stock are assumed to be retained-catch ABCs so that implications can be judged by direct comparison with the TAC or GHL as currently determined by the SOA. Although the harvest control rule for determining the TAC for the AIGKC stock exists in SOA regulations, there is no harvest control rule in SOA regulations for either the WAIRKC or PIGKC stocks.

Due to the lack of assessment models for these stocks and lack of reliable biomass estimates, implications of a buffer (either the fixed buffer, *b*, or the P*-based buffer, b_y) cannot be estimated in terms of the biological effects to stock biomass and productivity beyond computing the removals from the unknown stock biomass due to the retained catch. Likewise, due to lack of an assessment model in the Tier 5 scenario, the long-term implications are not analyzed.

Values of P* were computed under the Tier 5 assumption that the average retained catch is an "appropriate proxy for the long-term average production potential" (June 2008 SSC minutes, p. 15) and that the years chosen to compute the long-term average are from a time period that is, in fact, "representative of the production potential of the stock." Under that assumption one can conceptualize the catch in each year during the chosen time period as a random observation from an imaginary infinite sequence of annual catches during which the "long-term average production potential" was maintained. In that case, buffer, b_y, based on the P* approach can be determined from the distribution of the sample mean by using a t-distribution to compute the lower bound of the approximate (1-2P*) confidence interval for the mean (i.e., of the "long-term average production potential"). That is, the b_y can be computed as,

$$b_y = \frac{\bar{x} - t_{(P*,df=n-1)} s_{\bar{x}}}{\bar{x}} \qquad (3.3)$$

where,

$$\bar{x} = sample\ mean\ of\ n\ annual\ catches\ in\ time\ period,$$
$$t_{(P*,df=n-1)} = the\ P*\ percentile\ of\ a\ t\ distribution\ with\ n-1\ degrees\ of\ freedom, and$$
$$s_{\bar{x}} = the\ standard\ error\ of\ the\ mean\ computed\ from\ the\ sample\ of\ n\ annual\ catches.$$

This approach has appeal in that buffers so computed will decrease the ABC relative to the OFL not only with increasing estimated variability of the OFL (as measured by the CV = ratio of standard error of the mean to the mean), but also with decreasing sample size (i.e., the time period over which the mean catch was used to estimate the OFL). Although the sample distributions of annual retained catch for each of the stocks show some strong departures from a normal distribution and sample sizes are small (as few as 6 years for the PIGKC sample and up to 24 years for the WAIRKC sample), an analysis (not reproduced in this report) of 1,000 bootstrapped sample means generated from the annual retained catches from each of the Tier 5 stocks for the time periods from which the OFLs were computed show that a t-distribution with the appropriate degrees of freedom provides a useful approximation to the sampling distribution of the mean retained catch.

The standard error of the mean does not capture all uncertainty on the OFL for the Tier 5 stocks, however. There is, for example, qualitatively large uncertainty on whether the time period chosen actually is a time period that is "representative of the production potential of the stock." Uncertainty on the time period for computing OFLs can also exist due to the length of the time period relative to the life span of the species. Additionally, the time since the last year of the time period used to compute the OFL increases uncertainty on the OFL because of uncertainty that that time period is applicable to present conditions of the stock and environment.

Three additional options were explored for incorporating additional uncertainty in the computation of buffers and ACLs: scaling the buffer to the ratio of the length of the time period used to compute the OFL to the life span of the species; use of an extra variance term in the measure of uncertainty (i.e., the standard error of the mean); and increasing the measure of uncertainty (i.e., the standard error of the mean) in proportion to the time since the last year of the time period used to compute the OFL.

To examine the effects of scaling the buffer to the ratio of the length of the time period used to compute the OFL to the life span of the species, we followed Zheng and Siddeek (2009) in assuming that the lifespan of BSAI king crabs is 25 years.

To examine use of an extra variance term to account for additional uncertainty, Equation 3.3 was modified by adding an extra variance term, σ^2, to the measure of uncertainty, $s_{\bar{x}}$, to obtain a buffer, $b_{y,\sigma}$, computed as,

$$b_{y,\sigma} = \frac{\bar{x} - t_{(P*,df=n-1)}\left(s_{\bar{x}}^{2} + \sigma^{2}\right)^{1/2}}{\bar{x}} \, \mathrm{B}_{y,\sigma} = \frac{\bar{x} - t_{(P*,df=n-1)}\left(s_{\bar{x}}^{2} + \sigma^{2}\right)^{-2}}{\bar{x}} \, . \tag{3.4}$$

Buffers, $B_{y,\sigma}$, were computed according to Equation 3.4 for each of three values of σ^2, determined by $\sigma = CV \cdot \bar{x}$, for values of CV = 0.2, 0.3, and, 0.4 and for values of P* from 0.1 to 0.5 in increments of 0.1.

Lastly, use of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period used to compute the OFL was examined as a means to account for additional uncertainty. To do so the measure of uncertainty, $s_{\bar{x}}$, was scaled by $(1+l/n)$, where l is the time lag (in years) since the last year of the time period used to compute the OFL and n is the number of years in the time period, and Equation 3.4 was modified to obtain a buffer, $b_{y,l}$, computed as,

$$b_{y,l} = \frac{\bar{x} - t_{(P*,df=n-1)}\left(1+\frac{l}{n}\right) s_{\bar{x}}}{\bar{x}} \, . \tag{3.5}$$

3.3.2.2 Medium-term implications for Tier 5

Assuming that the OFL and time periods for computing the OFLs remain constant, buffers will be unchanged for all P*-based approaches except for the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL. Buffers determined under the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL will decrease linearly (until reaching 0) with time for fixed values of $P*_l$ and the implications are examined through fishing years 2018/19.

3.4 Methodology for evaluating ACLs for Tanner crab and ACLs and rebuilding scenarios for Snow crab

Snow crab are in Tier 3, which means that there is an assessment model that provides estimates of mature male biomass. Estimates of F_{MSY} and B_{MSY} are not available for this stock, so status determination depends on proxies. For snow crab, it is possible to reliably estimate $F_{35\%}$ (the rate of fishing mortality which reduces the mature male biomass (at the time of mating)-per-recruit to 35% of the unfished mature male biomass (at the time of mating)-per-recruit). The proxy for B_{MSY} for snow crab is computed multiplying the average recruitment over a range of years recommended first by the CPT and finally by the SSC by the mature male biomass (at the time of mating)-per-recruit corresponding to $F_{35\%}$.

A stock assessment for Tanner is under development and the stock is in Tier 4. The defining characteristic of Tier 4 stocks is that it is not possible to estimate $F_{35\%}$ (or the estimates has not been accepted by the CPT / SSC). The proxy for F_{MSY} is γM for these stocks, where at present γ equals 1 for all Tier 4 stocks. The proxy for B_{MSY} for Tier 4 stocks is the average mature male biomass (at the time of mating) over a range of years recommended by the CPT / SSC.

The focus for the evaluation of the alternatives on snow crab and Tanner crab stocks is the impact of lack of precision, i.e., this evaluation assumes that on average[46] the assessment is correct and assumptions regarding proxies for F_{MSY} are also correct.

The OFL for snow and Tanner stocks applies to all sources of catch, retained and discard in the directed fishery and discard mortality from other crab and groundfish fisheries.

The "within" uncertainty for snow and Tanner stocks is quantified by the variance of ending MMB from the ADMB output of the assessment model run.

3.4.1.1 Short-term implications

The short-term implications of the alternatives are evaluated by calculating the ABC for the most recent year (2009 or 2009/10 depending on the stock and the structure of the stock assessment) using Equations 3.1 and 3.2. The ABC values for each stock include removals due to several sources so the value corresponding to the retained catch by the directed fishery is also listed. This value is most comparable with the output from the SOA control rule.

The value of P* is reported for each buffer value (and choice for the extent of additional uncertainty) and the buffer corresponding to each choice of P* is also reported. This provides a basis to explore how these two currencies relate for each stock. The relationships between P* and buffer will differ due to differences among stocks in the uncertainty of the last estimate of MMB (σ_b, see Table 3.3).

3.4.1.2 Medium- and long-term implications

The medium- and long-term implications are evaluated by projecting each stock ahead 30 years[47] under the assumptions that the catch equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule (for runs with the SOA control rule, this is equivalent to assuming that the TAC is set equal to the component of the ABC which is estimated to consist of legal male crab

[46] In the sense of multiple "replicates" of each stock.

[47] 30 years is sufficiently long so the resource equilibrates close to the proxy for B_{MSY} under deterministic conditions (no fluctuations in recruitment about the assumed stock-recruitment relationship).

(retained male crab for snow crab) caught by the directed fishery), and that the catch equals the ABC. The medium-term implications are evaluated using the results of projections for the first six years of the projection period while the long-term implications consider the implications of the entire 30-year projection period.

The medium- and long-term implications of the different buffers are quantified in terms of their impact on stock status (measured in terms of mature male biomass at the time of mating relative to B_{35}, the probability of overfishing (.e. total catch > OFL) and the probability of the stock becoming overfished, $B < 0.5B_{35}$) as well as economic impacts. The probability that the TAC is constrained by the ABC control rule to be below that computed by the SOA control rule (expressed as the probability that the output from the SOA control rule exceeds the component of the ABC which is estimated to the retained in the directed fishery) is also reported.

The projections account for uncertainty related to: (a) the values for the parameters of the population dynamics model used to model the stock, (b) the recruitment to the modeled population for each future year, (c) the form of the stock-recruitment relationship, and (d) the stock assessment models used for population size estimation. These sources of uncertainty reflect the scientific uncertainty which the buffer between the OFL and ABC (and hence ACL) is meant to account for.

The methods for projecting the stock for snow and Tanner crab differ from the king crabs (section 3.3) in that no MCMC methods were used. One run of the assessment model was conducted and the appropriate output used as input to a separate projection model, which was essentially the same projection model used for king crab evaluations. However, unlike king crab, there is no variability in $F_{35\%}$ and $B_{35\%}$ in the projections and variability in initial numbers by length is added as described below.

The algorithm used is as follows (see also Figure 3-4):

1) Fit the stock assessment model to the data for the stock to obtain the "best estimates" of parameters of the model.
2) Given parameter estimates from the assessment model, a separate projection model then:
    a. Calculates $F_{35\%}$ and sets F_{MSY} to $F_{35\%}$ (Tier 3 stocks)
    b. Find the value for the steepness of the stock-recruitment relationship so that MSY occurs at F_{MSY} (either $F_{35\%}$ or M depending on which Tier the stock is in).
    c. Set R_0 (the virgin recruitment) so that B_{MSY} occurs at the proxy for B_{MSY}
3) Set the value for F_{OFL} used when setting the OFL to the median of the values for $F_{35\%}$ across the draws from the posterior (i.e., the projections are undertaken under the assumption that the proxy for F_{MSY} is correct on average when setting OFLs).
4) σ_R was calculated from the variability in estimated recruitments from the assessment model.
5) For each run of the projection model and choice of a buffer:
    a. Generate an initial bias, b, based on a lognormal distribution with mean zero and variance σ_b[48] applied to initial numbers by length (since initial values are not from MCMC runs as with BBRKC).
    b. Generate an assessment bias, b, based on a lognormal distribution with mean zero and variance σ_b[49].
    c. For each year of the thirty-year projection period:
        i. Compute the true OFL (the OFL based on the parameters generated from the assessment model and the OFL control rule).

[48] This source of uncertainty reflects the "additional uncertainty" not captured within the assessment.
[49] This source of uncertainty reflects the "additional uncertainty" not captured within the assessment.

ii. Generate the data on which the ACL will be based by generating a random variable ε_y from a lognormal distribution with mean 0, variance σ_w^2 which represents the annual deviation in the assessment result from the true value and then multiplying all of the population-related information needed to set the ABC (mature male biomass at mating, numbers-at-length) by $\exp(b+\varepsilon_y-\sigma_b^2/2-\sigma_w^2/2)$ to generate the data used when setting the ABC.[50]

iii. Compute the OFL based on the data generated at step ii) and multiply it by the buffer to compute the ABC (and hence the catch).

iv. Apply the SOA control rule.

v. For runs with the SOA control rule, if the output from the SOA control rule is larger than the retained-directed component of the ABC, the catch (ACL) equals the ABC otherwise the catch equals the output from the SOA control rule multiplied by the ratio of the ABC to the retained-directed component of the ABC.

vi. For runs without the SOA control rule, the catches were solely determined by the OFL control and the buffer.

vii. Project the population ahead one year and generate the recruitment for the next year.

The uncertainty associated with the long-term projections is necessarily higher than that associated with the medium-term projections given that the 30-year projections rely to a much greater extent on assumptions regarding the form of the stock-recruitment relationship, which is very uncertain for all BSAI crab stocks.

3.5 Methodology for economic analysis

Methods used to characterize the economic implications of the ACL and rebuilding alternatives depicted in Chapters 4-13 focus on estimating gross economic revenue associated with short-, medium-, and long-term directed catch projections for the respective stocks. Estimated gross revenues are those accruing at the first wholesale level of production, and encompass all income associated with harvest and production in the BSAI crab fisheries up to the point of first wholesale transfer. While projected catch levels under ACL alternatives alone provide a measure of economic impact, the monetary value of directed catch projections provides a useful metric that allows comparisons of economic impacts across alternatives, particularly with regard to those which alter the timing of economic production and revenues in the crab fisheries, and in a scale that is more broadly comparable to other economic objectives in the context of decision making. A key element of this analysis is the development of time series price forecasting models of king and snow crab prices, which permit estimation of the probability distribution of prices for finished crab production in each year of the period of prospective analysis.

Before describing methods used to forecast crab prices and estimate and project gross revenues in greater detail, it should be noted that this analysis does not attempt to provide a complete evaluation of welfare effects of ACL or rebuilding alternatives. Implicit in the evaluation of alternatives for reducing the risk of overfishing by implementing ACL protocols is the determination that there is an economic benefit produced by reducing the probability of future fishery resource limitations and other resource impacts and associated financial and social losses. Apart from those benefits reflected in projected changes in the trajectory of directed catch over the specified time frames of the analysis, evaluation of the broader economic benefits of ACL and stock rebuilding alternatives is considered beyond the scope of this analysis. Due to insufficient information available to evaluate changes in the fixed and variable operating costs incurred by operators in the fisheries, we do not attempt to evaluate net revenue effects of the

[50] The data used when setting the ABC thus differ from the true values due to a random component which is common across years and a random component which varies among years,

alternatives in this analysis.[51] The relative economic impacts of ACL and rebuilding alternatives are summarized in the following chapters as the difference in gross revenue impacts between each alternative and one or more baseline alternative. These relative impacts are somewhat less sensitive to the effect of changes in operating costs in the fisheries under forecasted catch levels and to a certain extent obviate the need to represent net welfare effects; however, a fuller accounting of changes in net revenue would provide a more appropriate measure of welfare effects for each alternative. Finally, the gross revenue effects evaluated herein are those associated only with directed catch, and any effects of crab ACLs on other BSAI fisheries in which managed crab stocks are caught as bycatch are not evaluated.

3.5.1 Framework for economic analysis

To evaluate economic impacts of each ACL and rebuilding alternative, the following metrics are calculated and reported for the analyzed alternatives in Chapters 4 – 13 for the respective stocks:

$$R_{yi} = C_{yi} \times K \times P_y \qquad (3.6)$$

where R_{yi} is the estimated revenue in year y projected for alternative scenario i, C_{yi} is the projection of retained catch in year y under the ith alternative scenario, K is the product recovery rate for the species, and P_y is the forecasted first wholesale price in year y. Product recovery rate is used to convert the value for retained catch into estimated finished product for use with forecasted wholesale price to calculate gross wholesale revenue. For this analysis, P_y is assumed to be independent from retained catch. Since finished crab products from the BSAI crab fisheries are sold into the international market and represent a relatively small fraction of total supply, the assumption of price-taking is deemed to be well-supported[52]. For each scenario i, the present value of revenue in each year and the total present value over all years in the relevant time frame is calculated as

$$PV(R_y) = R_y / (1+r)^{y-1}, \; B_{y,l} = \frac{\bar{x} - t_{(P*, df=n-1)}\left(1+\frac{1}{n}\right) s_{\bar{x}}}{\bar{x}} \qquad (3.7)$$

$$TPV(R) = \sum_{y=1}^{Y} PV(R_y) \qquad (3.8)$$

For evaluation of medium- and (for Tier 3-4 only) long-term implications, the above metrics are reported in Chapters 4-13 in both nominal (undiscounted) terms and discounted to 2008 present value using real discount rates of 2.7% and 7.0% following OMB guidance (OMB, 1992; 2009).

Under each of the alternatives analyzed for the respective stocks, probabilistic estimates for directed catch C_y in year y are produced using Monte Carlo methods outlined above and detailed in the following chapters, and the probability distributions of P_y are estimated using forecasting methods as described below. In principal, for each alternative, revenue in year y is estimated by multiplying the projected catch

[51] Considerable information on vessel and plant operating costs has been collected in the BSAI Crab Economic Reporting program. Significant data quality limitations for some important elements of variable cost (e.g., fuel), and the lack of most elements of fixed costs, limit the use of these data for evaluating net revenue effects of ACL alternatives. In addition, further work is needed to quantify the effect of consolidation in the crab fisheries (which would likely accelerate under some ACL alternatives) and the effect thereof on fixed and variable costs. Given the time available to prepare this analysis, the authors determined that estimation and comparison of gross revenue effects of ACL alternatives would be more useful than an analysis of quasi-rent effects which would inject additional complexity and uncertainty into the exposition.

[52] As described in the discussion of time series model testing below, price model specifications that included physical product volume were in most cases outperformed by models that used lagged price data only.

in year y by a forecasted price in year y. However, because both price forecasts and catch projections are probabilistic, appropriate representation of the uncertainty of projected revenue values requires treating both sources of uncertainty jointly in the revenue estimation. To estimate the distribution of R_y and TPV(R) for Tier 3 and 4 stocks, revenue calculations are performed within the Monte Carlo simulations described in Section 3.4.1.2. For each run of the simulation, a vector of prices is generated from the forecast distributions of P_y, (y=1,…30), and multiplied by the vector of retained catch values C_y adjusted by *PRR* to calculate a vector of annual revenue values:

$$R_y = C_y \times [\overline{K} + (x_1 + S_K)] \times [\overline{P}_y + (x_2 \times S_{P_y})] \qquad (3.9)$$

where $\overline{K}$ and S_K are the mean and standard error of the product recovery rate, $\overline{P}_y$ and S_{P_y} are the mean, and standard deviation of the price forecast for year y, and x_1 *and* x_2 are drawn randomly in independently for each of 800 simulations from $X \sim N[0,1]$. Six TPV calculations are made for medium and long-term impacts by summing discounted R_y values over the respective time-frames (where $TPV_{r,Y}$ is calculated for discount rate r =(0.0, 0.027, and 0.070) and time frame Y= (6, 30)) for each of 800 simulated catch vectors for each scenario *i*. To generate median and confidence bound values, the 800 outcomes for each value of revenue $R_{y,\,i}$ and $TPV_{r,Y,i}$ are independently sorted and the median, lower- and upper- 5th percentile values are reported out as the prediction intervals for $R_{y,i}$ and $TPV_{r,Y,i.}$. Values for $\overline{P}_y$, S_{P_y}, and *PRR* for each crab species are reported below.

Except where noted, all historical monetary (price and revenue) values reported in this analysis are adjusted to 2008 equivalent dollars using the producer price index (PPI) available from the U.S. Bureau of Labor Statistics (BLS) for the processed and unprocessed fish category (WPU0223), a general category that includes frozen shellfish commodities. 2008 is the most recent base year for which the PPI is available. Forward projections of dollar values are presented in 2008 dollar terms as well, whether projected values are discounted to present 2008 dollars according to a particular real discount rate value, or presented in undiscounted (nominal) terms.

3.5.2 Comparison of economic impacts across alternatives

The economic results in the chapters for each stock show four different sets of scenarios. To facilitate comparison of the relative impacts of the ACL alternatives for buffer levels and incorporation of additional uncertainty, pairwise comparisons of the median TPV of revenues projected for each alternative against two reference-level alternative scenarios are reported for each stock-level analysis. One set of comparisons evaluate the revenue impact of each buffer or P* alternative against a baseline scenario of no additional uncertainty (σ_b=0) and buffer=1 (P*=0.5). The other set of comparisons evaluate the effects of reducing buffer sizes relative to buffer=1 for varying levels of σ_b. Separate tables of pairwise comparison results are shown for model scenarios where estimated catch is constrained by the TAC set according to the SOA control rule for stock, and for scenarios where estimated catch reflects the ABC unconstrained by the SOA control rule. Because the selection of an alternative specifying P* or a particular buffer level reflects a preference for a particular level of risk avoidance, the selection is subject to weighting against expected costs (and benefits, if known) of the alternative in the decision to be made by fishery managers. In contrast, specification of σ_b is premised on an assessment of the degree of predictive uncertainty that is not captured in the assessment model and available data, and essentially describes a belief about the level of an unknown but empirical quantity, i.e. "the state of the world". As such, alternative specifications of σ_b are not properly weighted against each other in the calculation of a single economic metric. That is, comparison of outcomes under different levels of σ_b is arguably not an "apples-to-apples" comparison. However, in the context of a sensitivity analysis of the effect of alternative assumptions regarding the value of σ_b on the economic outcome of specifying a given buffer level, the comparison is analytically useful. To support consideration of the alternatives from both of these perspectives, the following values are reported for Tier 3 and 4 stocks:

$$\Delta TPV(i)_{1,0} = TPV_{b,\sigma} - TPV_{1,0}\text{, and} \tag{3.10}$$

$$\Delta TPV(i)_{1,\sigma} = TPV_{b,\sigma} - TPV_{1,\sigma} \tag{3.11}$$

where $\Delta TPV(i)_{1,0}$ evaluates the reduction in total revenue associated with a given alternative *i* relative to the reference alternative b=1 and σ_b=0; and $\Delta TPV(i)_{1,\sigma}$ evaluates the reduction in total revenue associated with a given alternative *i* relative to the reference alternative *b*=1, holding σ_b constant between compared alternative pairs. In each case, the calculated difference in *TPV* represents the estimated value of foregone gross revenue relative to the reference level alternative. Surface plots depicting the tradeoff between median *TPV* estimates, buffer size, and levels of σ_b are included in the analyses for Tier 3 and 4 stocks.

Readers should note the caveat that the revenue forecasts and the calculated estimates of changes in TPV are provided to support relative comparisons between ACL and rebuilding alternatives. Interpreting these values too strongly as predicted absolute outcomes in the event of a chosen alternative buffer level is not advised, particularly in light of the width of the confidence intervals for the price forecasts and both medium- and long-term revenue projections. In particular, the PV and TPV forecasts are based on the historical range of variation in crab prices, which have been notably volatile over the available time series. For the purpose of forecasting to support consideration of relative impacts of management alternatives, it is necessary to assume that the historical range of variation in prices will continue into the future. This does not represent a prediction that there will be no additional variation or "shocks" in the markets for crab and associated prices. While the forecasted revenue intervals represent the best available information, the absolute forecasted values are subject to a high degree of uncertainty. Relative differences in revenue impacts between alternatives effectively net out a considerable portion of this uncertainty, however, and the authors of this analysis focus on the relative impacts to describe the economic implications of ACL and rebuilding alternatives.

3.5.3 Price Forecasts for Alaska King and Snow Crab

Preliminary analysis for snow crab rebuilding alternatives (presented at the October, 2009 NPMFC meeting) employed forward projection of the mean first wholesale price for Alaska snow crab from BSAI Crab Economic Data Report (EDR) crab production data, averaged over 1998-2007. To permit more formal treatment of uncertainty in price projections, forecasting methods are used in this analysis to produce probabilistic estimates of wholesale prices for red and golden king and snow crab species for the 30 year period of the analysis. Due to the closure of blue king and Tanner crab fisheries over much of the last two decades, there is not sufficient data on blue king crab production and sales to develop a price forecasting model for these species. As described below, red king and snow crab forecasts are adjusted to act a proxy price forecasts for blue king and Tanner crab fisheries.

Time series econometric models of Alaska red and golden king crab and snow crab were developed using vector autoregression (VAR) methods to model historical data series from Alaska's Commercial Operators Annual Report (COAR), over the period 1991-2008, and time series from the U.S. Merchandise Trade Statistics on king crab imports over the same period. A detailed description of the model development and forecasting method is provided in Dalton (2008)[53] and documentation of additional testing procedures for model selection are provided in Appendix 3. The selected price models for red and golden king and snow crab were then used to produce 30-year probabilistic forecasts of wholesale prices (see Table 3-1 and Figure 3-2) for these species. The median and standard error of the price forecast for each year was applied to the catch projections from the population projection simulations as described above to simulate revenue trajectories for each ACL alternative for the Tier 3 and 4 analyses. Median and 90% confidence intervals for the values calculated using equations 3.7 and 3.8 above are reported in the individual stock assessments.

Models were tested that incorporated 1991-2008 time series from COAR reports and U.S. Census Bureau Merchandise Trade Statistics. In particular, series were derived from COAR data that represent i) the physical quantity of production in each year and ii) an index of real first-wholesale prices for finished product (frozen sections) for red and golden king and snow crab. Similarly, quantities and price indices for exports and imports were retrieved from the TPIS and converted into real economic values using a price deflator based on a producer price index (PPI) available from the U.S. Bureau of Labor Statistics (BLS) for the processed and unprocessed fish category (WPU0223), a general category that includes frozen shellfish commodities. This pair of time series (spanning 1991-2006), representing COAR real wholesale prices and U.S. import prices for king crab products, was the basis of the previous model and analysis for king crab that was considered by the SSC in 2008. In addition to this pair (each of which incorporate two additional years of data for 2007-8), time series were derived that represent physical quantities and price indices (i.e., economic value per physical unit) for i) king crab exports, ii) snow crab production and wholesale value based on COAR data, iii) snow crab export and import volumes and economic values. In total, six time series are available for analysis (2 COAR, 2 export, and 2 import), 3 for each type of crab (king, snow).

Vector autoregression (VAR) models specified with lags of 1 to 3 years were tested using the 1991-2008 dataset. Testing procedures described in Appendix 3 indicated the strongest support for the VAR(3) model specification with three price series based on COAR wholesale prices for red and golden king crab, respectively, COAR wholesale prices for snow crab, and TPIS king crab import price. Model specifications that included physical quantities for the same price series were tested in all possible combinations and found to be outperformed by the specification with three price series only, which was chosen as the basis for the price forecasts used in this analysis. Therefore, as noted above, the price forecasts are not dependant of the level of production in the respective crab fisheries in Alaska and there is no endogeneity between catch and price in the revenue projections. It should be noted that the dependence of Alaska wholesale price on catch level and production volume is not definitively rejected by this analysis, however, incorporation of both price and quantity series in the VAR regressions exhausts the available degrees of freedom given the length of available time series. Further model development may identify alternative methods or specifications that permit incorporation of physical quantity and will be incorporated into final analysis for ACLs and rebuilding alternatives if warranted and to the extent possible.

The price forecasts for red and golden king crab produced with the VAR models reflect recorded prices for the frozen segment product form, and does not differentiate between different red or golden king crab

[53] A principal focus of the Dalton (2008) paper is testing hypotheses regarding the effect of rationalization and the influx of king crab imports to the U.S. on Alaska COAR prices. Comments from the SSC when the paper was presented at the October 2008 NPFMC meeting focused on the length of the time series and statistical power of the hypothesis tests. The model developed therein is used here to forecast both king and snow crab prices, with the addition of two additional years in the COAR price series and additional model diagnostics and specification tests. No tests for specific structural breaks in the COAR price series are being made in this analysis and the critique of conclusions in the paper in that regard are of less concern in the present use of the model.

stocks harvested in the BSAI, and does not control for changes in the relative proportions of king crab species or finished product forms in the total volume and value of annual of production. The forecasts for red king and snow crab prices were used as proxy estimates for blue king crab, and Tanner crab, respectively, with adjustments using the historical differences between the red and blue king crab prices, and the differences between snow and Tanner crab in the COAR price series for each species. As depicted in Figure 3.1, prices for king crab species, as well as Tanner and snow crab price, tend to track each other in that they generally move in the same direction, although the ratio or difference between prices is not constant through time. Price ratio data and correlation statistics are reported in Table 3-14. Mean ratio values for 1991-2008 were used to adjust the red king crab price forecast values to estimate the blue king crab prices by a factor of 0.69. Product recovery rate constants calculated from BSAI Crab EDR data were used to adjust retained catch values to finished product values and are reported in Table 3-15.

As described above, short-, medium-, and long-term implications of ACL alternatives are analyzed in this document. Short-term impacts are limited to the effect that ACL's would have had on directed catch and revenues in the 2009 or 2009/2010 fisheries. Medium term impacts are considered those limited to the 2009-2015 period, and long-term impacts are limited to the next 30 years. Only Tier 3 and 4 stocks are examined in the long-term context, where quantitative methods permit representation of the uncertainty associated with long-term projections. As indicated by Figure 3-1, price forecasts for both snow and king crab exhibit considerable variation over the 30–year forecast, both in the oscillating value of the mean and the range of predicted confidence intervals. This is a standard result in vector autoregression models, which oscillate most strongly in the short run (capturing the autoregressive dynamics) and then trend toward the mean price in the sample, with the standard error increasing over time. As such, the mean value of the price forecast tends over the long term to converge toward the mean price in the data series, producing the same mean revenue projection estimate one would produce by simply projecting the sample mean forward, but with confidence bounds indicating increasing uncertainty in the estimate as the length of the forecast increases. By treating uncertainty in market prices explicitly, this forecasting method provides price estimates that are compatible with the probabilistic population and catch projections within the analytical framework or the assessment approach. By capturing the observable price volatility in the time series, the forecast permits improved representation of the potential for prices to deviate in the short run from the current or very recent periods.

3.6 Tables and Figures

Table 3-1 Five-Tier System for setting overfishing limits for crab stocks. The tiers are listed in descending order of information availability. Table 3.2 contains a guide for understanding the five-tier system.

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* $F_{OFL} \le F^{*}_{35\%}$
B, M, $B_{msy^{prox}}$	**4**	a. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$
		b. $\beta < \frac{B}{B_{msy^{prox}}} \le 1$	$F_{OFL} = \gamma M \frac{B/B_{msy^{prox}} - \alpha}{1-\alpha}$
		c. $\frac{B}{B_{msy^{prox}}} \le \beta$	*Directed fishery F = 0* $F_{OFL} \le \gamma M$
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 $F_{OFL} \le F_{MSY}$ or proxy F_{MSY} will be determined in the development of the rebuilding plan for that stock.

Table 3-2 A guide for understanding the five-tier system.

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

Table 3-3 Buffer values resulting from a range of P* values and σ_b values for a stock for which the internal variance σ_w is 0.08.

	Sigma-b values			
	0	0.2	0.4	0.6
P*	Buffer values below OFL			
0.5	0.00%	0.00%	0.00%	0.00%
0.45	1.00%	2.67%	5.00%	7.32%
0.4	2.01%	5.31%	9.82%	14.22%
0.35	3.04%	7.96%	14.55%	20.80%
0.3	4.11%	10.68%	19.26%	27.20%
0.25	5.25%	13.52%	24.05%	33.52%
0.2	6.51%	16.58%	29.06%	39.92%
0.15	7.96%	20.01%	34.48%	46.60%
0.1	9.74%	24.12%	40.71%	53.96%
0.05	12.33%	29.83%	48.88%	63.05%

Table 3-4 Summary of the current tier assignments for the 10 BSAI crab stocks. The final column lists the standard deviation of the logarithm of the estimate of mature male biomass (at mating) for the most recent year based on applications of assessment models.

Stock	Tier	Status (a, b c)	Standard deviation of log MMB
EBS snow crab	3	b	
BB red king crab	3	a	0.050
EBS Tanner crab	4	b	
Pribilof Islands red king crab	4	b	0.180
Pribilof Islands blue king crab	4	c	0.271
St. Matthew Island blue king crab	4	a	0.160
Norton Sound red king crab	4	a	0.110
AI golden king crab (Adak)	5	N/A	0.027
AI golden king crab (Dutch)	5	N/A	0.021
Pribilof Islands golden king crab	5	N/A	N/A
Adak red king crab	5	N/A	N/A

Table 3-5 Current buffer size for a selection of NPFMC species compared to the P* necessary to obtain that buffer for two different CV types. SSB CV is CV for ending year spawning biomass. Survey CV of last 3 stocks is the average CV of the last 3 trawl surveys. P*=0.12 is the buffer size at the mean P* from the P* Survey column (excerpted from Hanselman, 2009).

Stock	Tier	F_{40}	F_{35}	Buffer size	SSB CV	Survey CV of last 3	P* SSB	P* Survey	(1-Buffer) at P*=0.12 (SSB)	(1-Buffer) at P*=0.12 (Survey)
GOA POP	3	0.06	0.07	0.84	29%	17%	0.27	0.15	0.72	0.82
GOA Arrowtooth	3	0.19	0.22	0.84	4%	9%	0.00	0.03	0.95	0.90
GOA Pollock	3	0.13	0.15	0.87	11%	14%	0.10	0.15	0.88	0.85
GOA P. Cod	3	0.44	0.54	0.81	16%	18%	0.10	0.13	0.83	0.81
GOA Rougheye	3	0.04	0.05	0.83	40%	17%	0.31	0.13	0.64	0.82
Sablefish	3	0.09	0.10	0.84	4%	13%	0.00	0.09	0.95	0.86
GOA Harlequin	5			0.75		51%		0.28		0.57
GOA Sleeper shark	6			0.75		29%		0.15		0.72
EBS Pollock	1	0.28	0.33	0.85	24%	10%	0.25	0.06	0.76	0.89
BSAI Flathead	3	0.28	0.34	0.82	6%	11%	0.00	0.03	0.93	0.88
BS N. Rockfish	3	0.04	0.05	0.83	9%	24%	0.02	0.22	0.90	0.75
BSAI Shortraker	5			0.75		26%		0.13		0.74
BSAI G. Grenadier	6			0.75		10%		0.00		0.89

Table 3-6 Summary of stock-specific analyses of variation in abundance estimates from assessments of groundfish and CPS species for the Pacific Council.

Group	Common Name	Scientific Name	Number of Assessments	Log-scale standard deviation
Rockfish	Bocaccio	*Sebastes paucispinis*	5	0.367
Rockfish	Canary rockfish	*Sebastes pinniger*	7	0.375
Rockfish	Chilipepper	*Sebastes goodei*	2	0.354
Rockfish	Darkblotched rockfish	*Sebastes crameri*	3	0.103
Rockfish	Pacific Ocean Perch	*Sebastes alutus*	3	0.352
Rockfish	Shortspine thornyhead	*Sebastolobus alascanus*	3	0.923
Rockfish	Widow rockfish	*Sebastes entomelas*	5	0.241
Rockfish	Yelloweye rockfish	*Sebastes ruberrimus*	4	0.492
Rockfish	Yellowtail rockfish	*Sebastes flavidus*	6	0.269
Roundfish	Cabezon	*Scorpaenichthys marmoratus*	3	0.154
Roundfish	Lingcod	*Ophiodon elongatus*	4	0.263
Roundfish	Pacific whiting	*Merluccius productus*	15	0.286
Roundfish	Sablefish	*Anoplopoma fimbria*	7	0.340
Flatfish	Dover sole	*Microstomus pacificus*	3	0.360
Flatfish	Petrale sole	*Eopsetta jordani*	3	0.227
CPS	Pacific sardine	*Sardinops sagax*	3	0.206
CPS	Pacific mackerel	*Scomber japonicus*	4	0.415

Table 3-7 Model-estimated σ_w values (as CV on MMB), recommended σ_b values per Table 2-6, and calculated σ_{total} (where $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$) utilized in this analysis.

Stock	σ_w	σ_b recommended	σ_{total}
Bristol Bay red king crab	0.050	0.2	0.206
EBS snow crab	0.085	0.2	0.218
Tanner crab	0.140	0.3	0.331
Pribilof Island red king crab	0.574	0.4	0.699
Pribilof Island blue king crab	0.271	0.4	0.483
St. Matthew blue king crab	0.160	0.3	0.340
Norton Sound red king crab	0.111	0.4	0.415
AIGKC-Dutch	0.021	0.4	0.401
AIGKC-Adak	0.027	0.4	0.401

Table 3-8 Relationship between the size of the buffer between the OFL and the ABC for a P* of 0.4 with different values for the extent of additional variability σ_b based on the assumption that the OFL is log-normally distributed about its best estimate. Note that additional variance of 0.3 was calculated for all 'medium' level stocks as listed in Table 2-4 as well as some additional stocks for comparative purposes only. Shading indicates the recommended level of σ_b

P* 0.4		Additional uncertainty, σ_b			
Stock	**0**	**0.2**	**0.3**	**0.4**	**0.6**
Bristol Bay red king crab	1%	6%	11%	16%	28%
EBS snow crab	3%	8%	--	16%	29%
Pribilof Island red king crab	50%	50%	54%	58%	69%
St. Matthew blue king crab[54]	0%	0%	0%	1%	11%
Norton Sound red king crab	5%	8%	13%	16%	28%
Dutch Harbor golden king crab*	3%	10%	15%	20%	32%
Adak golden king crab*	9%	11%	15%	19%	29%

* These two stocks comprise the Aleutian Islands golden king crab stock (results shown for the Tier 4 analysis)

Table 3-9 Relationship between the size of the buffer between the OFL and the ABC for a P* of 0.4 with different values for the extent of additional variability σ_b based on the assumption that the OFL is log-normally distributed. The best estimate is assumed to be the median of the distributions for the OFL for all stocks. Note that additional variance of 0.3 was calculated for all 'medium' level stocks as listed in Table 2-4 as well as some additional stocks for comparative purposes only. Shading indicates the recommended level of σ_b .

P* 0.4		Additional uncertainty, σ_b			
Stock	**0**	**0.2**	**0.3**	**0.4**	**0.6**
Bristol Bay red king crab	1%	5%	8%	10%	14%
EBS snow crab	2%	8%	--	10%	14%
Pribilof Island red king crab	13%	14%	15%	16%	19%
St. Matthew blue king crab[55]	4%	6%	8%	10%	15%
Norton Sound red king crab	3%	6%	8%	10%	15%
Dutch Harbor golden king crab*	1%	5%	7%	10%	14%
Adak golden king crab*	1%	5%	7%	10%	14%

* These two stocks comprise the Aleutian Islands golden king crab stock (results shown for the Tier 4 analysis)

[54] Note that buffer results for SMBKC and PIRKC are strongly influenced by the skewness in the OFL distribution for this stock. See Section 3.2.4.2 for more details.
[55] Note that buffer results for SMBKC and PIRKC are strongly influenced by the skewness in the OFL distribution for this stock. See Section 2.3.1.4 for more details.

Table 3-10 Range of P* values for a constant buffer of 10% for 7 BSAI Crab stocks, for different values for the extent of additional variability σ_b based on the assumption that the OFL is log-normally distributed about its best estimate. Shading indicates the recommended level of σ_b.

Buffer = 10%		Additional uncertainty, σ_b			
Stock	**0**	**0.2**	**0.3**	**0.4**	**0.6**
Bristol Bay red king crab	0	0.25	0.36	0.43	0.50
EBS snow crab	0.11	0.36	--	0.45	0.50
Pribilof Island red king crab	>0.50	>0.50	>0.50	>0.50	>0.50
St. Matthew blue king crab	0.13	0.19	0.26	0.32	0.41
Norton Sound red king crab	0.21	0.37	0.43	0.48	0.54
Dutch Harbor golden king crab*	0.07	0.40	0.47	0.50	0.50
Adak golden king crab*	0.36	0.42	0.45	0.49	0.50

Table 3-11 Range of P* values for a constant buffer of 10% for 7 BSAI Crab stocks, for different values for the extent of additional variability σ_b. The best estimate is assumed to be the median of the distributions for the OFL for all stocks. Shading indicates the recommended level of σ_b.

Buffer = 10%		Additional uncertainty, σ_b			
Stock	**0**	**0.2**	**0.3**	**0.4**	**0.6**
Bristol Bay red king crab	0.02	0.30	0.36	0.40	0.43
EBS snow crab	0.11	0.31	--	0.40	0.43
Pribilof Island red king crab	0.43	0.43	0.46	0.44	0.45
St. Matthew blue king crab	0.26	0.34	0.38	0.40	0.43
Norton Sound red king crab	0.17	0.32	0.37	0.40	0.43
Dutch Harbor golden king crab*	0.00	0.30	0.37	0.40	0.43
Adak golden king crab*	0.00	0.30	0.37	0.40	0.43

Table 3-12 BSAI groundfish stocks, tiers, and resulting 2010 buffer levels (and ABC as a % of OFL) in 2010.

Stock	ABC/OFL	Buffer	Tier
Pollock	**83%**	**17%**	**1**
Pcod	**86%**	**14%**	**3**
Sablefish	**85%**	**15%**	**3**
Atka	**84%**	**16%**	**3**
Arrowtooth	**82%**	**18%**	**3**
FheadSole	**85%**	**15%**	**3**
AKPlaice	**78%**	**22%**	**3**
POP	**84%**	**16%**	**3**
NrthrnRF	**84%**	**16%**	**3**
Rougheye rockfish	**82%**	**18%**	**3**
Other rockfish	**75%**	**25%**	**5**
Squid	**75%**	**25%**	**5**
Oflats	**75%**	**25%**	**5**
Shortraker rockfish	**75%**	**25%**	**5**

Table 3-13 Data and Forecast Values, Alaska King and Snow Crab COAR Wholesale Price: Forecast values are in italics.

year	all_king_mean	all_king_se	RKC_mean	RKC_se	GKC_mean	GKC_se	SNOW_mean	SNOW_se
1991	25.15		26.48		22.17		6.75	
1992	25.54		29.9		17.42		6.87	
1993	23.66		26.78		16.52		8.74	
1994	28.81		40.08		21.45		12.4	
1995	20.88		31.32		19.09		17.45	
1996	23.34		28.73		17.58		10.95	
1997	17.35		19.44		14.96		6.91	
1998	15.81		16.91		13.1		6.22	
1999	28.64		33.12		19.46		8.52	
2000	18.32		19.96		16.05		9.92	
2001	23.57		25.81		20.28		10.95	
2002	29		33.1		21.76		10.36	
2003	26.42		27.91		22.45		12.64	
2004	22.3		25.13		16.41		13.04	
2005	20.25		21.44		15.08		9.71	
2006	15.9		17.62		10.99		6.84	
2007	18.29		19.76		13.08		9.09	
2008	19.99		21.4		15.17		8.91	
2009	21.43	2.76	19.19	4.78	17.46	2.43	7.38	1.67
2010	22.45	4.54	22.95	5.25	17.12	2.96	9.08	1.98
2011	24.09	4.81	25.82	6.26	16.69	3.23	11.34	2.67
2012	20.91	4.91	23.33	6.37	14.53	3.39	11.33	2.97
2013	16.31	5.5	19.42	6.94	13.61	3.64	8.98	3.06
2014	16.23	6.1	16.75	7.41	13.52	3.83	6.77	3.32
2015	16.18	6.15	16.82	7.49	14.45	3.96	6.32	3.45
2016	17.99	6.19	19.38	7.5	15.61	4.02	7.21	3.47
2017	21.62	6.32	21.71	7.67	16.12	4.14	8.54	3.49
2018	22.63	6.6	23.49	7.78	15.88	4.24	9.73	3.53
2019	21.8	6.69	24.2	7.87	15.14	4.27	10.44	3.6
2020	20.26	6.69	22.8	7.89	14.49	4.31	10.3	3.65
2021	17.73	6.75	20.41	7.98	14.32	4.36	9.16	3.66
2022	16.27	6.92	18.26	8.1	14.61	4.39	7.69	3.72
2023	17.01	7.01	17.62	8.19	15.1	4.4	6.88	3.8
2024	18.77	7.03	19.08	8.2	15.43	4.42	7.18	3.84
2025	20.76	7.08	21.34	8.25	15.46	4.44	8.32	3.85
2026	22.05	7.19	23.14	8.33	15.21	4.44	9.55	3.89
2027	21.54	7.27	23.64	8.39	14.91	4.45	10.2	3.94
2028	19.76	7.28	22.53	8.4	14.74	4.46	10	3.96
2029	17.97	7.33	20.6	8.43	14.79	4.46	9.08	3.97
2030	16.98	7.41	18.91	8.49	14.97	4.47	7.98	4
2031	17.4	7.46	18.33	8.54	15.15	4.47	7.31	4.04
2032	19	7.47	19.26	8.56	15.22	4.47	7.43	4.06
2033	20.66	7.51	21.02	8.58	15.16	4.47	8.26	4.07
2034	21.45	7.58	22.59	8.62	15.03	4.47	9.27	4.09
2035	21.03	7.62	23.14	8.67	14.93	4.47	9.9	4.12
2036	19.62	7.62	22.36	8.68	14.91	4.48	9.8	4.14
2037	18.13	7.66	20.79	8.69	14.97	4.48	9.09	4.14
2038	17.44	7.71	19.37	8.73	15.05	4.48	8.18	4.16

1991-2008 Values, Source: Commercial Operators Annual Reports, Alaska Department of Fish & Game.

Table 3-14 Alaska Crab COAR Wholesale Price and Calculated Price Ratios, by Species, 1991-2008.

	COAR Mean First Wholesale Price, all product forms, by Species					Weighted Mean Price		Price Ratio			
YEAR	RKC	BKC	GKC	EBT	EBS	All KC	Snow+ Tanner	RKC/ KC	BKC/ RKC	GKC/ RKC	EBT/ EBS
1991	7.01	5.8	5.89	3.56	1.79	6.66	2.01	1.05	0.83	0.84	1.99
1992	8.29	5.87	4.83	3.58	1.91	7.08	2.11	1.17	0.71	0.58	1.88
1993	7.44	4.84	4.59	3.61	2.43	6.58	2.56	1.13	0.65	0.62	1.48
1994	11.49	10.08	6.15	5.98	3.55	8.26	3.86	1.39	0.88	0.54	1.68
1995	9.5	5.86	5.79	6.98	5.29	6.34	5.46	1.5	0.62	0.61	1.32
1996	8.46	5.86	5.18	5.2	3.22	6.88	3.34	1.23	0.69	0.61	1.61
1997	6.18	5.04	4.78	5.03	2.13	5.55	2.15	1.11	0.82	0.77	2.36
1998	5.5	4.8	4.26	4.46	2.02	5.15	2.05	1.07	0.87	0.77	2.2
1999	11.23	9	6.6	3.95	2.89	9.71	2.9	1.16	0.8	0.59	1.37
2000	7.02	10.14	5.69	5.79	3.49	6.45	3.59	1.09	1.44	0.81	1.66
2001	8.76	8.18	6.87	5.02	3.71	8	3.81	1.1	0.93	0.78	1.35
2002	11.26	9.19	7.39	5.22	3.52	9.89	3.58	1.14	0.82	0.66	1.48
2003	9.68	10.4	7.79	6.13	4.39	9.17	4.46	1.06	1.07	0.8	1.4
2004	9.21		6.01	6.59	4.78	8.17	4.88	1.13		0.65	1.38
2005	8.4		5.96	4.29	3.84	7.95	3.89	1.06		0.71	1.12
2006	7.43		4.64	3.92	2.88	6.71	2.98	1.11		0.62	1.36
2007	8.52		5.64	4.41	3.92	7.89	3.97	1.08		0.66	1.13
2008	9.7		6.87	4.73	4.04	9.06	4.09	1.07		0.71	1.17
						Mean price ratio: 1991-2008		1.15	0.86	0.69	1.55
						Pearson		1	0.66	0.73	0.78
						Mean price ratio: 2006-2008		1.08		0.68	1.19
						Pearson		1		1	0.95

Source: Commercial Operators Annual Reports, Alaska Department of Fish & Game, 2008.

Table 3-15 Mean Product Recovery Rate, 1998-2008, by BSAI Crab Fishery

Fishery	PRR (Mean)	PRR- Std. Err.
AIG	0.689	0.00225
BBR	0.664	0.01535
BSS	0.660	0.00527
BST	0.678	0.00245
PIK	0.666	0.0092
SMB	0.668	0.01022
WAI	-*	

Source: BSAI Crab Economic Data Report, NMFS Alaska Fisheries Science Center, Seattle, WA.
* Suppressed to prevent disclosure of confidential information.

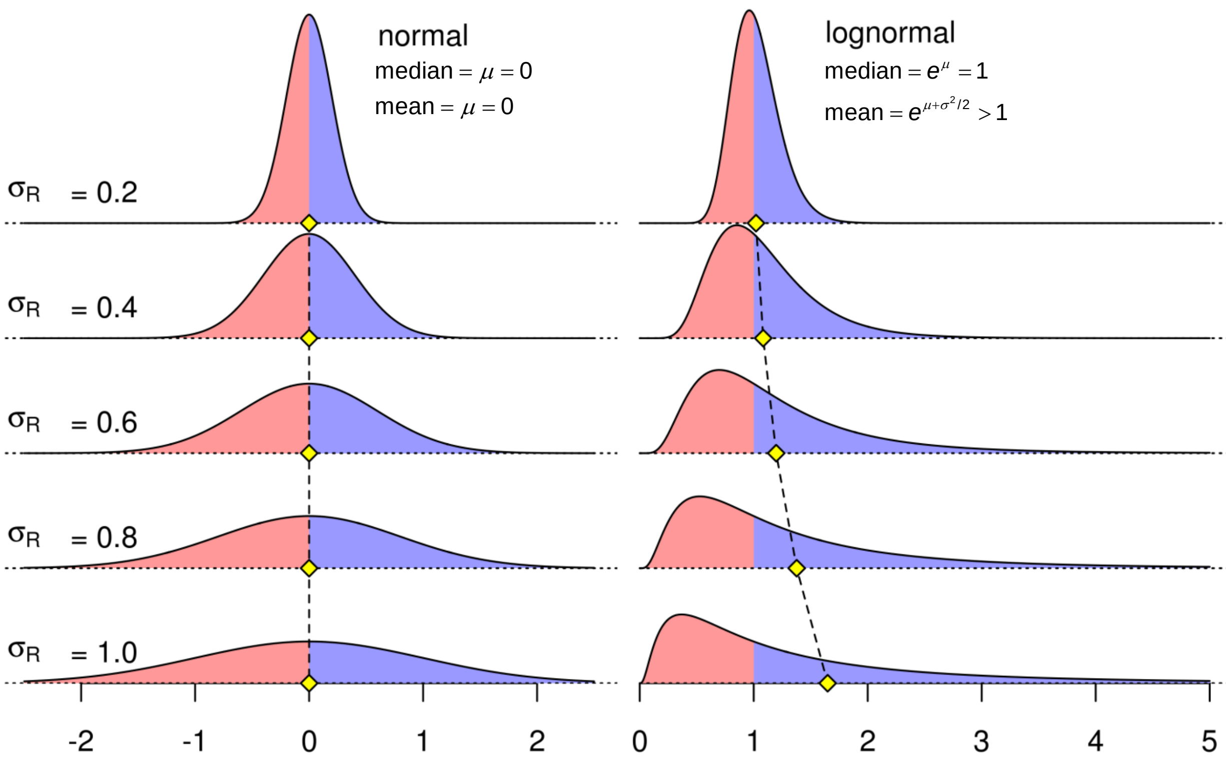


Figure 3-1 **Comparison of normal (left side) and lognormal distributions (right side) for different values of variability (σ_R) with dashed lines with diamonds connecting the means. Note that as the variability increases for a lognormal distribution, the mean increases.**

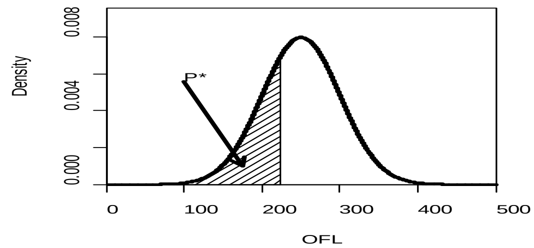


Figure 3-2 **Distribution for the OFL and the value for the ABC such that the probability that the ABC exceeds the OFL is P*.**

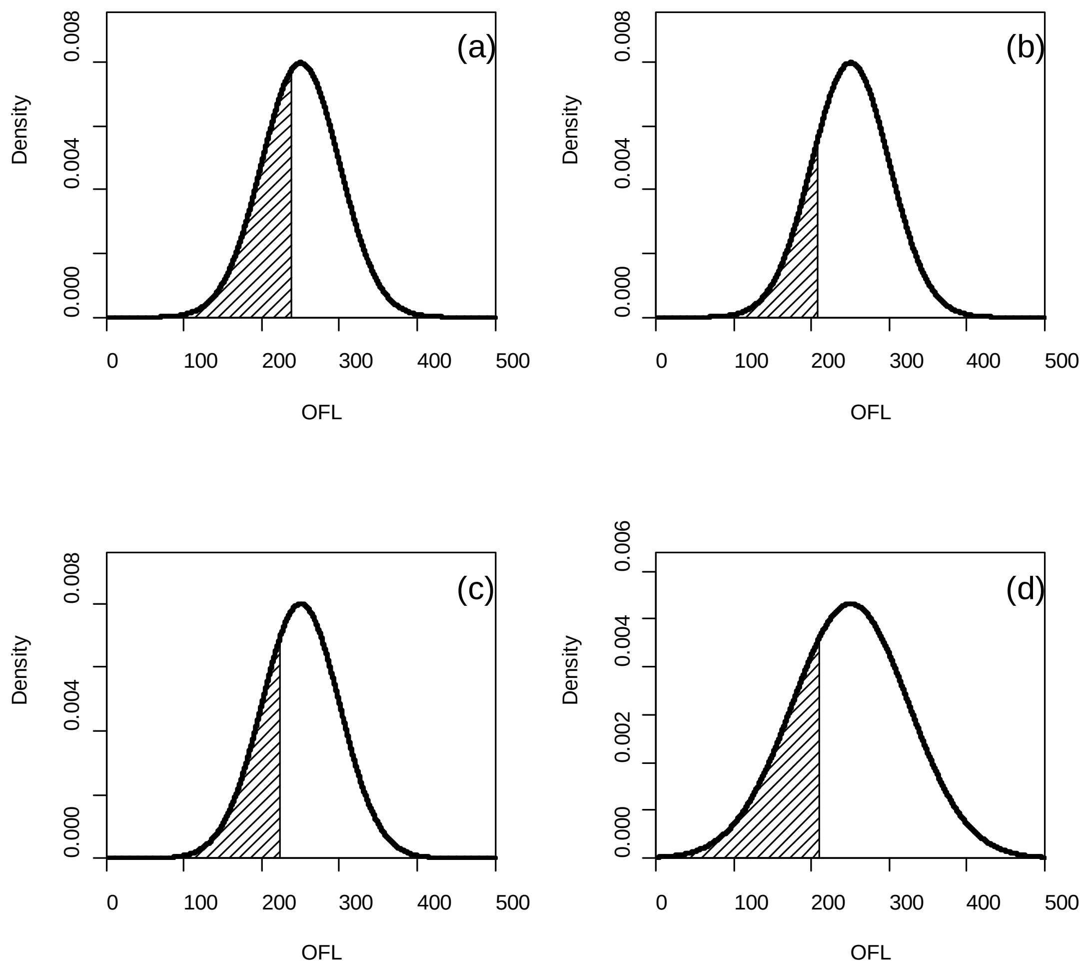


Figure 3-3 **Distributions of OFL, illustrating the impact of the choice of P* given a fixed level of uncertainty (upper panels) and the extent of uncertainty given a fixed value for P* (lower panels)**

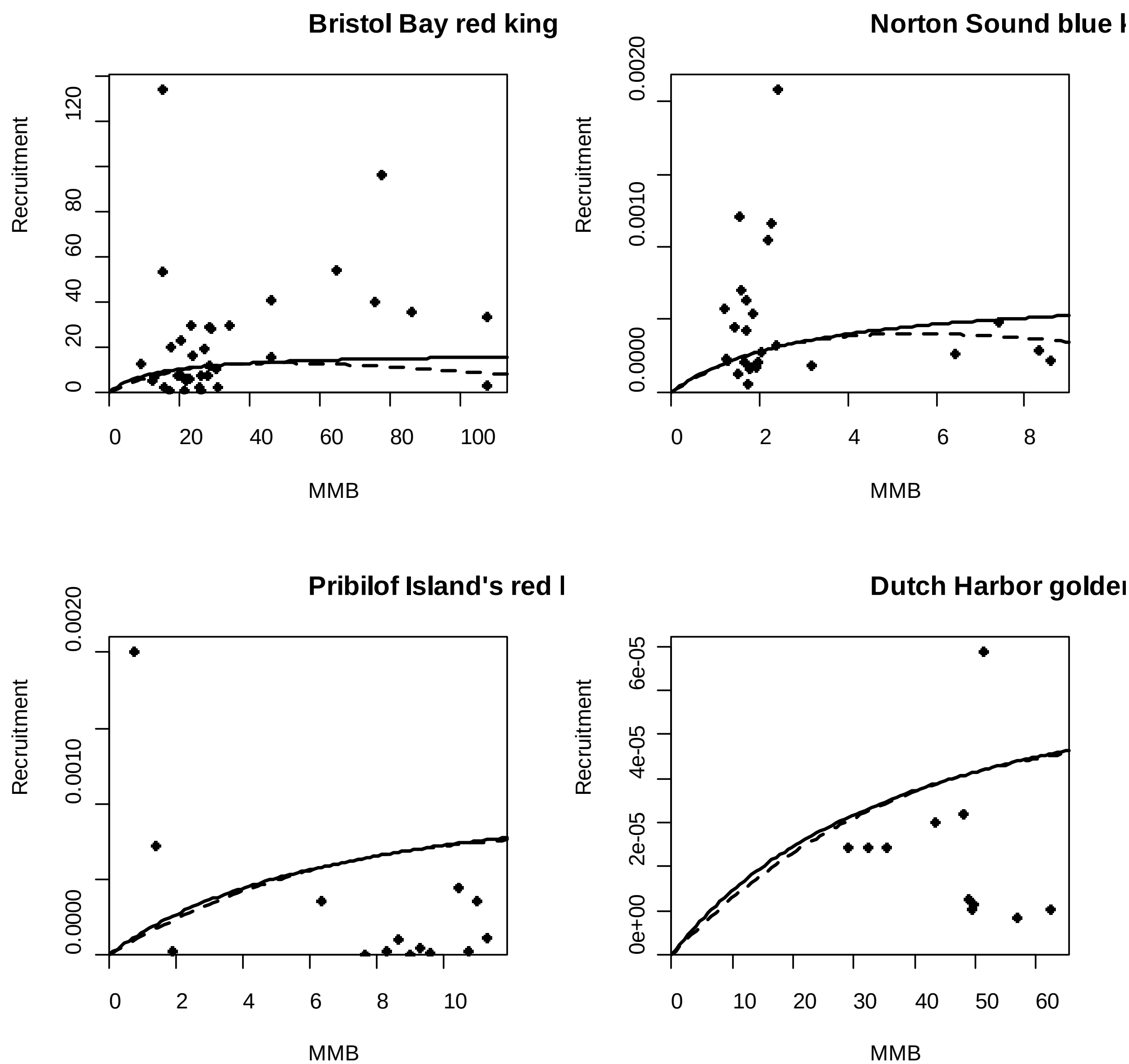

Bristol Bay red king
Recruitment
0 20 40 60 80 120
0 20 40 60 80 100
MMB
Norton Sound blue k
Recruitment
0.0000 0.0010 0.0020
0 2 4 6 8
MMB
Pribilof Island's red k
Recruitment
0.0000 0.0010 0.0020
0 2 4 6 8 10
MMB
Dutch Harbor golden
Recruitment
0e+00 2e-05 4e-05 6e-05
0 10 20 30 40 50 60
MMB

Figure 3-4 Fits of the Beverton-Holt (solid line) and Ricker (dashed lines) to the MMB and recruitment data for four of the ten stocks of BSAI crab.

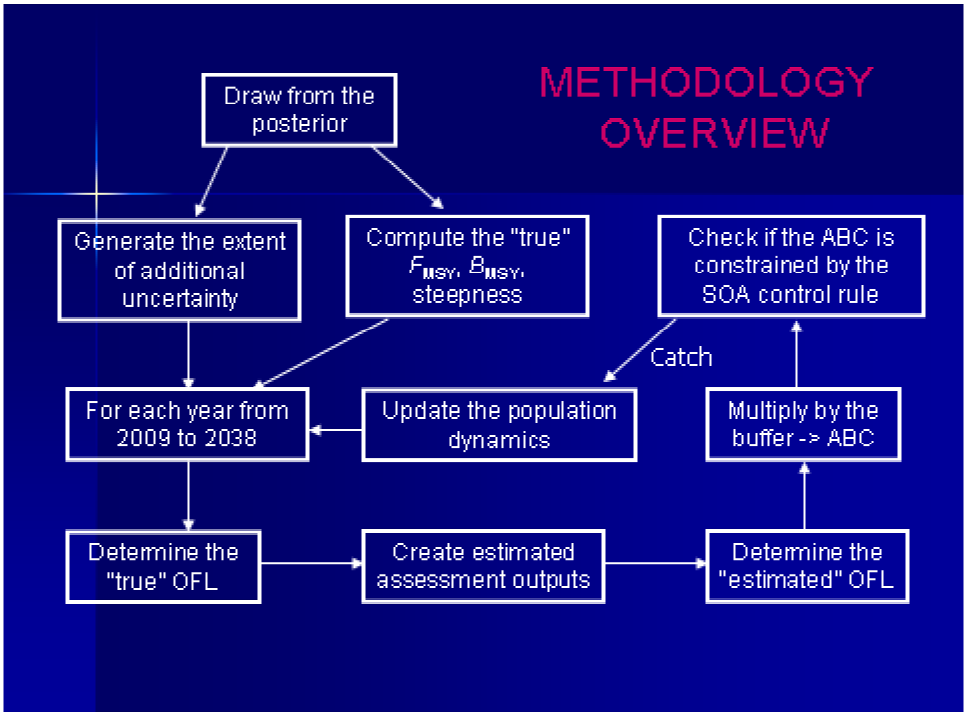


Figure 3-5 Flowchart of the algorithm used to evaluate the medium- and long-term implications of the alternatives. This step of checking whether the ABC is constrained by the SOA control rule is ignored if the SOA control rule is ignored for the projections.

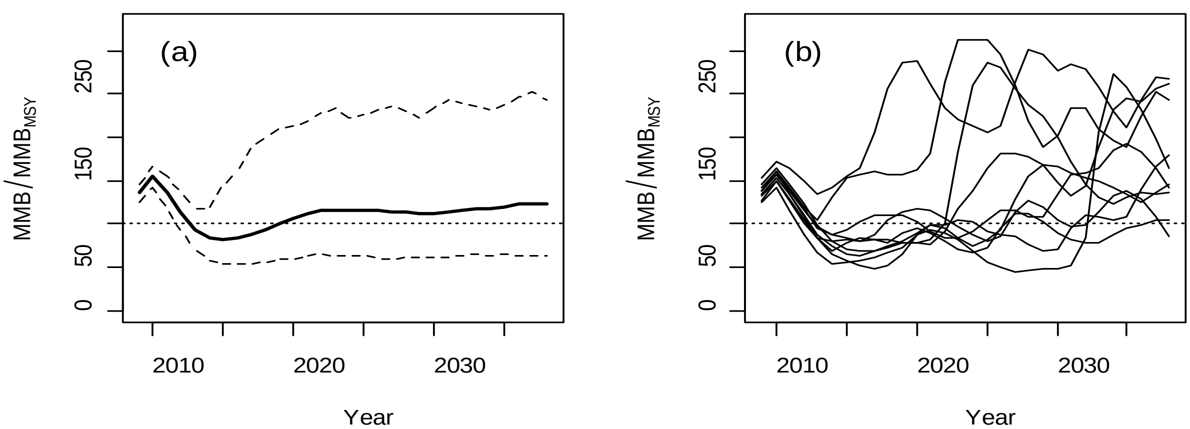


Figure 3-6 Time-trajectories of mature male biomass at mating relative to B35 (the proxy for BMSY) for Bristol Bay red king crab showing the median (solid line) and 90% intervals (dashed lines) (a), and time-trajectories of mature male biomass at mating relative to B35 for ten randomly-selected simulations.

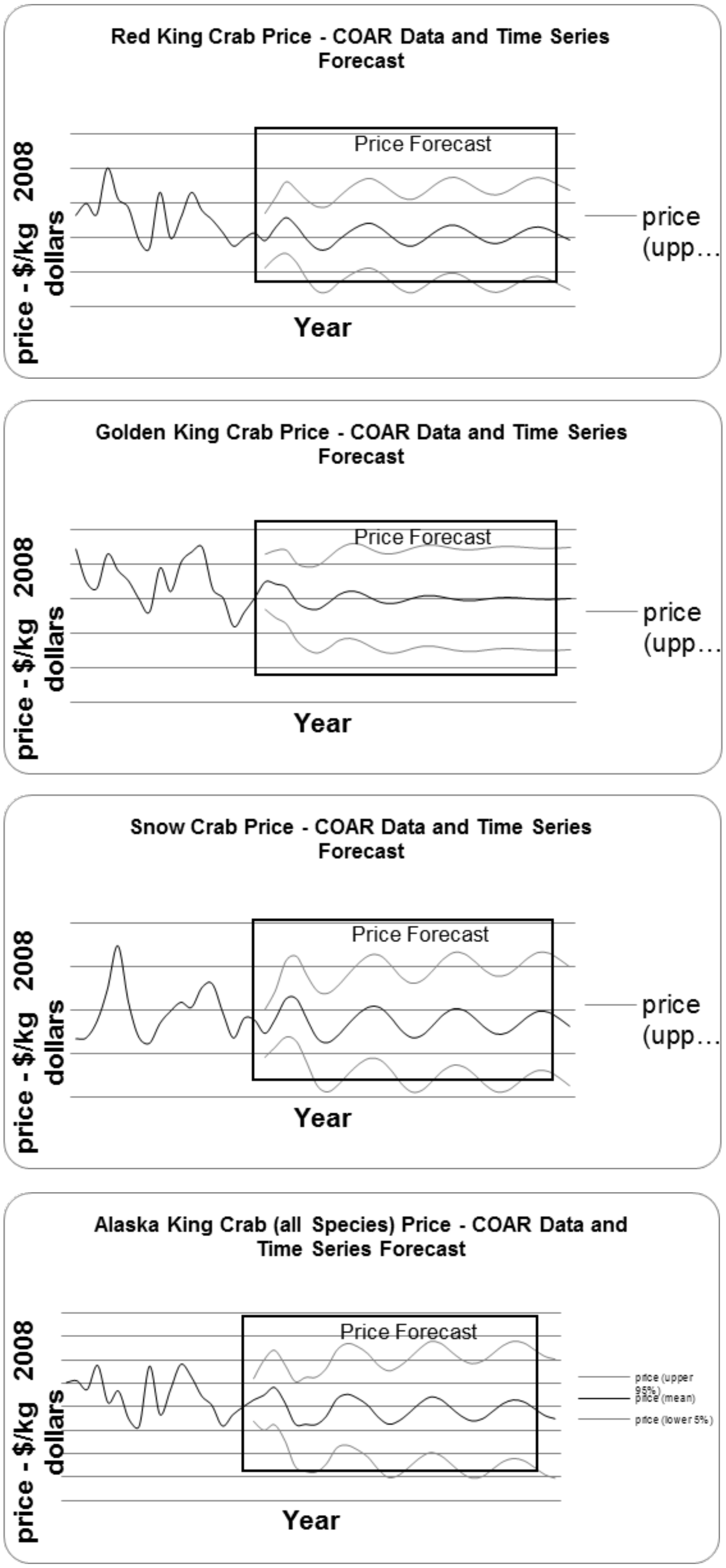


Figure 3-7 **Crab price data and forecast (mean and 90% confidence interval) values, Alaska king and snow crab COAR wholesale Price, 1991-2038. 2009-2038 values are forecasted using the VAR time series models.**

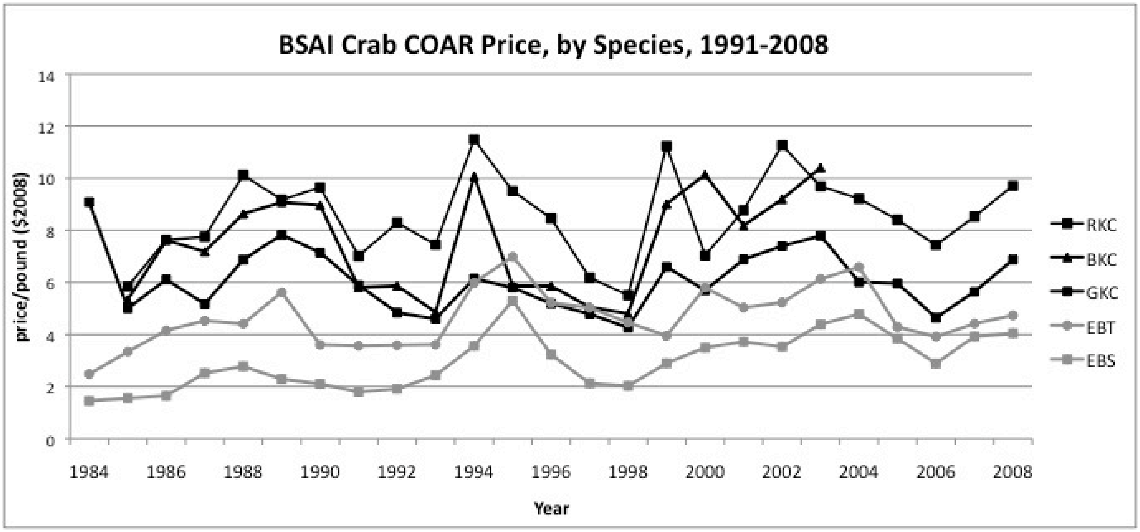


Figure 3-8 **Alaska Crab COAR Wholesale Price, by Species, 1991-2008. Source: Commercial Operators Annual Reports, Alaska Department of Fish & Game.**

4 Snow Crab

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. In the Bering Sea, snow crab are common at depths less than about 200 meters. The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population may extend into Russian waters to an unknown degree.

4.1 Assessment overview

The eastern Bering sea snow crab stock biomass is below its estimated B_{MSY} (139,200 t of mature male biomass at the time of mating (MMB)) with model estimated MMB having increased from 84.8 (1000t) in 2007/8 to 97.3 (1000t) in 2008/9 (Figure 4-1) snow crab was declared overfished in 1999 and a new harvest strategy implemented beginning in 2000/1 fishing season. The 10 year time frame of the rebuilding plan ended in 2009/10 with the stock not reaching the target biomass.

The most recent assessment of snow crab (Turnock and Rugolo 2010) is based on a sex- and size-structured population dynamics model which also considers the dynamics of maturity state[56]. The values for the parameters of this model are estimated using data on catch length-compositions, survey indices of biomass (survey selectivity either estimated or fixed in the model) as well as length-compositions from the surveys. The model is also fitted to discard length-frequency and catch biomass data and length-frequencies and catch biomass for the bycatch in the trawl fishery.

The most recent assessment of snow crab (Turnock and Rugolo 2010) includes various models that represent different survey selectivities and in some cases growth and natural mortality. Details of model scenarios and fits are in Turnock and Rugolo (2010). Results in this analysis are based on Model 5 that estimates survey selectivity using data collected in a select area of the Bering sea in 2009 using the standard survey net and a net assumed to have selectivity of 1.0, as an alternative survey. Model 5 estimates natural mortality for male crab at 0.29, and growth parameters with prior constraints.

The OFL for snow crab is currently based on the Tier 3 control rule, i.e. the proxy for F_{MSY} is taken to be $F_{35\%}$ while the proxy for B_{MSY} is taken to be $B_{35\%}$[57] (NPFMC, 2008). The OFL is a total-catch OFL and is computed as the sum of catches by four different sources of removals: (a) the retained males in directed (pot) fishery for snow crab, (b) discards of males and females in the directed fishery, and (c) bycatch in the trawl fishery.

The calculation of the OFL is based on the assumptions that the F_{OFL} is the F from the directed fishery for total males plus the F for males in the trawl fishery (full-selection fishing mortality). The future full-selection retained mortality of males in the directed fishery is given by the directed fishery component of the F_{OFL} multiplied by the fishery selectivity for retained males estimated from the assessment model. The future fishing mortality by the trawl fishery equals the average value over the last five years. Thus changes to F_{OFL} directly impact the predicted catches of retained males in the directed fishery as well as the predicted discard of males and females in the directed fishery, while the fishing mortality rates leading to bycatch in the trawl fisheries are constant and independent of $F_{OFL.}$

When compared to the OFL control rule, adopted as part of Amendment 24, the catches (Figure 4-2) and the fishing mortality rates (Figure 4-3) have, at times exceeded the OFL and F_{OFL}, respectively. This did

[56] The analyses of this chapter are based on an updated version of the assessment model. The results are therefore different than Turnock *et a*l. (2009).

[57] The biomass corresponding to $F_{35\%}$ and not 35% of the average unfished biomass.

not constitute overfishing in the past because Amendment 24 was only implemented in 2008. Moreover, the harvest strategy used to make recommendations for TACs has changed over time in response to changes in knowledge regarding the dynamics of the resource [see Appendix 4].

4.1.1 Uncertainty in stock assessment

The coefficient of variation for the estimate of mature male biomass from the assessment model for the most recent year is 8.5%. However, several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment. Several of the key parameters of the model (growth and natural mortality), are fixed in the model. Some of the parameters of growth and male natural mortality are estimated in the model, however with prior constraints. Survey catchability is estimated in the model.

F_{msy} is assumed to be equal to $F_{35\%}$ when applying the OFL control rule. B_{msy} is assumed to be equal to $B_{35\%}$ with average recruitment corresponding to MSY calculated over the years 1978-2009.

For snow crab, additional uncertainty is thought to be low, given the relative amount of information available for snow crab. This analysis uses the additional standard deviation on the log scale of 0.2 to quantify this low level of additional uncertainty, which is the value recommended by the CPT and SSC. This analysis of the short-term implications includes results for a σ_b of 0, 0.4 and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different that 0.2. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

4.2 Impacts of alternatives

As described in Chapter 2, there are two alternatives under consideration for computing a total-catch ABC for snow crab: (a) the OFL can be multiplied by a pre-specified "multiplier" (Alternative 2); (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4).

The analyses of impacts in this chapter are based on the assumption that the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA harvest strategy (i.e. no sector-specific ACLs are implemented), that the ACL applies to all removals of snow crab (a total-catch ACL). The TAC computed using the SOA harvest strategy applies only to retained catch in the directed fishery. A total catch ACL can be computed from the output of the SOA harvest strategy (which pertains to the retained catch in the directed fishery) by adding the estimates of bycatch and discard in the directed fishery and the trawl fishery to the output from the SOA harvest strategy.

The short-, medium- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the multiplier value (shown as the result of application of the multiplier by the OFL) and P* on the ABC for the 2009/10 fishery, while the medium- and long-term implications are evaluated by projecting the population ahead 30 years[58] under the assumptions that the catch equals the lower of the ABC and the total catch corresponding to the TAC computed with the SOA harvest strategy (this is equivalent to assuming that the TAC is set equal to the component of the ABC which is estimated to consist of retained male crab caught by the directed fishery). Projections were also run without the SOA harvest strategy, where the

[58] 30 years is sufficiently long so the resource equilibrates close to the proxy for B_{MSY} under deterministic conditions (no fluctuations in recruitment about the assumed stock-recruitment relationship).

ABC (=ACL) was estimated from the OFL and multiplier alone. The effect of multipliers without the SOA may be different than with the SOA harvest strategy depending on how often the SOA harvest strategy restricts catch.

The medium-term implications are evaluated using the results of projections for the first 6 years of the projection period (2009-2014) while the long-term implications consider the implications of the entire 30-year projection period. The uncertainty associated with the long-term projections are necessarily higher than those associated with the short-term implications given that these projections rely on assumptions regarding the form of the stock-recruitment relationship, which is very uncertain for all crab stocks, including snow crab. The initial year retained catch (2009/10) is assumed to be equal to the TAC already set for that year and the total catch is estimated that corresponds to the retained catch plus discards in the directed fishery and the groundfish bycatch.

4.2.1 Short-term implications

The short-term implications focus on the size of the ABC for the 2009/10 fishing year. Given a one-year projection, it is not feasible to assess the biological implications of the choice of an alternative. These implications are addressed in Section 4.2.2.1 and 4.2.2.2. Table 4-1 lists the ABC values for the 2009/10 fishing year for each alternative, along with the corresponding estimate of the catch in the directed fishery. The probability of overfishing values are not based on projections, but simply a comparison of values randomly drawn from a log-normal distribution around the total OFL and retained catch distributions multiplied by the respective multiplier. The difference between ABC_{tot} and ABC_{dir} (retained catch) reflects the losses to discard in the directed fishery, and bycatch in groundfish trawl fisheries.

As expected, a lower multiplier leads to lower ABC levels and a lower probability that the ABC is less than the true (but unknown) OFL. However, future catches using projections for lower multipliers will be higher relative to multiplier = 1.0 than the values in Table 4-1 due to resulting higher levels of future biomass. For snow crab, the retained catch in 2009/10 was set at the TAC determined from the SOA harvest strategy (21,800t).

There is a linear relationship between the ABC and multiplier (Table 4-1a, Figure 4-4a) with the ABC set equal to the OFL for a multiplier of 1 and being 10% of the ABC for a multiplier of 0.1. The relationship between the multiplier and P* is, however, not simple linear proportionality (Table 4-1b, Figure 4-4b). Moreover, the impact of the (assumed) extent of additional variance is substantial given that the variability of the OFL estimated from the assessment is low (Figure 4-5). Specifically, the multiplier (and hence the ABC for 2009/10) gets smaller for the same value for P* as the value for σ_b (additional uncertainty not captured in the assessment) is increased. For example, the multiplier for a P* of 0.4 (40% probability that the ABC will exceed the true OFL) is 0.97 if there is no uncertainty that is not captured by the stock assessment, but decreases to 0.92, 0.85 and 0.71 if σ_b is 0.2, 0.4 or 0.6 (Table 4-1b-e; Figure 4-4b). The relationship between P* and the multiplier based on the OFL calculated for 2009/10 is given in the "P* (additional uncertainty)" column of Table 4-1a. This table also shows the 2009/2010 TAC in the ABC_{dir} column (21.08 kt). The analysis assumes that portion of the total catch ABC and the directed catch TAC will remain that same to account to bycatch. Thus, the directed catch portion decreases as the buffer size increases. The majority of bycatch for snow crab is from male crab in the directed fishery (8.3% of total catch) (Table 4-2), with groundfish fishery second (1.5%), female catch in the directed fishery is very small. The P* and buffer values for the snow crab harvest strategy were not calculated. Until the stock rebuilds, however, the harvest rate will not exceed 75% F_{OFL}, and may be lower. This suggests that buffer values below 0.25 would not constrain the catch in the short term.

4.2.2 Medium- and long-term implications

Table 4-3 lists summaries of the key parameters which determine the productivity of the population for the Beverton-Holt stock-recruitment relationships and the six model scenarios. Note that B_{35} is not 35% of the unfished mature male biomass at mating. This is because recruitment is not independent of mature male biomass at mating. The extent of uncertainty captured within the stock assessment (estimated by the ADMB software), σ_w, is 0.085. The Beverton-Holt SR curve estimated using Fmsy=F35% and Bmsy = B35% compared to estimated recruits and MMB at mating is shown in Figure 4-6.

4.2.2.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized by the projected values for the ABC (which includes all sources of catch), ABC_{tot}, the output of the State of Alaska harvest strategy (which pertains to retained catches in the directed fishery), SOA, the retained catch in the directed fishery (which is the lower of the retained directed component of the ABC and the SOA retained catch), C_{dir}, percent mature male biomass at the time of mating relative to $B_{35\%}$ and the probability of overfishing occurring. Results are shown in Table 4-4 for analyses based on the Beverton-Holt stock-recruitment relationship, for additional uncertainty 0.2, and for four multiplier levels (1.0, 0.8, 0.6 and 0.4).

The SOA harvest strategy would restrict the retained catch in the directed fishery in the short term until the multiplier is less than about 0.1 to 0.6 (Table 4-4a through Table 4-4h). The impacts of Alternative 4 would be similar to the impacts shown in Table 4-4a for the multiplier of 1 under the SOA control rule. The probability of overfishing[59] is low with the SOA harvest strategy due to the change in the assessment model in 2010 which estimates higher $F_{35\%}$ and lower $B_{35\%}$ than previous assessments. The results of the medium-term projections are not sensitive to whether the stock-recruitment relationship is correct, primarily because the projections over the first six years do not depend greatly on the amount of recruitment generated from the recruitment curve. In terms of the probability of overfishing and the probability of the stock becoming overfished, Alternative 4, with the SOA harvest strategy, compares to a P* value of 0.05 or multipliers of 0.4 to 0.6.

Table 4-4e - Table 4-4h show 6 years projections for multipliers of 1.0, 0.8, 0.6 and 0.4 with additional uncertainty 0.2 similar to Table 4-4a-d, however, with no SOA harvest strategy (SOA column is 0). The retained catch in the directed fishery is greater and MMB lower for projections without the SOA harvest strategy. Catch in 2010/11 is fixed for all multipliers at 75% F35%. Catch and MMB are similar with and without the SOA harvest strategy for a multiplier of 0.8. The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) is higher for the projections without the SOA harvest strategy.

The multipliers range from 0.70 to 0.96 for P* values from 0.1 to 0.4 (Tables 4-4i-k with SOA and Tables 4-4l-p without SOA). The reduction in retained catch ranged from 7% to 14% in the first few years of the projection between P* = 0.4 and P* = 0.1. The multipliers corresponding to the P* values were determined from projections without the SOA harvest strategy. The results with the SOA harvest strategy for each P* have the same multiplier values as the projections without the SOA harvest strategy. The State of Alaska harvest strategy produces catches roughly equivalent to catch levels that correspond to a P* value of 0.1.

[59] The probability of overfishing is the probability that the total catch exceeds the OFL.

4.2.2.2 Long-term implications - Biological

Table 4-5 summarizes the results of the 30-year projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"),(b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B") (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of retained catch being determined by the SOA control rule (column "Prob (SOA)"), and (e) the median and 90% intervals for the catch of retained males by the directed fishery in the last year of the projection period.

The probability of overfished is higher and the probability of overfishing is higher without the SOA strategy for the same multiplier compared to results with the SOA strategy. Retained catches are similar at multipliers from 0.6 (51.2 to 53.0 (1000t)) without SOA. Retained catches are only about 6% lower with the SOA strategy at a Multiplier of 1.0 in the long term due to higher average biomass levels with lower fishing mortality with the SOA harvest strategy. The impacts of Alternative 4 are indistinguishable from the impacts under the SOA control rule. At lower multipliers the difference in median retained catches is less than at a multiplier of 1.0 (< 6% difference). A lower multiplier is needed without the SOA strategy to achieve the same probability of overfishing when the multiplier is combined with the SOA strategy.

Figure 4-7 shows the time-trajectories of retained catch and percent mature male biomass at mating relative to B_{35} for two illustrative choices for the multiplier (1; ABC= 1.0 OFL; 0.6; the ABC =0.6 OFL) for the Beverton-Holt stock-recruitment relationship. As expected, the mature male biomass is larger when the multiplier is lower. As noted above the mature male biomass is fairly flat over the early years of the projection period because of relatively low or average recruitment estimates in the last few years.

Figure 4-8 illustrates the differences among the 10 multipliers and the P* values (0.05 to 0.45) in terms of the median time-trajectory of percent mature male biomass at mating relative to B_{MSY} and the median time-trajectory of the catch of retained males in the directed fishery with the SOA harvest strategy (Figure 4-9 without SOA harvest strategy). The percent mature male biomass relative to B_{MSY} increases essentially continuously with changes in the multiplier. The rate at which catch drops with increasing multiplier sizes is, however, not the same as that at which biomass increases (Figure 4-8 and Figure 4-9; Table 4-4 and Table 4-5) with very little difference in the catch in 2038 for multipliers between 0.7 and 1.0 (Beverton-Holt) (Table 4-5). The multipliers for P* from 0.05 to 0.5 were between 0.622 and 1.0, resulting in less difference in catch and percent MMB at mating relative to Bmsy than the range of multipliers shown in Figure 4-8 and Figure 4-9.

The catch is constrained most of the time by the SOA harvest strategy for the multipliers greater than 0.6. There is a 72% to 100% probability that the retained-directed component of ABC is larger than the SOA harvest strategy for a multiplier of 0.6 to 1.0 (Table 4-5). The probability of overfishing is less low with the SOA harvest strategy due to the higher F35% value in the current (2010) assessment model relative to the SOA harvest strategy which was based on a lower F reference point (Table 4-5).

The current analyses are unable to predict whether the uncertainty in terminal biomass will change over time (the next 30 years) nor whether estimates of the extent of uncertainty not captured by the assessment will change over time. The results in Table 4-5 and Figure 4-8 and Figure 4-9 are based on pre-specified multipliers. There is, however, a direct relationship between multiplier values and choices for P* under the assumption that estimates of σ_b and σ_w do not change over time (Table 4-5). The results in Table 4-5 provide a basis to evaluate different choices for P*. For example a P* equal to 0.3 corresponds to a multiplier of 0.885, if uncertainty were estimated to be less in the future, then a higher multiplier would result in a P* of 0.3.

4.2.2.3 Medium- and Long-term implications - Economic

The medium and long-term impacts of ACL alternatives are summarized in Table 4-4 and Table 4-5. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term. Table 4-6 (a) and (b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to a zero buffer. For snow crab, uncertainty was fixed at σ=0.2 (note that stocks simulation results for σ=0 were not produced for snow crab).

Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC, (Table 4-6(a)) and scenarios without the SOA control rule (Table 4-6 (b)). With the SOA control rule, results for P* values, with σ_b= 0.2, show minimal foregone revenue relative to a zero buffer (P*=0.5, multiplier = 1). The estimate of total potential foregone revenues for the six years ranges from 1% to 6%, for multiplier levels 0.6 to 0.4. This reflects the fact that SOA control rule constraints are more limiting than the ABC at higher multiplier levels. Results of economic comparisons between P* values and multiplies resulting from catch projections without SOA constraints (which means assuming catch = ABC) are shown in Table 4-6 (b). The reduction in revenue from a zero buffer ranges from 6% at a multiplier of 0.8 to 25% at a multiplier of 0.4. While the SOA control rule remains in effect as the protocol for TAC-setting, the potential foregone revenues that could result from the P* values or multipliers would increase substantially relative to a zero buffer if the ABC was the binding constraint on TAC rather than the SOA control rule. Note that a zero buffer does not represent the status quo alternative, but is intended to provide a representation of the effects of P* values and multipliers under potential future decision-making scenarios when the SOA control rule is not binding. It should be noted that this comparison shows that the SOA rule effectively represents a buffer in itself.

Economic results of ACL alternatives over the long term (2009-2038) are represented in Table 4-7 (a) and (b). With the SOA control rule as a binding constraint, P* values and multipliers have a modest effect on revenues at higher multiplier levels and only result in substantial revenue losses at multiplier levels lower than 0.5. As with the mid-term results, the relative effects of the P* values and multipliers are more pronounced when the effective constraint of the SOA rule is removed from the analysis. It should be noted that the relative economic effects of the ACLs are not qualitatively different between the mid- and long-term, nor do alternative discount rates appreciably change the relative ranking of alternatives in terms of economic outcomes. This is largely due to the effect of the constancy of the buffer in the model projections, in both the buffer and P* scenarios. None of the alternatives under consideration implement different buffers over time according to stock conditions, and thus the timing of relative economic benefits from the fishery across the time horizon are not appreciably different under the alternatives analyzed.

4.2.3 Rebuilding Implications

The multipliers and rebuilding years for each Action 2 alternative and option described in Chapter 2 are shown in Table 4-8. Projections from 2009 to 2020/21 for each alternative and option are in Table 4-9a-g. The projections switch to a multiplier of 0.8 (as an example ABC) after MMB at mating after the stock is rebuilt for evaluation of catch and revenue. All Alternatives fish at 75% F35% in 2010/11. Alternative 2 determines Tmin (2012/13), the year when the probability of rebuilding (1 year above B35%) is greater than or equal to 50%. Tend (2014/15) is the year when greater than or equal to 50% of rebuilding is achieved fishing at an F of 75% F35% control rule (Alternatives 1 and 4). Alternative 3 is determined by setting Ttarget at one year greater than Tmin. There is only one alternative (at 2013/14) between Tmin (2012/13) and Tend (2014/15). Alternative 3 (Ttarget 2013/14) the multiplier is 0.42. Option 2 increases the probability of rebuilding to 75% by Ttarget resulting in multipliers of 0.15 and 0.47 for Alternative 3 and Alternative 4 respectively. Option 3 increases the probability of rebuilding to 90% by Ttarget resulting in multipliers of 0.03 and 0.22 for Alternative 3 and Alternative 4 respectively. Option 1 increases Tend to 8 years (2019/20) while continuing to fish at a multiplier of 0.75 which achieves 86% probability of rebuilding in 2019/20.

The probability of rebuilding by year and multipliers from 0.75 to 0.0 are shown in Figure 4-10 and Figure 4-11.

The economic effects of rebuilding alternatives are presented in Table 4-6 and Figure 4-13and Figure 4-14. Revenue forecasts and analytical methods applied to ACL alternatives as described Section 3.5 were used in the analysis of snow crab rebuilding alternatives. Using price forecasts and stocks projections, probabilistic estimates were produced to portray the economic value of retained catch forecasts produced from the stock assessment model. Economic value of forecasted snow crab retained catch values shown in Table 4-6 is presented for five, ten, and fifteen year periods, under three alternative discount rates (r=0.0%, 2.7%, and 7.0%) and under one- and two-year definitions of rebuilt.

In addition to the no action alternative, Alternatives 4-(T_{END}) and Alternative 4, Option 1 result in no reductions in catch and production, and therefore have no effect on revenue. In contrast, Alternative 2 rebuilds the stock in the shortest time possible, with near-term restrictions to the fishery resulting in nearly 25% loss in gross revenue over the first five years. Over the longer term, differences between the alternatives are dampened, particularly if a one year definition of rebuilt is applied. As shown in Figure 4-13, the effect of discounting is somewhat pronounced over the longer (15 year) period, where elevated biomass produced over the 15 year period as a result of more rapid rebuilding reflected in positive net gains relative to the no-action alternative stock in the case of zero discount rate. Higher discount rates place greater emphasis on revenue foregone in the short term.

4.2.3.1 Community-level economic impacts of rebuilding

This section provides an overview of the potential socioeconomic effects of Bering Sea snow crab rebuilding alternatives, particularly in the early years of the various rebuilding alternatives. This section identifies the range of fishery participants that may be affected and the likely effects. Quantification of socioeconomic effects is limited by available data and constricted by the lack of an economic impact model (e.g. input-output model) for crab. Thus, this section will provide qualitative discussion of the likely impacts of the various rebuilding alternatives. It should be understood; however, that this treatment is not intended to determine effects in terms of net economic welfare as the necessary data for conducting a formal economic welfare analysis is not available.

This discussion of the social and economic implications of the Bering Sea snow crab rebuilding plan alternatives rely on several documents that have been prepared in the past several years. Critically important to this discussion is the three year program review completed in September of 2008. In addition to the comprehensive overview of the program, the three year review contains a social impact assessment appendix that provided detailed information for several potentially affected fishery dependent communities. To understand the scope of potential impacts the reader is directed to the review and its social impact appendix, which are incorporated here by reference. In addition, this discussion relies on the 2009 Economic Status Report (Garber-Yonts and Lee 2010) for BSAI crab that is appended to the annual Crab SAFE. Further, two relatively recent documents provide considerable treatment of baseline socioeconomic conditions in potentially affected Alaska fishing communities. The first of these is the Socioeconomic Baseline Information for the Pribilof Islands, which was commissioned by the North

Pacific Research Board and completed in 2007 by a team lead by Ecotrust. The second is the Comprehensive Baseline Commercial Fishing Community Profiles: Unalaska, Akutan, King Cove and Kodiak, Alaska which was commissioned by the North Pacific Research Board and the Council and completed in 2005 by EDAW, Inc, and Northern Economics, Inc. Both of these volumes offer much greater coverage of the underlying baseline conditions in fishing dependent communities than is permitted by the scope of this discussion and they are, therefore, also incorporated herein by reference.

Analysis of Annual Revenue Projections by Alternative

Annual catch data is displayed in Tables 7 and 8 and Figure 3 in Chapter 4 as directed catch estimates and is also displayed as short, medium, and long term revenue projections in Table 4-10 (see Table 4-10c). This discussion presents the underlying annual revenue estimates, not presented previously, in order to identify comparative impacts of the alternatives on an annual basis, and in the short term. This discussion highlights constraining aspects of the alternatives in the early years of the rebuilding plan as opposed to the view of the short, medium, and long range summations of revenue presented previously. In this way, one may discern whether the alternative in question is likely to have adverse socioeconomic consequences that may be somewhat obscured by net present value calculations at five, ten, and 15 year increments.

Table 4-11 presents the underlying annual revenue estimates for the ten year rebuilding analysis, with r=0%, and with a one year rebuilding definition as identified by the Council as the preliminary preferred definition. These estimates are associated with the total present value estimates presented previously in Table 4-10c (see errata). This information is presented graphically in Figure 4-1. Note that with r=0%, this discussion omits the effects of discounting in order to focus on changes in base revenue estimates of the alternatives and options. The effects of discounting on the total net present value estimates in the longer term are treated earlier in this chapter but will be highlighted here as well.

The annual revenue estimates reveal that Alternative 2 is the most constraining of the Alternatives in that it rebuilds the snow crab stock in the least amount of time by halting directed fishing for three years. Under Alternative 2, no revenue is earned for three years; however, in the fourth year of rebuilding revenue is projected to be approximately $359 million. Thus, Alternative 2 would be the most impacting of the Alternatives, in the near term, on fishery participants and dependent communities.

The impacts associated with the other alternatives order by the length of time to rebuild and the rebuilding probability. Alternative 3, Option 3, rebuilds in three years with a 90% probability and is thus slightly less constraining than Alternative 2 in the early years of the rebuilding plan. Alternative 3, Option 2, rebuilds in three years with a 75% probability and is thus slightly less constraining than Alternative 3, Option 3 (Note that Option 1 (70%) was functionally equivalent to Option 2 (75%)). Alternative 3 without the options would rebuild in three years at 50% probability and is the least constraining of the Alternative 3 scenarios. Note, however, that Alternative 4 with Option 3 is more constraining than Alternative 3. This is due to the increased probability of rebuilding even though rebuilding occurs a year later. Alternative 4, Option 2 and Alternative 3 are relatively similar in their effect on revenue in the near term.

Finally, Alternative 1, Alternative 4, and Alternative 4 with Option 1 all modeled with the same revenue projections. These alternative scenarios allow for longer rebuilding thus providing more directed catch in the first several years than any of the other, more constraining, alternatives. Of note; however, is that Alternative 4 with Option 1 would rebuild in four years at a 70% probability while still allowing directed catch, and revenue, consistent with the status quo. Further, by 2017, all alternatives would provide for estimated revenue that is within 5% of $400 million. The inherent tradeoff is the longer length of time to rebuild and that once rebuilding has occurred catch and revenue would not be as large as estimated for the other, more constraining in early years of the rebuilding plan, alternatives. Figure 4-15 provides a graphical depiction of the rank of each alternative and option and clearly demonstrates these tradeoffs in the early years, the point where they are most similar in 2017, and that future revenue from 2017 forward is highest among the most constraining alternatives. Evaluation of the total economic effect over time of these tradeoffs is best done using the net present value estimates provided in table 4-10.

Table 4-10a provides the five-year estimates of total present value of revenue by Alternative and Option with a one year rebuilding definition. One can see that Alternative 2, which shuts the fishery down for three years, would result in a reduction of $250 million in total over five years. Despite a three year closure, this impact is only 21% of the estimated status quo revenue because revenue increases dramatically in the last two years of this time frame. The next most constraining scenarios are Alternative 3 with options 2 and 3, which have similar total impacts over five years. As discussed above, each of these Alternative 3 scenarios do allow for directed harvest in the first three years. Alternative 3 allows for some harvest while rebuilding over three years, at 50% probability, and generates $151 million in forgone total revenue, or about 11% of the status quo projection.

Table 4-10c provides the ten-year estimates of total present value of revenue by Alternative and Option with a one year rebuilding definition. By 2021, the benefits of greater harvest in later years of the rebuilding plan, associated with alternatives and options that rebuild earlier and/or with greater probability, effectively reduce the overall percentages of non-discounted revenue to 4% or less of status quo revenue when summed over ten years. Applying discounting elevates those percentages as the discount rate increases to as much as 8% (Alt. 2, Alt. 3 option 2) of total revenue, which reflects the economic reality that receiving revenue later in time, rather than sooner, is economically less advantageous and thus future revenue is “discounted” in the calculation of net present value.

As shown in Table 4-11and Figure 4-15, the stream of future revenue is projected to decline from highs clustered around $450 million in 2019 to between $316 million and $337 million, depending on alternative and option, by 2021. Thus, by comparing the annual data presented above with the total present value data of table 4-10 one can see that the most constraining alternatives could have severe consequences on near term harvests and thereby on fishery participants and dependent communities but that the total present value calculations at five and ten years somewhat mask those near term impacts. Now that the potential for near term socioeconomic impacts has been identified, with the annual analysis, it is necessary to characterize the types of impacts that might occur and to whom they may accrue.

Potentially Affected Parties

The rebuilding plan alternatives affect the TAC and thereby the directed snow crab catch. Since allocation of Directed Catch is determined by quota share holdings, the alternatives would directly affect holders of all classes of quota share (A, B, and C), processor shares, as well as CDQ organizations and those who fish the CDQ allocations. Impacts to individual operators would be a percentage change in their allocated poundage, under the program, that is equal to the overall percentage change in Directed Catch. In other words, everyone bears the same burden in percentage terms and total direct affect on any particular quota share holders is dependent on their proportion held of the total quota share. In this case, processors who hold class A shares that are matched to harvester class A shares also would see a direct effect from changes in allocation of Directed Catch under the program. Since revenue is shared among vessel owners, quota share holders, captains, and crew, affects on total revenue, and thereby shared revenue payments to labor could also be considered a direct effect.

There are several identifiable indirect effects to be considered. Changes in payments to labor would then affect expenditures by crew in landing ports and in their place of residence. In addition to direct effects on processors with matched shares there may also be indirect effects of changes in receipt of non-matched quota share landings via changes in those allocations and possibly through redistribution of landings. These changes in the quantity of crab delivered for processing can then have indirect effects on the numbers of processing plant workers hired during the first several months of the year with associated implications for processor worker wages, local expenditures by processing workers, as well as remittances of wages to primary residences supported by processing workers who are working away from home. In the worst case, a three year fishery closure, it is obvious that impacts to potentially affected parties could be substantial.

Relative dependence on snow crab

In the South regional allocation area processors also process other crab, groundfish, as well as IFQ Halibut and Sablefish. The 2009 Groundfish Economic SAFE (Hiatt et al. 2009 table 35, page 70) indicates that the Being Sea Pollock processors, which include AFA shoreside processors operating in King Cove, Akutan, Sand Point, Dutch Harbor, and two floating processors earned nearly 84% of their all species combined gross revenue from groundfish processing in 2008. In these communities groundfish processing provides the majority of first wholesale processor revenue and changes in Bering Sea snow crab Directed Catch and deliveries to these communities, though having effects on processor earnings, crew wages, municipal finance, and community structure, are less likely to threaten the viability of processing operations.

In the North region, where a shore plant and a floating processor receive deliveries of nearly half of the Bering Sea snow crab quota, and a small share of the Bristol Bay Red King Crab quota, diversification into groundfish processing does not exist within the community of Saint Paul. Saint Paul is heavily dependent on the Bering Sea snow crab fishery and only receives between $1 and $2 million worth of Halibut landings from area 4C and 4D halibut IFQ (Sholtz et. al, 2007). Actual halibut landings are confidential due to the existence of a single processing plant. The plant in Saint Paul does not process groundfish. Thus, the Bering Sea snow crab fishery is critical to the operation of the processing plant in Saint Paul and is the primary source of processor wages earned in the community as well. The plant is also critical to the processing of Halibut, and Saint Paul Mayor Simeon Swetzof Jr., writing in an opinion article in the Alaska Journal of Commerce stated:

> "The local halibut fishery, in which many local fishermen are engaged, also depends on crab processing. Without the levels of crab processing guaranteed by regionalization, the processors would have closed their facilities a long time ago. This would have left local fishermen with no place to deliver their halibut."

Municipal Finance and Provision of Services

Many fisheries dependent communities rely on fisheries taxes and/or sales taxes for a substantial portion of their annual operating budget. Thus, reductions in landings will result in reductions in such tax revenue although future increases in landings, as stock rebuild, will result in improved tax collections in later years of the rebuilding plan. In the South allocation region the City of Unalaska levies a 2% raw fish tax, and a 3% sales tax, the latter of which is largely derived from fisheries related services (Kelty, Frank: Personal Communication, August 24, 2010). In contrast, Akutan and Sand Point do not levy sales or fish taxes. King Cove levies a 4% sales tax and flat rate fisheries impact tax. In addition, the Aleutians East Borough levies a 2% raw fish tax. In the North region, Saint Paul levies 3% sales and 3% raw fish taxes, while Saint George levies neither a sales or raw fish tax. In addition, the State of Alaska levies a Fisheries Business Tax that is shared with municipalities that demonstrate fishery related impacts.

The City of Unalaska, for example, earned more than $620,000 in local raw fish tax revenue from snow crab landings in 2009. This tax revenue is in excess of 60 percent of the raw fish tax earned by Unalaska from shoreside landings of Pollock. Clearly the loss of this revenue, or a substantial reduction in it, would impact city service provision. Also important to recognize is that the City of Unalaska also depends heavily on sales taxes, nearly all of which are tied directly to fishery related purchases. In addition, the Port of Dutch Harbor would likely have reduced moorage, wharfage, and tariff collections, which would impact the provision of port services. Thus, snow crab fishery closure, or severe harvest restrictions, would place a considerable burden on the City of Unalaska and would likely lead to a reduction in services the city is presently able to provide (Frank Kelty, personal comm.). This would also be true of Saint Paul, with similar tax collections likely to be put at risk given that the north and south allocations are similar; however, tax collections on snow crab for Saint Paul are confidential. A substantial difference; however, between Saint Paul and Unalaska is that Unalaska has a more diversified fisheries based economy and would continue to collect tax revenue related to other fisheries such as groundfish and other crab species. Saint Paul would have to rely on the relatively small halibut fishery as its primary source of fishery related revenue were the snow crab fishery to be closed or severely limited under rebuilding alternatives such as Alternatives 2 and 3.

Payments to Labor

The 2010 BSAI Crab SAFE Economic Status Report presents statistics on economic activity from 1998 to 2008 in the rationalized crab fisheries of the BSAI. Statistics on harvesting and processing activity, revenue, labor employment, labor compensation, fixed and variable costs, and quota usage and disposition among participants in these fisheries are provided. The primary source of data for these statistics is the crab Economic Data Report (EDR), which has been administered for the calendar years 1998, 2001, 2004, and 2005-2009. Table 11 on page 52 of the draft report provides crew and captain share payments for catcher vessels and indicates that total crew share payments in the Bering Sea snow crab fishery exceeded $15 million and Captain's share payments exceeded an additional $7 million in 2008. Another $1.38 million and $490,000 were earned by crew and captains, respectively, on catcher processors in 2008. There were a total of approximately 560 captain and crew position in the Bering Sea snow crab fishery in 2008 (Table 13, page 54). Tables 16 through 19, on pages 58 through 61, further indicate that processing wages from all sources combined were in excess of $9.3 million in 2008 and that more than 900 processing jobs existed in the Bering Sea snow crab fishery.

Clearly, closure of the fishery (Alternative 2) for three years would mean that all of these positions and associated payments to labor would be forgone for that period of time. It is true that the in the fourth rebuilding year, following the closures, harvest increases dramatically and so too would crew and processing wages. However, it is also possible that some crew and processing workers may leave the fishery during the three years of the closure if they do not make adequate income from other fisheries. The potential effects of the other alternatives on payments to labor are difficult to predict as these alternatives may affect fleet size, crew sizes, and the large contraction in snow crab in the global market may have price impacts that could increase the value of the crab that is landed. What is important to recognize; however, is that the more constraining alternatives (Alt.2, Alt 3, Option 3, etc) will have impacts on payments to labor in the near term and while some of those losses may be made up in later years via larger harvests, there would likely be substantial near term impacts on payments to labor.

Fleet Consolidation and Business Viability

Since implementation of the Crab Rationalization Program there has been considerable consolidation within the snow crab fleet. Under a rebuilding alternative that closes, or severely restricts harvests for several years, some operations may struggle to meet debt obligations without revenue from the snow crab fishery. This could lead to additional consolidation. In the extreme case of the rebuilding alternatives where no directed catch is allowed for several years early in the rebuilding period, there may be severe consequences for both processing and harvesting entities. Most businesses that must invest in highly valued capital operate under credit instruments that provide needed cash flow and may have substantial loan financed debt. A complete closure of the Bering Sea snow crab fishery, or a severe restriction in harvests for the early period of a rebuilding alternative, would eliminate or severely restrict operating revenue from snow crab. If a harvesting or processing operation is highly dependent on snow crab revenue they may have difficulty maintaining their credit and dept instruments and could be forced to refinance, which may not be possible for some entities and such a situation could lead to business sale and/or bankruptcy. The potential that the most extreme case of business failure could occur is greatest with Alternative 2, which closes the fishery for three years, but could also be possible with Alternative 3 and its various options. The extent to which such impacts on business operations may be realized is impossible to evaluate given the proprietary nature of business finance information. However, it is a necessary consideration when evaluating the various rebuilding options and is most likely in the case of the Saint Paul processing operation given its nearly total dependence on snow crab.

Summary of Potential Socioeconomic Effects

Analysis of annual revenue estimates reveal that Alternative 2 is the most constraining of the Alternatives in that it rebuilds the Bering Sea snow crab stock in the least amount of time by halting directed fishing for three years. The impacts associated with the other alternatives order by the length of time to rebuild and the rebuilding probability with longer rebuilding periods and lower probability of rebuilding (e.g. Alternative 4) having the lowest impact on fishery participants in the early years of the rebuilding plan. Alternative 1, Alternative 4, and Alternative 4 with Option 1 all modeled with the same revenue projections. These alternative scenarios allow for longer rebuilding periods thus providing more directed catch in the first several years than any of the other, more constraining, alternatives. Of note; however, is that Alternative 4 with Option 1 would rebuild in four years at a 70% probability while still allowing directed catch, and revenue, consistent with the status quo. Further, by 2017, all alternatives would provide for estimated revenue that is within 5% of $400 million.

The inherent tradeoff in the Alternatives is that, while Alternatives that take longer to rebuild provide for near term harvest, longer rebuilding timeframes means that catch, and revenue, would not be as large in the years immediately after the rebuilding time as projected for the Alternatives that rebuild more quickly. However, by comparing the annual revenue projections with the total present value data of table 4-10 one can see that the most constraining alternatives could have severe consequences on near term harvests and thereby on fishery participants and dependent communities but that the total present value calculations, at five and ten years, somewhat mask those near term impacts. Near term impacts associated with Alternative 2 and possibly Alternative 3, Option 3, would substantially affect all quota share holders, captains and crew, processing workers, processing plants, support services, municipal and port revenue collections, the provision of city services, and in the case of Saint Paul could threaten the viability of the snow crab processing operation there (Pers. Comm. Swetzof, Paz-Soldan).

4.3 Tables and Figures

Table 4-1 Values for catch-related quantities for 2009/10 for each of the alternatives. The column P* in Table 4.1a shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The additional uncertainty value used in this analysis is shaded. Values are calculated from log normal distributions not from projections.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (1000t)	ABC_{dir} (1000t)	P * (additional uncertainty				Revenue	
			None	0.2	0.4	0.6	$Millions	%Change
Multiplier = 1	24.20	21.80	0.50	0.50	0.50	0.50	122	0%
Multiplier = 0.9	21.78	19.57	0.11	0.36	0.45	0.50	110	10%
Multiplier = 0.8	19.36	17.34	0.00	0.18	0.34	0.47	97	20%
Multiplier = 0.7	16.94	15.11	0.00	0.07	0.24	0.39	85	31%
Multiplier = 0.6	14.52	12.88	0.00	0.01	0.14	0.31	72	41%
Multiplier = 0.5	12.10	10.65	0.00	0.00	0.07	0.21	60	51%
Multiplier = 0.4	9.68	8.42	0.00	0.00	0.02	0.13	47	61%
Multiplier = 0.3	7.26	6.19	0.00	0.00	0.01	0.05	35	72%
Multiplier = 0.2	4.84	3.96	0.00	0.00	0.00	0.01	22	82%
Multiplier = 0.1	2.42	1.73	0.00	0.00	0.00	0.00	10	92%

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$&	24.13	21.74	0.997
$P^* = 0.4$	23.56	21.21	0.974
$P^* = 0.3$	23.07	20.75	0.953
$P^* = 0.2$	22.46	20.20	0.928
$P^* = 0.1$	21.68	19.48	0.896

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier	Revenue	
				$Millions	%Change
$P^* = 0.5$&	23.43	21.09	0.968	118	3%
$P^* = 0.4$	22.24	19.99	0.919	112	8%
$P^* = 0.3$	21.05	18.90	0.870	106	13%
$P^* = 0.2$	19.78	17.73	0.818	100	18%
$P^* = 0.1$	17.80	15.90	0.736	90	26%

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$&	22.68	20.40	0.937
$P^* = 0.4$	20.44	18.34	0.845
$P^* = 0.3$	18.48	16.53	0.764
$P^* = 0.2$	15.81	14.07	0.653
$P^* = 0.1$	13.08	11.55	0.540

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5^{\&}$	20.80	18.66	0.859
$P^* = 0.4$	17.11	15.27	0.707
$P^* = 0.3$	14.32	12.70	0.592
$P^* = 0.2$	11.70	10.28	0.484
$P^* = 0.1$	8.82	7.63	0.364

& - set to the point estimate

Table 4-2 Breakdown of the 2009/10 OFL for Bering Sea snow crab among the sources of mortality included in the OFL.

Component	Catch (1000t)
Directed fishery retained	**21.8**
Male discard in the directed fishery	**2.07**
Female discard in the direct fishery	**0.02**
Bycatch in the groundfish fishery	**0.36**
Total	**24.2**

Table 4-3 Parameters used for projections. All projections used the Beverton-Holt SR curve to generate future recruitment.

Parameter	Distribution
Model 5	
Virgin recruitment, R_0 (/1000)	1,196,960
Virgin MMB	445.3
Steepness, h	0.744
F_{MSY} ($F_{35\%}$)	1.278
B_{MSY} ($B_{35\%}$)	128.8
σ_R	1.11
Survey Q (estimated)	0.73
Male natural mortality (estimated)	0.29

Table 4-4 Summary of the medium-term consequences of a subset of the alternatives (multiplier levels of 1, 0.8, 0.6 and 0.4) (Beverton-Holt stock-recruitment relationship). The point estimates are medians and the intervals 90% intervals. Runs are with the SOA harvest strategy. Revenues reported are median and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009-2014.

(a) Multiplier = 1.0; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	21.8(20,23.7)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.5,24.7)	83.4(69.2,105.9)	0.006
2013	25.4(12,48.7)	21.1(9.9,41.1)	20.9(10.1,37.7)	95.8(75.9,146.1)	0.024
2014	33.4(14.5,112.8)	28.5(12.3,94.7)	28.2(12.5,89.3)	119.8(84.9,209.3)	0.047

(b) Multiplier = 0.8; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	21.8(20,23.7)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.5,24.7)	83.4(69.2,105.9)	0.006
2013	25.4(12,48.7)	21.1(9.9,41.1)	20.9(10.1,37.7)	95.8(75.9,146.1)	0.025
2014	33.4(14.5,106.5)	28.5(12.3,94.7)	28.2(12.5,84.7)	119.8(84.9,209.6)	0.035

(c) Multiplier = 0.6; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	21.8(20,23.7)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.3(10,29.6)	15.5(8.3,26.3)	15.4(8.4,24.7)	83.4(69.2,105.9)	0.006
2013	25.2(12,46.8)	21.2(9.9,41.1)	20.8(10,37.4)	95.7(75.9,149.8)	0.021
2014	33.4(14.5,86.6)	28.5(12.3,96.2)	28.2(12.5,69.7)	120.5(84.6,220.7)	0.005

(d) Multiplier = 0.4; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	21.8(20,23.7)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.8,102.4)	0.003
2011	17.2(9.9,29.4)	15.4(8.4,28.3)	15.1(8.4,26.2)	83.9(70.5,97.9)	0.004
2012	16.8(9.2,27)	15.5(8.3,26.3)	14.1(7.7,22.7)	84.9(69.7,108.7)	0.008
2013	23(11.2,34)	21.3(9.9,41.6)	18.9(9.5,27.1)	99.3(76.8,157.3)	0.002
2014	32.1(14.5,66.7)	29.4(12.5,100.4)	27.1(12.6,54.4)	125.7(85.1,241.5)	0.002

(e) Multiplier = 1.0; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	28.2(17.1,42.3)	0(0,0)	24.5(15.1,36.8)	67.4(54.1,81.7)	0.473
2012	22.6(13.2,38.2)	0(0,0)	18.4(10.8,29.1)	68.3(53.6,90.8)	0.45
2013	33.2(16.7,55.9)	0(0,0)	26(13.7,40.6)	80.2(58.3,134.3)	0.433
2014	51.6(23.6,115.2)	0(0,0)	41.8(20.3,88.9)	98.2(61.6,190.6)	0.439

(f) Multiplier = 0.8; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	24.5(14.6,37.7)	0(0,0)	21.3(12.8,32.6)	69.9(56.9,83.9)	0.306
2012	20.7(12,35.1)	0(0,0)	17(9.7,27.2)	71.4(56.6,94)	0.27
2013	30.6(15.3,49.9)	0(0,0)	24.3(12.6,37.3)	84.6(61.9,139.3)	0.257
2014	48(21.8,101.8)	0(0,0)	39(18.7,80.4)	104(66,202.7)	0.193

(g) Multiplier = 0.6; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	20.2(11.8,32)	0(0,0)	17.5(10.3,28)	72.8(60.1,87)	0.121
2012	18.3(10.3,30.6)	0(0,0)	15.1(8.3,24.4)	75.4(60.2,98.8)	0.101
2013	27.3(13.3,42.7)	0(0,0)	22(11.2,32.7)	90(66.7,146.1)	0.08
2014	41.8(19.5,85.5)	0(0,0)	34.8(16.7,68.7)	112(72.1,219.1)	0.055

(h) Multiplier = 0.4; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	15.1(8.6,24.5)	0(0,0)	13(7.4,21.4)	76.6(64,90.5)	0.013
2012	14.8(8,24.6)	0(0,0)	12.3(6.5,20)	80.9(65.5,104.6)	0.012
2013	22.4(10.9,33.2)	0(0,0)	18.2(9,26)	97.3(73.5,155.2)	0.004
2014	32.8(16,66.2)	0(0,0)	27.6(13.9,53.8)	123.5(81.5,240.3)	0.003

(i) P* = 0.4; Multiplier = 0.958; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.5,24.7)	83.4(69.2,105.9)	0.006
2013	25.4(12,48.7)	21.1(9.9,41.1)	20.9(10.1,37.7)	95.8(75.9,146.1)	0.024
2014	33.4(14.5,112.8)	28.5(12.3,94.7)	28.2(12.5,89.3)	119.8(84.9,209.3)	0.047

(j) P* = 0.3; Multiplier = 0.885; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.5,24.7)	83.4(69.2,105.9)	0.006
2013	25.4(12,48.7)	21.1(9.9,41.1)	20.9(10.1,37.7)	95.8(75.9,146.1)	0.024
2014	33.4(14.5,112.8)	28.5(12.3,94.7)	28.2(12.5,89.3)	119.8(84.9,209.3)	0.049

(k) P* = 0.2; Multiplier = 0.812; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.5,24.7)	83.4(69.2,105.9)	0.006
2013	25.4(12,48.7)	21.1(9.9,41.1)	20.9(10.1,37.7)	95.8(75.9,146.1)	0.025
2014	33.4(14.5,106.5)	28.5(12.3,94.7)	28.2(12.5,84.7)	119.8(84.9,209.6)	0.035

(l) P* = 0.1; Multiplier = 0.703; Impose SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	17.5(10.5,30.9)	15.5(8.9,29)	15.4(9.1,27.5)	87.8(73.6,102.4)	0.006
2011	17.5(10,30.4)	15.4(8.4,28.3)	15.3(8.7,26.7)	83.5(69.9,97.4)	0.009
2012	18.4(10,29.6)	15.5(8.3,26.3)	15.5(8.4,24.7)	83.4(69.2,105.9)	0.006
2013	25.3(12,49.4)	21.1(9.9,41.1)	20.9(10.1,38)	95.8(75.9,146.3)	0.026
2014	33.4(14.5,96.2)	28.5(12.3,94.5)	28.2(12.5,76.2)	119.9(84.9,212.8)	0.019

(m) P* = 0.4; Multiplier = 0.958; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	27.5(16.6,41.4)	0(0,0)	23.9(14.6,36)	67.9(54.7,82.2)	0.444
2012	22.3(13,37.5)	0(0,0)	18.1(10.6,28.9)	68.9(54.2,91.3)	0.411
2013	32.6(16.5,54.9)	0(0,0)	25.6(13.5,40)	81.1(59,135.2)	0.397
2014	51(23.2,112.4)	0(0,0)	41.3(20.1,87.6)	99.3(62.4,192.7)	0.398

(n) P* = 0.3; Multiplier = 0.885; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	26.1(15.7,39.7)	0(0,0)	22.7(13.8,34.5)	68.7(55.7,83)	0.372
2012	21.6(12.6,36.3)	0(0,0)	17.7(10.2,28)	70(55.2,92.6)	0.346
2013	31.7(16,52.7)	0(0,0)	25.1(13.1,38.8)	82.5(60.3,137)	0.33
2014	49.7(22.6,107.1)	0(0,0)	40.4(19.5,84.9)	101.4(63.9,196.9)	0.304

(o) P* = 0.2; Multiplier = 0.812; No SOA control rule.

Year	ABC_{tot} ('000t)	SOA ('000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	24.7(14.8,37.9)	0(0,0)	21.5(12.9,32.9)	69.7(56.7,83.8)	0.311
2012	20.8(12.1,35.3)	0(0,0)	17.1(9.8,27.2)	71.2(56.4,93.7)	0.281
2013	30.7(15.4,50.3)	0(0,0)	24.4(12.7,37.5)	84.2(61.7,139)	0.27
2014	48.3(21.9,102.7)	0(0,0)	39.1(18.8,81.1)	103.7(65.7,201.8)	0.21

(p) P* = 0.1; Multiplier = 0.703; No SOA control rule.

Year	ABC_{tot} (‘000t)	SOA (‘000t)	C_{dir} (1000 t)	Percent MMB/Bmsy	Prob (overfishing)
2009	24.6(22.6,26.8)	0(0,0)	21.8(20,23.7)	91.1(77,105.6)	0
2010	32.4(19.1,50.9)	0(0,0)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.221
2011	23.7(14.1,36.7)	0(0,0)	20.6(12.3,31.7)	70.4(57.5,84.4)	0.263
2012	20.3(11.7,34.6)	0(0,0)	16.7(9.4,26.7)	72(57.2,94.9)	0.246
2013	30.1(15,48.7)	0(0,0)	23.9(12.4,36.6)	85.6(62.7,140.4)	0.224
2014	46.9(21.3,98.9)	0(0,0)	38.3(18.3,78)	105.3(67,205.6)	0.155

Table 4-5 Summary of the long-term consequences of the alternatives (Beverton-Holt stock-recruitment relationship). The column "directed catch" lists the median and 90% intervals for the retained catch males in the directed fishery in 2038. The results assume $\sigma_b = 0.2$.

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Directed catch (2038)('000 t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Directed catch (2038)('000 t)
M = 1		0.023	0.004	0.032	1.000	49.8(13.3,174.4)	0.216	0.038	0.457	53.0(12.8,178.2)
M = 0.9		0.023	0.004	0.032	0.999	49.8(13.3,174.4)	0.175	0.030	0.32	53.1(13.1,176.2)
M = 0.8		0.023	0.004	0.031	0.976	49.7(13.3,174.5)	0.138	0.019	0.183	52.7(13.1,173.1)
M= 0.7		0.023	0.004	0.027	0.883	49.5(13.4,173.3)	0.098	0.011	0.097	52.3(13.1,168.8)
M = 0.6		0.023	0.004	0.013	0.723	49.0(13.5,163.8)	0.066	0.007	0.037	51.2(13.2,158.6)
M = 0.5		0.021	0.004	0.006	0.482	48.4(13.3,152.4)	0.042	0.005	0.015	49.7(13.2,151.9)
M = 0.4		0.016	0.002	0.002	0.238	46.0(13.5,143.3)	0.024	0.004	0.003	46.6(13.3,143.7)
M= 0.3		0.013	0.002	0.000	0.033	42.8(13.9,127.8)	0.014	0.002	0.000	42.7(13.6,127.7)
M = 0.2		0.004	0.000	0.000	0.001	35.6(12.8,101.2)	0.008	0.002	0.000	35.5(12.7,101.1)
M = 0.1		0.001	0.000	0.000	0.000	23.3(9.0,66.1)	0.003	0.000	0.000	23.3(9.0,66.0)
P* = 0.5	1.000	0.023	0.004	0.032	1.000	49.8(13.3,174.4)	0.216	0.038	0.457	53.0(12.8,178.2)
P* = 0.45	0.995	0.023	0.004	0.032	1.000	49.8(13.3,174.4)	0.216	0.038	0.457	53.0(12.8,178.2)
P* = 0.4	0.958	0.023	0.004	0.032	1.000	49.8(13.3,174.4)	0.200	0.037	0.402	52.9(13.0,178.6)
P* = 0.35	0.922	0.023	0.004	0.032	0.999	49.8(13.3,174.4)	0.183	0.031	0.343	53.0(13.1,178.2)
P* = 0.3	0.885	0.023	0.004	0.032	0.999	49.8(13.3,174.4)	0.168	0.028	0.288	53.0(13.1,174.8)
P* = 0.25	0.849	0.023	0.004	0.031	0.976	49.7(13.3,174.5)	0.157	0.025	0.249	52.8(13.1,174.8)
P* = 0.2	0.812	0.023	0.004	0.031	0.976	49.7(13.3,174.5)	0.140	0.019	0.204	52.8(13.1,173.8)
P* = 0.15	0.762	0.023	0.004	0.027	0.883	49.5(13.4,173.3)	0.119	0.016	0.146	52.6(13.1,170.8)
P* = 0.1	0.703	0.023	0.004	0.027	0.883	49.5(13.4,173.3)	0.098	0.011	0.097	52.3(13.1,168.8)
P* = 0.05	0.622	0.023	0.004	0.013	0.723	49.0(13.5,163.8)	0.068	0.008	0.048	51.6(13.2,161.1)

Table 4-6 **Summary of medium-term economic impacts of a subset of the ACL alternatives for snow crab. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the five year period 2009-2014, and percentage differences in revenues relative a zero buffer. Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4, and P* levels 0.5, 0.4, 0.3, 0.2, and 0.1) and reflecting effects of additional uncertainty (σ_b = 0.2). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint, respectively.**

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, ($ Million), discounted at r=0.27%**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.2**
0.2	Multiplier = 1	796(371,1491)	744(351,1369)	671(325,1215)	NA	0
	Multiplier = 0.8	796(371,1477)	744(351,1359)	671(325,1205)	NA	0
	Multiplier = 0.6	788(370,1427)	734(351,1316)	665(324,1163)	NA	1
	Multiplier = 0.4	744(349,1268)	698(331,1176)	634(307,1046)	NA	6
0.2	P* = 0.5	796(371,1491)	744(351,1369)	671(325,1215)	NA	0
	P* = 0.4	796(371,1491)	744(351,1369)	671(325,1215)	NA	0
	P* = 0.3	796(371,1498)	744(351,1369)	671(325,1205)	NA	0
	P* = 0.2	796(371,1477)	744(351,1359)	671(325,1205)	NA	0
	P* = 0.1	795(371,1452)	741(351,1341)	669(325,1192)	NA	0

(b) Results are exclusive of the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0.2	Multiplier = 1	1088(506,1901)	1013(478,1751)	914(439,1549)	NA	0
	Multiplier = 0.8	1020(478,1767)	953(452,1630)	862(422,1450)	NA	6
	Multiplier = 0.6	938(446,1591)	876(424,1470)	791(392,1309)	NA	14
	Multiplier = 0.4	811(395,1344)	760(376,1251)	695(349,1127)	NA	25
0.2	P* = 0.5	1088(506,1901)	1013(478,1751)	914(439,1549)	NA	0
	P* = 0.4	1074(501,1876)	1001(473,1728)	903(436,1529)	NA	1
	P* = 0.3	1048(491,1829)	980(464,1685)	885(429,1492)	NA	3
	P* = 0.2	1024(479,1776)	957(454,1638)	865(423,1455)	NA	6
	P* = 0.1	985(461,1685)	921(440,1556)	830(409,1382)	NA	9

Table 4-7 **Summary of long-term economic impacts of the ACL alternatives for snow crab. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the 30-year period 2009-2038 (2008 dollars), and percentage differences in revenues relative to a zero buffer. Alternatives include fixed buffers (multipliers of 1.0 to 0.1) and P* levels (0.5 to 0.05), for additional uncertainty (σ_b= 0.2). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.**

(a): Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.2**
0.2	Multiplier = 1	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	Multiplier = 0.9	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	Multiplier = 0.8	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	Multiplier = 0.7	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	Multiplier = 0.6	8829(1924,21431)	5834(1391,13681)	3358(874,7743)	NA	1
	Multiplier = 0.5	8583(1845,20721)	5669(1368,13184)	3238(844,7442)	NA	4
	Multiplier = 0.4	8072(1739,19344)	5398(1252,12423)	3038(793,6974)	NA	9
	Multiplier = 0.3	7280(1539,17136)	4850(1102,10966)	2724(713,6140)	NA	18
	Multiplier = 0.2	5917(1238,13859)	3921(872,8784)	2217(574,4926)	NA	34
	Multiplier = 0.1	3784(785,8772)	2485(556,5496)	1403(383,3091)	NA	58
0.2	P* = 0.5	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.45	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.4	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.35	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.3	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.25	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	P* = 0.2	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	P* = 0.15	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	P* = 0.1	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	P* = 0.05	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0

(b): Results are exclusive of the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.2**
0.2	Multiplier = 1	9921(2230,23542)	6710(1633,15507)	3977(1052,8861)	NA	0
	Multiplier = 0.9	9804(2194,23344)	6629(1599,15302)	3907(1037,8696)	NA	1
	Multiplier = 0.8	9660(2151,23023)	6526(1577,14972)	3815(1020,8491)	NA	3
	Multiplier = 0.7	9453(2092,22538)	6371(1554,14635)	3705(990,8253)	NA	5
	Multiplier = 0.6	9174(2014,21752)	6173(1503,14124)	3564(945,7967)	NA	8
	Multiplier = 0.5	8757(1912,20826)	5896(1396,13452)	3378(906,7561)	NA	12
	Multiplier = 0.4	8195(1773,19439)	5484(1287,12422)	3136(837,7014)	NA	18
	Multiplier = 0.3	7274(1581,17139)	4889(1123,10994)	2802(749,6177)	NA	27
	Multiplier = 0.2	5979(1285,13887)	3984(902,8844)	2283(629,5024)	NA	41
	Multiplier = 0.1	3896(869,8816)	2594(641,5647)	1533(474,3251)	NA	61
0.2	P* = 0.5	9921(2230,23542)	6710(1633,15507)	3977(1052,8861)	NA	0
	P* = 0.45	9921(2230,23542)	6710(1633,15507)	3977(1052,8861)	NA	0
	P* = 0.4	9870(2217,23471)	6676(1621,15430)	3951(1046,8797)	NA	1
	P* = 0.35	9831(2204,23396)	6647(1607,15356)	3925(1041,8736)	NA	1
	P* = 0.3	9785(2185,23304)	6616(1592,15269)	3894(1035,8667)	NA	1
	P* = 0.25	9733(2171,23198)	6581(1585,15129)	3862(1029,8593)	NA	2
	P* = 0.2	9674(2157,23069)	6540(1579,15006)	3826(1023,8515)	NA	3
	P* = 0.15	9602(2130,22861)	6475(1569,14855)	3779(1013,8408)	NA	4
	P* = 0.1	9453(2092,22538)	6371(1554,14635)	3705(990,8253)	NA	5
	P* = 0.05	9237(2033,21910)	6226(1523,14249)	3597(953,8038)	NA	7

Table 4-8 T_{target} values, probability of rebuilding (1 yr) and multipliers on the $F_{35\%}$ control rule for Alternatives 1-5 and Options 1-3.

Alternative	Probability rebuilding Specified by Alternative	T_{TARGET} year-ending date	Probability Rebuilding (1 yr) from projections	Multiplier
Alternative 1 (no action)	50%	2014/15	0.646	0.75
Alternative 2 (T_{MIN})	50%	2012/13	0.508	0.00
Alternative 3	50%	2013/14	0.5	0.42
Alternative 3-Option 2	75%	2013/14	0.751	0.15
Alternative 3-Option 3	90%	2013/14	0.91	0.03
Alternative 4 (T_{END})	50%	2014/15	0.646	0.75
Alternative 4-Option 2	75%	2014/15	0.756	0.47
Alternative 4-Option 3	90%	2014/15	0.91	0.22
Option 1		2019/20	0.864	0.75

Table 4-9 Rebuilding for Alternatives 1-4 and Options 1, 2, and 3, rebuilding 2 years in a row. $B_{35\%}$ = 139,200 t. Fishing at 75%F35% in 2010/11. All projections have rebuilding strategy (multiplier) in effect until rebuilt, then strategy switches to a 0.8 multiplier. Total catch (ABC_{tot}) and retained catch (C_{dir}) and fishing mortality are medians. Percent MMB at mating relative to B35%. Values in parentheses are 90% CI. Probability of rebuilding for 1 year above B35% and probability of rebuilding to 2 years in a row above B35%.

(a) Alternative 1, alternative 4 and Option 1 (multiplier = 0.75), Model 5, Additional uncertainty = 0.2. When rebuilt multiplier increased to 0.8.

Year	ABC_{tot} (1000t)	C_{dir} (1000t)	Percent MMB/ $B_{35\%}$	Prob Rebuildin g(1 yrs)	Prob Rebuilding(2 yrs)	Full Selection Fishing Mortality
2009	24.5(24.5,24.6)	21.7(21.7,21.7)	91.2(75.9,106.8)	0.181	0	0.45
2010	32.6(18.8,51.3)	28.9(16.6,45.4)	77.4(64,91.1)	0.181	0.002	0.69
2011	23.1(13.6,36.3)	20.6(12.2,31.8)	70.7(57.7,85)	0.182	0.002	0.63
2012	19.9(11.1,33.8)	16.8(9.4,26.8)	72.5(57.5,95.4)	0.208	0.004	0.63
2013	29.4(14.5,47.3)	23.9(12.4,36.5)	85.9(63.1,141)	0.379	0.037	0.78
2014	46.1(20.9,96.9)	38.3(18.3,77.7)	106(67.5,207.1)	0.646	0.262	0.87
2015	58.6(21.7,154.6)	49.9(19.2,133)	120.3(67.5,274.7)	0.744	0.572	0.9
2016	63.5(19.5,166.6)	54.2(17.2,143.8)	125.1(64.3,291.9)	0.789	0.663	0.93
2017	62.2(16.8,165.1)	52.3(14.7,143.1)	126.6(61.1,290.6)	0.818	0.716	0.91
2018	62.1(14.9,165.1)	52.4(13.3,139.8)	130.2(59.1,305)	0.844	0.758	0.91
2019	62(14.9,162)	51.8(12.4,137.1)	125.7(58.9,310.2)	0.864	0.792	0.92
2020	57.2(12.8,163.3)	48.3(10.7,142.3)	121.8(58.1,301.8)	0.883	0.817	0.91

(b) Alternative 2, Model 5, Additional uncertainty = 0.2. Directed catch = 0.0 (groundfish bycatch extracted). When rebuilt multiplier increased to 0.8.

Year	ABC_{tot} (1000t)	C_{dir} (1000t)	Percent MMB/ $B_{35\%}$	Prob Rebuildin g(1 yrs)	Prob Rebuilding(2 yrs)	Full Selection Fishing Mortality
2009	24.5(24.5,24.6)	21.7(21.7,21.7)	91.2(75.9,106.8)	0.181	0	0.45
2010	32.6(18.8,51.3)	28.9(16.6,45.4)	77.4(64,91.1)	0.181	0.002	0.69
2011	0.5(0.4,0.7)	0(0,0)	87.6(74.1,101.5)	0.203	0.002	0.63
2012	0.6(0.5,0.9)	0(0,0)	99.5(83,124.8)	0.508	0.082	0.63
2013	0.8(0.6,54.3)	0(0,44.7)	123.1(97.3,183.9)	0.943	0.485	0.78
2014	1.3(0.7,131.8)	0(0,109.5)	146.3(102.9,229.6)	0.996	0.943	0.87
2015	83.8(0.9,167.7)	73.6(0,143.4)	136.5(85.7,280.8)	0.998	0.994	0.9
2016	72(27.4,171.4)	62.3(24.1,148)	131.8(73.1,296.3)	0.998	0.996	0.93
2017	64.3(19.3,167.9)	54.6(16.9,145.1)	129.3(64.3,294.5)	0.998	0.996	0.91
2018	63.1(16.1,166.2)	53.4(13.9,140.7)	131.8(60,307.2)	0.999	0.997	0.91
2019	63.2(15.8,162.2)	52.7(13.1,138.1)	128.3(60.3,314.5)	0.999	0.998	0.92
2020	59.1(13.6,170)	49.6(11.7,143)	125.9(59.2,321.2)	0.999	0.998	0.91

(c) Alternative 3, Model 5, Additional uncertainty = 0.2. Multiplier = 0.34. When rebuilt multiplier increased to 0.8.

Year	**ABC_{tot} (1000t)**	**C_{dir} (1000t)**	**Percent MMB/ $B_{35\%}$**	**Prob Rebuilding(1 yrs)**	**Prob Rebuilding(2 yrs)**	**Full Selection Fishing Mortality**
2009	24.5(24.5,24.6)	21.7(21.7,21.7)	91.2(75.9,106.8)	0.181	0	0.45
2010	32.6(18.8,51.3)	28.9(16.6,45.4)	77.4(64,91.1)	0.181	0.002	0.69
2011	13.3(7.6,22)	11.5(6.4,19)	77.9(65,92.2)	0.182	0.002	0.32
2012	13.6(7.2,22.2)	11.3(5.8,18.2)	83(67.4,106.8)	0.253	0.008	0.33
2013	20.4(9.9,30.1)	16.6(8.1,23.8)	99.9(76.1,158.3)	0.562	0.105	0.4
2014	29.3(14.7,110.2)	24.9(12.6,89.2)	127.6(84.8,228.4)	0.826	0.499	0.43
2015	48.9(16.3,165)	42.5(14.2,139.6)	139.5(84.4,284.9)	0.886	0.802	0.64
2016	74(16.5,172.4)	64.3(14.4,149.3)	134(79.2,297.3)	0.912	0.861	0.91
2017	66.5(14.7,167.2)	56.2(12.7,143.9)	132.8(70.9,294.9)	0.927	0.889	0.9
2018	63.6(14.5,166.2)	54(12.5,142.2)	132.8(65.3,306.4)	0.936	0.909	0.9
2019	63.7(13.5,162.5)	53.4(11.6,138.2)	128.4(62.9,311.6)	0.947	0.918	0.91
2020	58.1(12.2,166.6)	48.9(10.1,144.5)	125.7(62.8,310.2)	0.957	0.93	0.9

(d) Alternative 3, Option 2, Model 5, Additional uncertainty = 0.2. Multiplier = 0.14. When rebuilt multiplier increased to 0.8.

Year	**ABC_{tot} (1000t)**	**C_{dir} (1000t)**	**Percent MMB/ $B_{35\%}$**	**Prob Rebuilding(1 yrs)**	**Prob Rebuilding(2 yrs)**	**Full Selection Fishing Mortality**
2009	24.6(22.6,26.8)	21.8(20,23.7)	91.1(77,105.6)	0.181	0	0.45
2010	32.4(19.1,50.9)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.181	0.002	0.69
2011	6.5(3.7,10.4)	5.4(2.9,8.8)	82.9(70,96.4)	0.185	0.002	0.14
2012	7.4(3.9,11.3)	6(2.9,9.2)	91.2(75.8,115.6)	0.306	0.022	0.15
2013	10.7(5.5,16)	8.7(4.3,12.8)	111.9(87.5,172.5)	0.766	0.215	0.17
2014	15.4(8.4,124.8)	12.8(7.1,103.1)	143(99,237.6)	0.952	0.757	0.19
2015	81.7(10.7,167.7)	70.9(9.3,143)	141.6(95.4,279.3)	0.964	0.946	0.89
2016	74.2(16.1,172.1)	64.7(14.1,147.6)	134.4(79.6,299.2)	0.97	0.957	0.96
2017	66.2(15,168.5)	56.4(13,144.7)	130.5(68.6,294.6)	0.979	0.964	0.93
2018	63.6(13.7,166.9)	53.7(11.9,141.4)	132.6(62.4,306.3)	0.983	0.973	0.93
2019	63.8(13.4,162.3)	53.3(11.4,138)	128.5(61.1,313)	0.988	0.978	0.93
2020	58.8(12.4,168.4)	49.4(10.5,142.4)	125.6(59.5,315.5)	0.992	0.984	0.91

(e) Alternative 3, Option 3, Model 5, Additional uncertainty = 0.2. Multiplier = 0.03. When rebuilt multiplier increased to 0.8.

Year	**ABC_{tot} (1000t)**	**C_{dir} (1000t)**	**Percent MMB/ $B_{35\%}$**	**Prob Rebuildin g(1 yrs)**	**Prob Rebuilding(2 yrs)**	**Full Selection Fishing Mortality**
2009	24.5(24.5,24.6)	21.7(21.7,21.7)	91.2(75.9,106.8)	0.181	0	0.45
2010	32.6(18.8,51.3)	28.9(16.6,45.4)	77.4(64,91.1)	0.181	0.002	0.69
2011	1.9(1.2,2.8)	1.3(0.7,2)	86.5(73.1,100.6)	0.198	0.002	0.03
2012	2.4(1.4,3.3)	1.5(0.7,2.3)	97.3(81.3,122.7)	0.452	0.06	0.04
2013	3.2(1.9,36)	2.1(1.1,31)	120.7(95,183.2)	0.911	0.418	0.04
2014	5(2.8,130.2)	3.7(1.9,108.5)	146.5(103.3,230.7)	0.992	0.911	0.05
2015	84.8(3.7,167.3)	74(2.8,143.1)	139.2(88,280.2)	0.994	0.99	0.95
2016	72.1(27.8,171)	62.7(24.7,147.7)	133.3(74.1,297)	0.994	0.992	0.96
2017	64.6(19.6,167.8)	54.7(17.1,144.9)	129.2(64.8,294.4)	0.995	0.992	0.94
2018	63.2(16.2,166.7)	53.4(13.8,140.6)	132.6(59.8,307.2)	0.997	0.994	0.93
2019	63.6(15.7,162.2)	53(13.1,138)	128.2(60.3,314.1)	0.998	0.996	0.93
2020	59(13.5,169.4)	49.6(11.3,142.9)	126(59.1,319.6)	0.998	0.997	0.92

(f) Alternative 4, Option 2, Model 5, Additional uncertainty = 0.2. Multiplier = 0.41. When rebuilt multiplier increased to 0.8.

Year	**ABC_{tot} (1000t)**	**C_{dir} (1000t)**	**Percent MMB/ $B_{35\%}$**	**Prob Rebuildin g(1 yrs)**	**Prob Rebuilding(2 yrs)**	**Full Selection Fishing Mortality**
2009	24.5(24.5,24.6)	21.7(21.7,21.7)	91.2(75.9,106.8)	0.181	0	0.45
2010	32.6(18.8,51.3)	28.9(16.6,45.4)	77.4(64,91.1)	0.181	0.002	0.69
2011	15.4(8.8,25.1)	13.3(7.5,21.9)	76.4(63.5,90.6)	0.182	0.002	0.38
2012	15(8.2,25.1)	12.5(6.6,20.4)	80.6(65.2,104.2)	0.236	0.005	0.39
2013	22.7(11,33.8)	18.5(9.1,26.5)	96.8(73.1,154.6)	0.517	0.082	0.47
2014	33.3(16.2,103.9)	28.1(14,83.7)	122.9(80.9,227.2)	0.792	0.435	0.51
2015	46.2(17.4,164.5)	40.1(15.4,139.8)	136.7(80.6,283.6)	0.861	0.758	0.65
2016	72.2(16.6,170.9)	62.7(14.7,148.3)	134.2(75.8,297.4)	0.886	0.832	0.89
2017	65.4(15.4,166.7)	55.9(13.2,145.4)	132.2(70.1,294.7)	0.907	0.86	0.89
2018	63.3(14.6,166)	53.5(12.6,142)	132.4(64.4,306.3)	0.921	0.885	0.89
2019	63.6(13.9,162.4)	53.1(12,138)	128.6(62.6,310.7)	0.931	0.902	0.9
2020	57.9(12.2,165.8)	48.9(10.2,145.5)	124.5(62.1,308.4)	0.947	0.915	0.89

(g) Alternative 4, Option 3, Model 5, Additional uncertainty = 0.2. Multiplier = 0.21. When rebuilt multiplier increased to 0.8.

Year	**ABC_{tot} (1000t)**	**C_{dir} (1000t)**	**Percent MMB/ $B_{35\%}$**	**Prob Rebuilding(1 yrs)**	**Prob Rebuilding(2 yrs)**	**Full Selection Fishing Mortality**
2009	24.6(22.6,26.8)	21.8(20,23.7)	91.1(77,105.6)	0.181	0	0.45
2010	32.4(19.1,50.9)	28.9(16.9,44.9)	77.4(64.2,90.5)	0.181	0.002	0.69
2011	9.1(5.1,14.8)	7.7(4.2,12.8)	81(68.2,94.5)	0.182	0.002	0.21
2012	9.9(5.2,15.6)	8.2(4.1,12.9)	87.9(72.5,112.6)	0.274	0.016	0.22
2013	14.7(7.3,21.5)	12(5.9,17.5)	107.1(83.1,166.4)	0.684	0.167	0.25
2014	20.9(11,119.3)	17.7(9.5,97.8)	137.3(93.1,237.6)	0.915	0.66	0.27
2015	76.5(13.2,168.5)	66(11.4,143.2)	141.7(93,287.6)	0.94	0.905	0.84
2016	74.2(15.3,172.8)	64.7(13.6,150)	134.4(80.8,298.6)	0.953	0.932	0.94
2017	66.7(15.6,167.7)	56.7(13.4,144.4)	130.8(71.3,295.5)	0.961	0.946	0.92
2018	63.5(14.6,166.6)	53.8(12.2,141.1)	132.7(63.7,306.5)	0.968	0.954	0.92
2019	63.5(13.5,162.7)	53(11.7,138.6)	128.6(61.3,312.2)	0.977	0.961	0.92
2020	58.5(12.5,167.5)	49.2(10.2,142.3)	126(59.2,313.3)	0.985	0.972	0.91

Table 4-10 Economic Effects of Rebuilding Alternatives: Estimated total present value of gross first wholesale value of projected snow crab catch under rebuilding alternatives and foregone revenue relative to no action alternative.

(a) Five year estimates (2012-2016), Rebuilt defined as one-year above B_{MSY}

	Present Value of Total Revenue, 2012-2016			**Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)**					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
Alternative	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	918(117,2738)	775(109,2336)	608(82,1823)	250	21%	250	24%	222	27%
Alternative 3	1017(242,2825)	884(210,2398)	713(173,1871)	151	13%	141	14%	117	14%
Alternative 3-Option 2	928(160,2714)	794(134,2326)	627(113,1816)	240	21%	231	23%	203	24%
Alternative 3-Option 3	918(131,2752)	783(117,2350)	614(93,1844)	250	21%	242	24%	216	26%
Alternative 4 (TEND)	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%
Alternative 4-Option 2	1044(252,2826)	898(218,2400)	734(181,1864)	124	11%	127	12%	96	12%
Alternative 4-Option 3	953(194,2732)	818(170,2322)	650(137,1812)	215	18%	207	20%	180	22%
Alternative 4-Option 1	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%

(b) Five year estimates (2012-2016), Rebuilt defined as two years above B_{MSY}

Alternative	Present Value of Total Revenue, 2012-2016			Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	918(117,2738)	775(109,2336)	608(82,1823)	250	21%	250	24%	222	27%
Alternative 3	975(224,2789)	852(195,2383)	681(156,1867)	193	17%	173	17%	149	18%
Alternative 3-Option 2	919(157,2719)	791(132,2326)	628(112,1822)	249	21%	234	23%	202	24%
Alternative 3-Option 3	918(131,2752)	783(117,2350)	614(93,1844)	250	21%	242	24%	216	26%
Alternative 4 (TEND)	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%
Alternative 4-Option 2	1013(238,2821)	878(208,2395)	708(170,1866)	155	13%	147	14%	122	15%
Alternative 4-Option 3	948(190,2729)	812(167,2319)	647(136,1819)	220	19%	213	21%	183	22%
Alternative 4-Option 1	1168(285,2955)	1025(251,2503)	830(207,1975)	0	0%	0	0%	0	0%

(c) Ten year estimates (2012-2021), Rebuilt defined as one-year above B_{MSY}

Alternative	Present Value of Total Revenue			Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	3127(655,8835)	2510(533,7038)	1770(388,4876)	147	4%	130	5%	161	8%
Alternative 3	3210(709,8930)	2558(592,7142)	1851(447,4898)	64	2%	82	3%	80	4%
Alternative 3-Option 2	3146(635,8981)	2496(540,7090)	1782(385,4817)	128	4%	144	5%	149	8%
Alternative 3-Option 3	3133(662,8893)	2502(532,7054)	1748(387,4886)	141	4%	138	5%	183	9%
Alternative 4 (TEND)	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%
Alternative 4-Option 2	3230(729,8953)	2581(617,7167)	1864(465,4906)	44	1%	59	2%	67	3%
Alternative 4-Option 3	3173(622,8949)	2517(510,7128)	1790(392,4850)	101	3%	123	5%	141	7%
Alternative 4-Option 1	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%

(d) Ten year estimates (2012-2021), Rebuilt defined as two years above B_{MSY}

	Present Value of Total Revenue			**Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)**					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
Alternative	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	3127(655,8835)	2510(533,7038)	1770(388,4876)	147	4%	130	5%	161	8%
Alternative 3	3205(706,8892)	2544(564,7105)	1833(425,4883)	69	2%	96	4%	98	5%
Alternative 3-Option 2	3165(621,8979)	2499(523,7085)	1785(381,4812)	109	3%	141	5%	146	8%
Alternative 3-Option 3	3133(662,8893)	2502(532,7054)	1748(387,4886)	141	4%	138	5%	183	9%
Alternative 4 (TEND)	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%
Alternative 4-Option 2	3208(712,8926)	2553(588,7141)	1840(447,4897)	66	2%	87	3%	91	5%
Alternative 4-Option 3	3167(622,8932)	2513(499,7120)	1800(386,4845)	107	3%	127	5%	131	7%
Alternative 4-Option 1	3274(785,9027)	2640(656,7181)	1931(504,4948)	0	0%	0	0%	0	0%

(e) Fifteen year estimates (2012-2026), Rebuilt defined as one-year above B_{MSY}

Alternative	**Present Value of Total Revenue, 2012-2026**			**Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)**					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	5313(1017,14153)	3969(737,10688)	2538(491,6834)	-22	0%	31	1%	158	6%
Alternative 3	5289(1068,14036)	3999(819,10448)	2647(550,6831)	2	0%	1	0%	49	2%
Alternative 3-Option 2	5271(1014,14019)	3956(751,10597)	2579(497,6847)	20	0%	44	1%	117	4%
Alternative 3-Option 3	5304(1014,14178)	3960(732,10687)	2555(481,6838)	-13	0%	40	1%	141	5%
Alternative 4 (TEND)	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%
Alternative 4-Option 2	5296(1076,14018)	3996(819,10443)	2654(555,6825)	-5	0%	4	0%	42	2%
Alternative 4-Option 3	5287(1007,14024)	3979(764,10566)	2587(510,6810)	4	0%	21	1%	109	4%
Alternative 4-Option 1	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%

(f) Fifteen year estimates (2012-2026), Rebuilt defined as two years above B_{MSY}

Alternative	Present Value of Total Revenue			Estimated Gross Revenue Foregone and Percentage (%) Reduction in Relative to Alternative 1 (no action)					
				$Millions	Percent	$Millions	Percent	$Millions	Percent
	r = 0%	r = 0.27%	r = 0.7%	r = 0%		r = 0.27%		r = 0.7%	
Alternative 1 (no action)	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%
Alternative 2 (TMIN)	5313(1017,14153)	3969(737,10688)	2538(491,6834)	-22	0%	31	1%	158	6%
Alternative 3	5289(1068,14036)	3999(819,10448)	2647(550,6831)	2	0%	1	0%	49	2%
Alternative 3-Option 2	5271(1014,14019)	3956(751,10597)	2579(497,6847)	20	0%	44	1%	117	4%
Alternative 3-Option 3	5304(1014,14178)	3960(732,10687)	2555(481,6838)	-13	0%	40	1%	141	5%
Alternative 4 (TEND)	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%
Alternative 4-Option 2	5296(1076,14018)	3996(819,10443)	2654(555,6825)	-5	0%	4	0%	42	2%
Alternative 4-Option 3	5287(1007,14024)	3979(764,10566)	2587(510,6810)	4	0%	21	1%	109	4%
Alternative 4-Option 1	5291(1091,13978)	4000(837,10416)	2696(576,6815)	0	0%	0	0%	0	0%

Table 4-11 **Annual Revenue Estimates by Alternative and Option, Over Ten Rebuilding Years. ($ millions)**

Year	A1, A4, A4O1	A2	A3	A3O2	A3O3	A4O2	A4O3
2012	$152	$0	$117	$59	$17	$124	$77
2013	$182	$0	$141	$70	$21	$148	$93
2014	$232	$0	$175	$91	$33	$187	$118
2015	$244	$359	$210	$294	$361	$218	$233
2016	$302	$362	$323	$389	$364	$312	$381
2017	$382	$400	$397	$411	$404	$392	$417
2018	$433	$444	$439	$450	$443	$436	$449
2019	$449	$455	$444	$454	$456	$444	$454
2020	$400	$416	$408	$413	$415	$402	$407
2021	$316	$337	$320	$331	$335	$318	$328

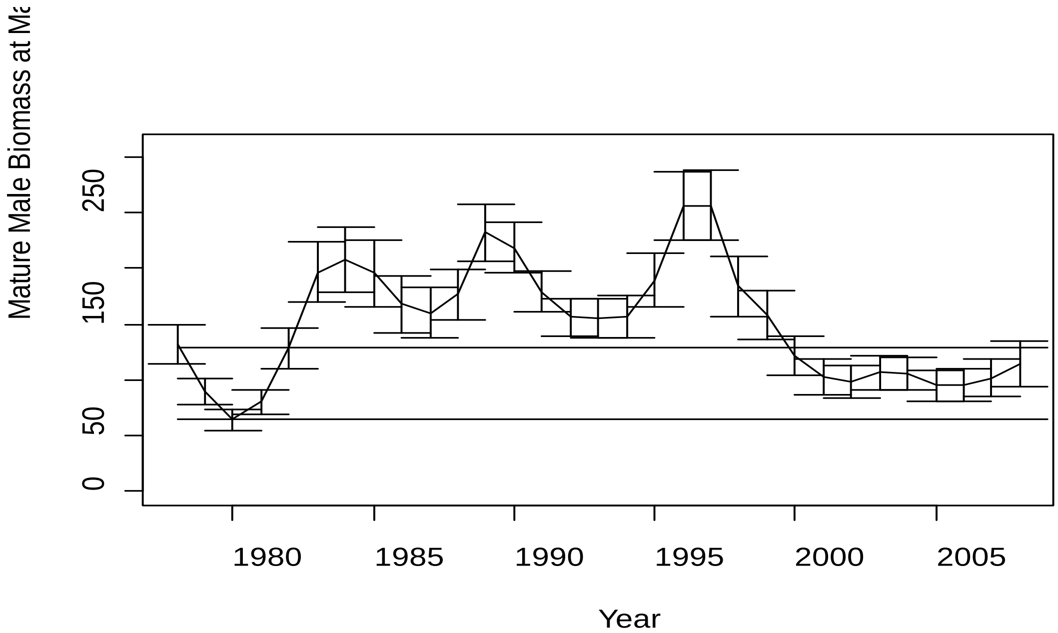


Figure 4-1 **Time-trajectory of mature male biomass at the time of mating for Bering sea snow crab (1000t) for Model 1. Upper horizontal line is B35%, lower horizontal line is 0.5 B35%.**

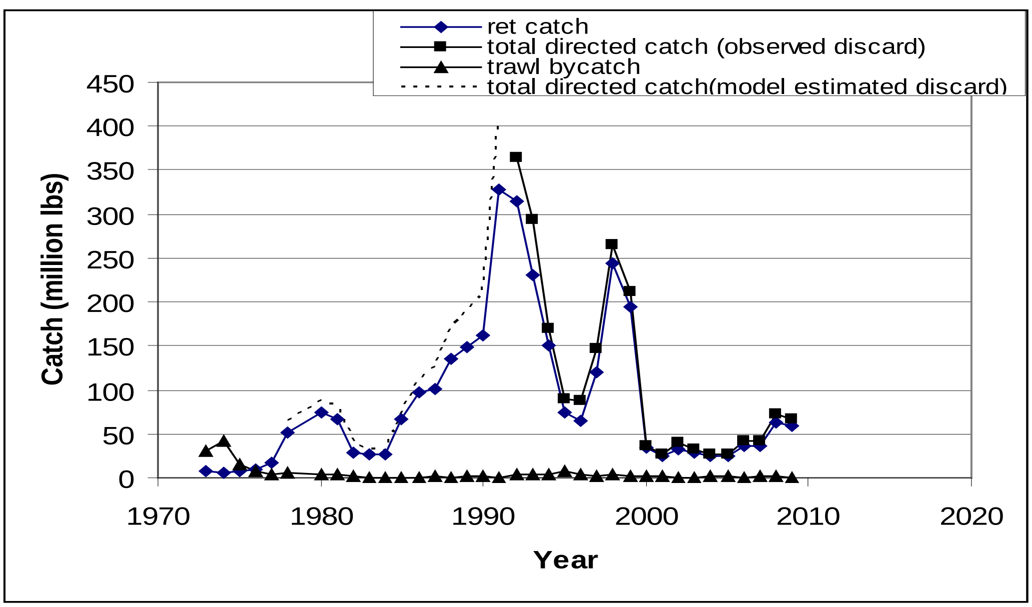


Figure 4-2 **Catch (million lbs) from the directed snow crab pot fishery and groundfish trawl bycatch. Total catch is retained catch plus discarded catch in the directed fishery.**

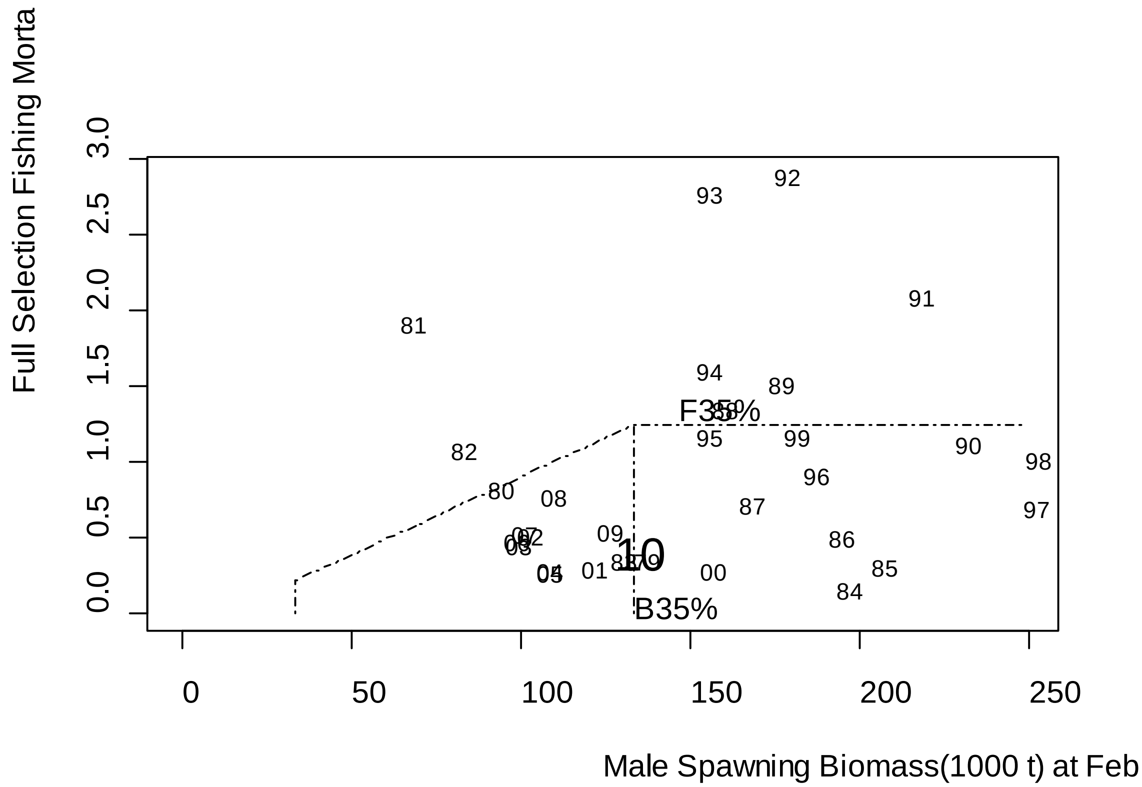


Figure 4-3 **Fully-selected fishing mortality Fofl and the mature male biomass at mating. The dotted line denotes the Tier 3 OFL control rule. The vertical line is $B_{35\%}$.**

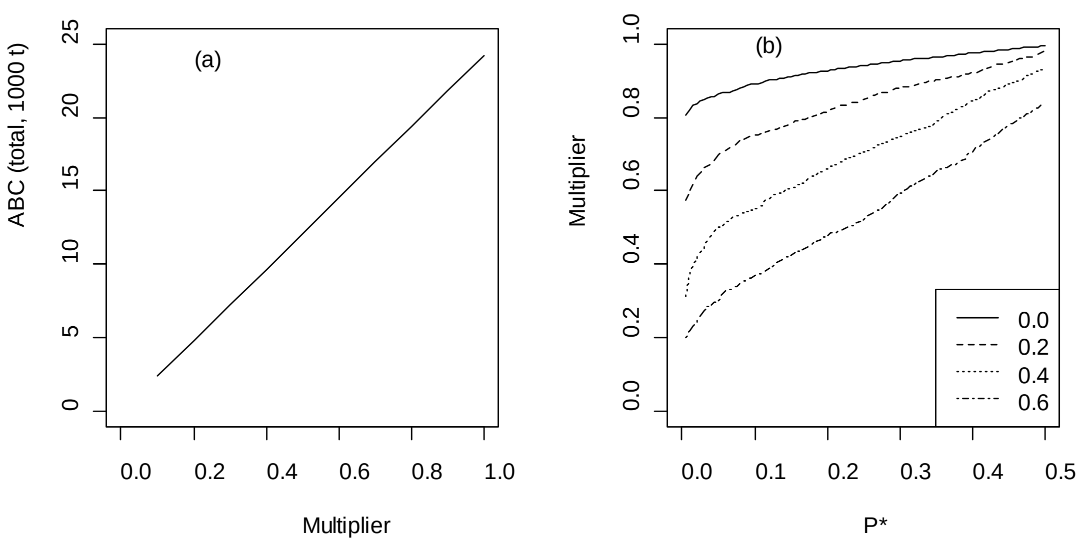


Figure 4-4 **Relationship between the multiplier and the ABC (a), and the relationships between P* and the multiplier for four values for the extent of additional uncertainty (b).**

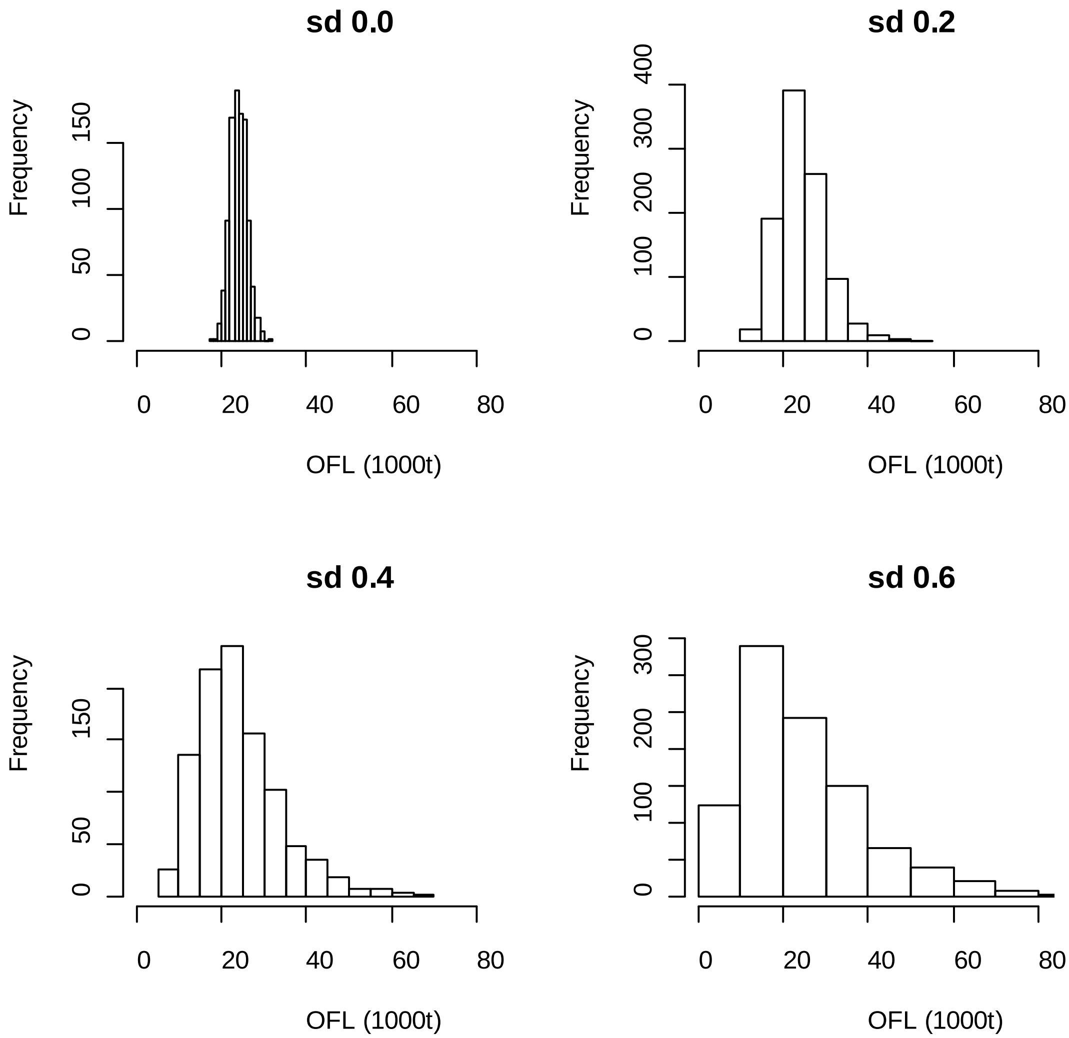


Figure 4-5 **Distribution of OFL values as a function of the assumed extent of additional uncertainty (σ_b = sd).**

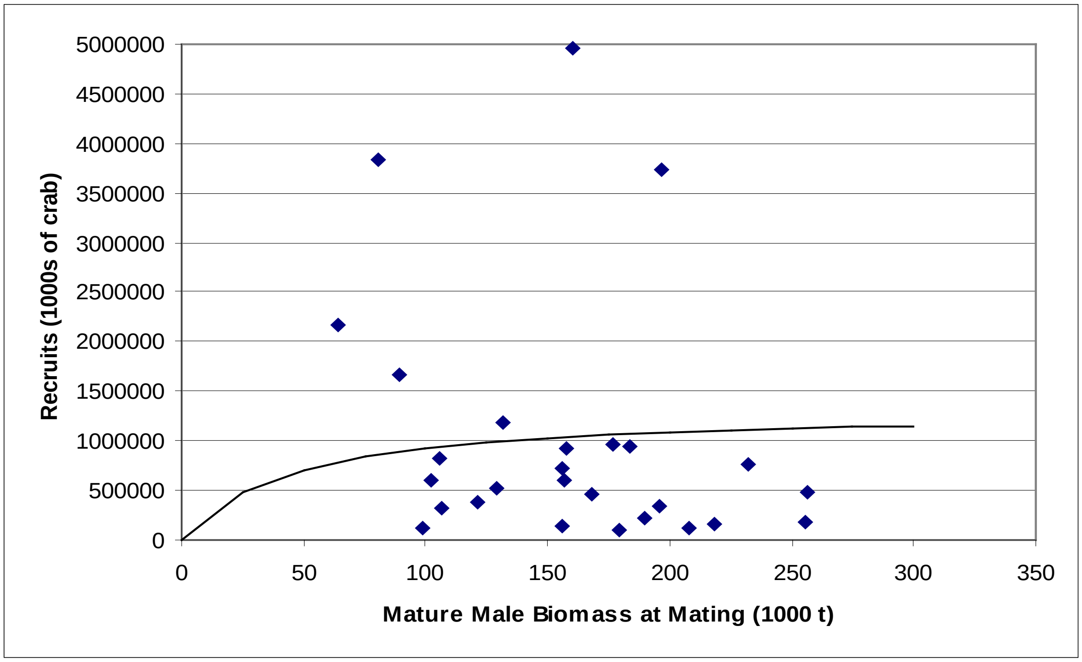


Figure 4-6 **Recruits (lag 5 years) and MMB (100t) with Beverton-Holt SR curve estimated using Fmsy=F35% and Bmsy= B35%.**

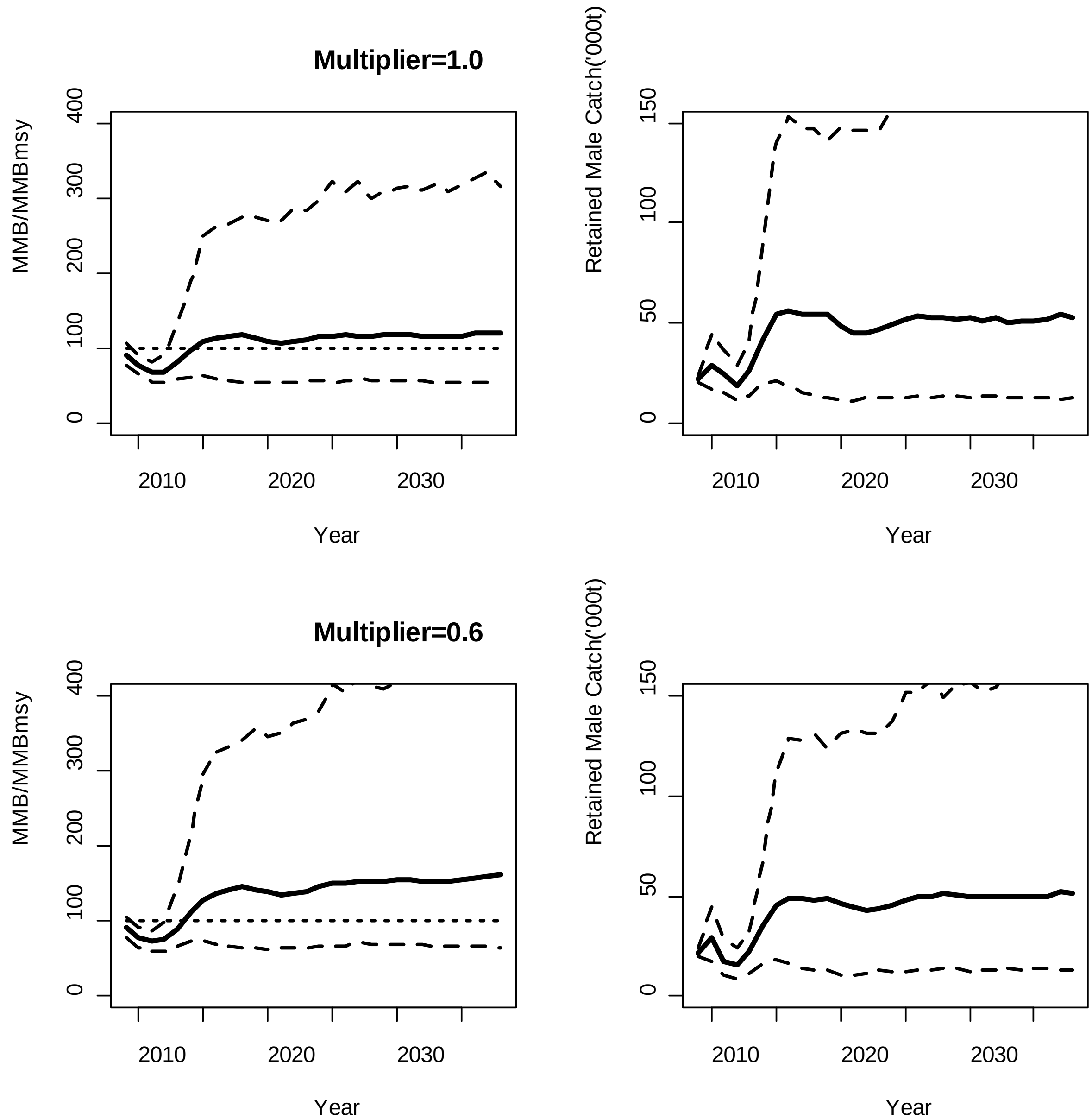


Figure 4-7 **Time-trajectories of mature male biomass at mating relative to B_{35} (the proxy for B_{MSY}) and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in this figure are based on additional cv = 0.2 and the Beverton-Holt stock-recruitment relationship.**

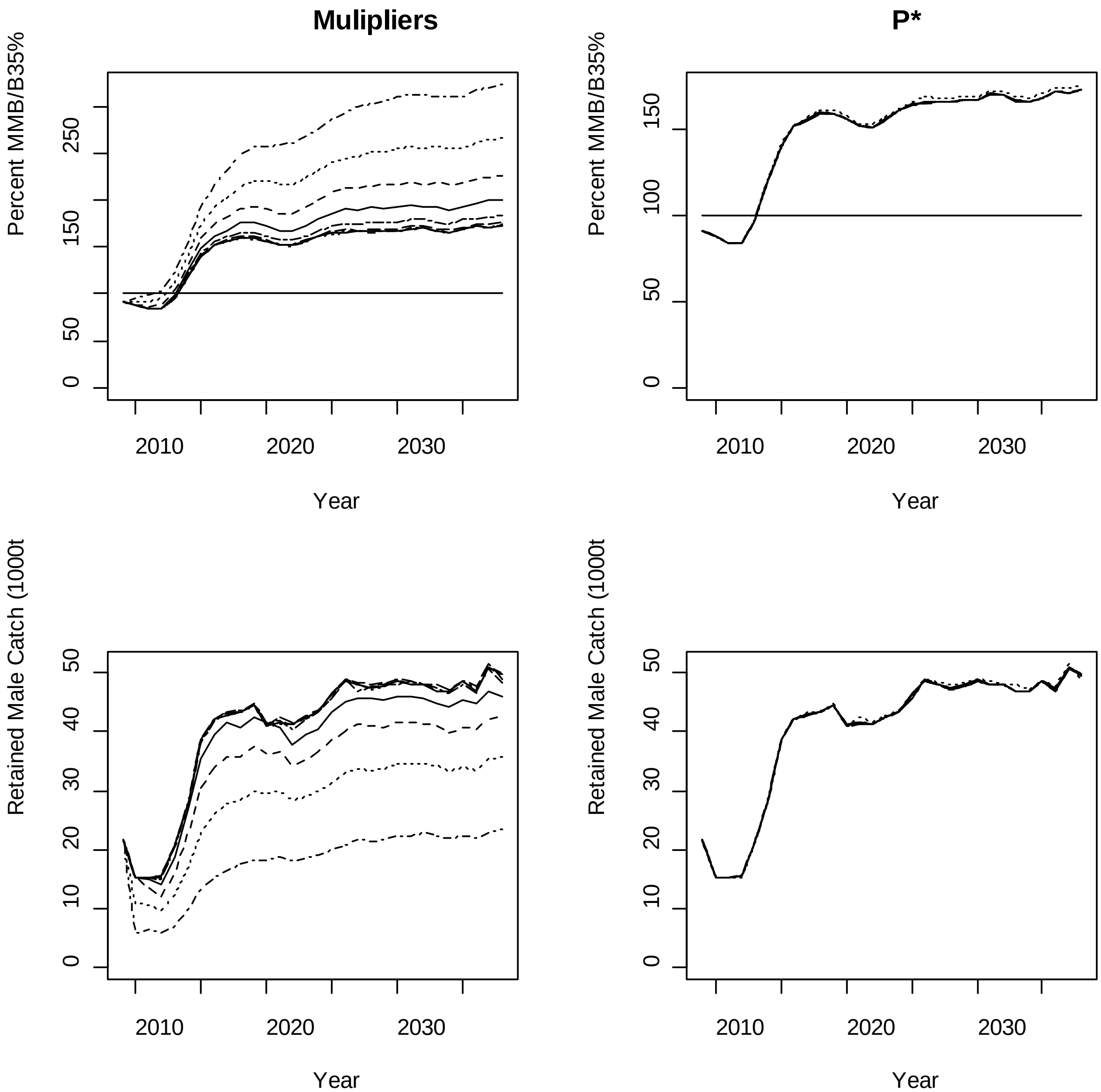


Figure 4-8 **Median time-trajectories of percent mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (B_{35}) and median time-trajectories of the catch of retained males in the directed fishery for different multipliers (0.10 to 1.0) and different P* (0.05 to 0.45). The results in this figure are based on the Beverton-Holt stock-recruitment relationship with the SOA harvest strategy.**

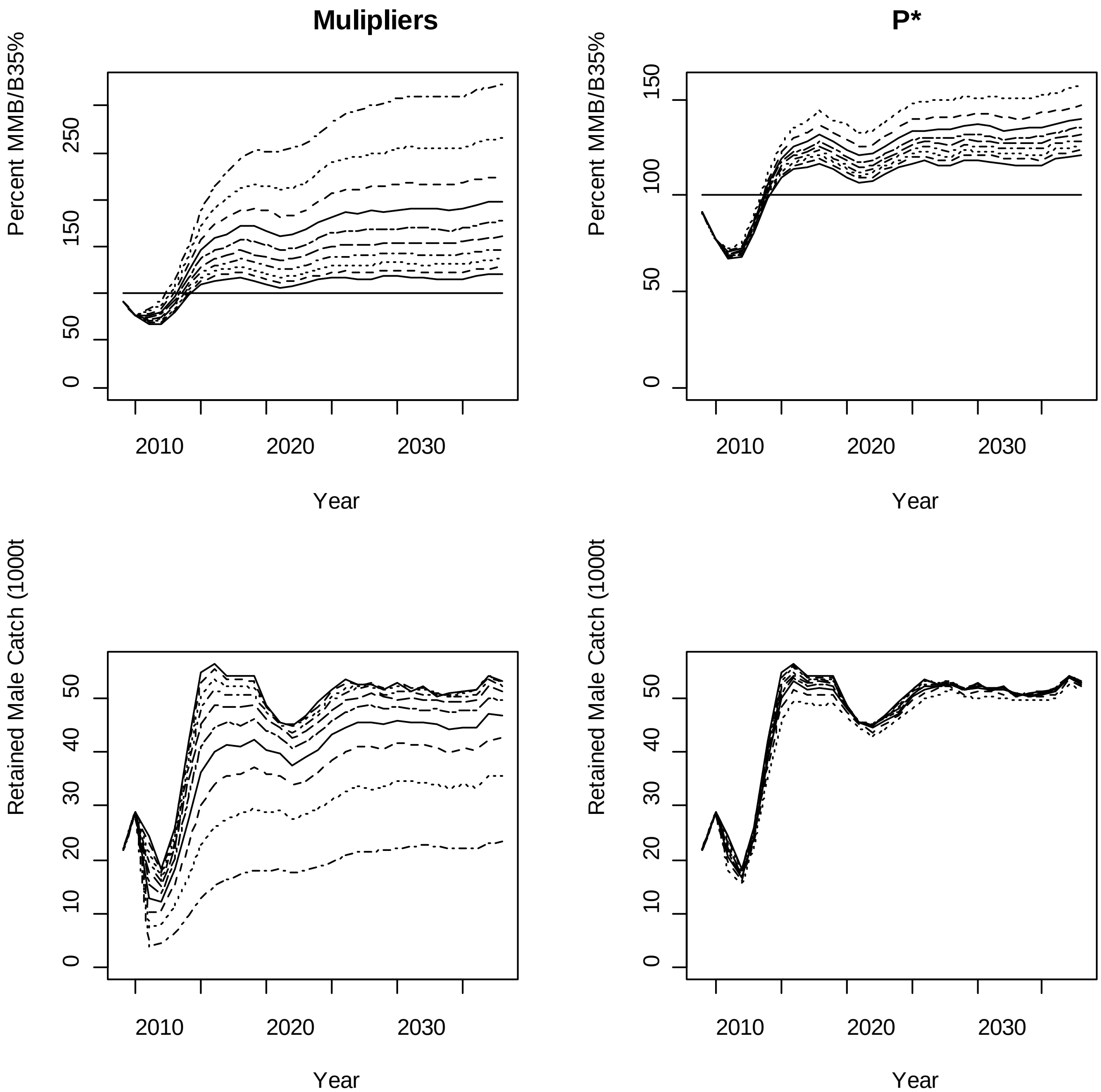


Figure 4-9 **Median time-trajectories of percent mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (B_{35}) and median time-trajectories of the catch of retained males in the directed fishery for different multipliers (0.10 to 1.0) and different P* (0.05 to 0.45). The results in this figure are based on the Beverton-Holt stock-recruitment relationship without the SOA harvest strategy.**

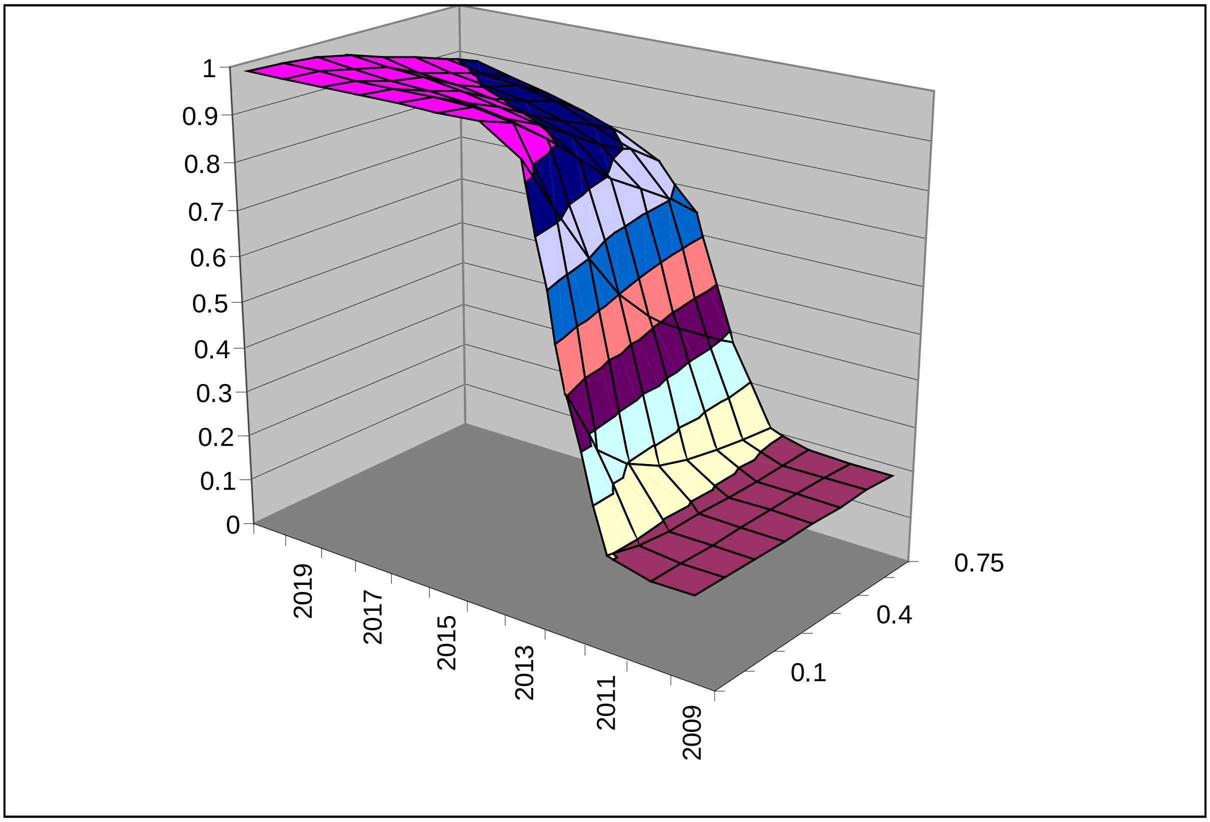


Figure 4-10 Probability of rebuilding (1 year) by multiplier and year.

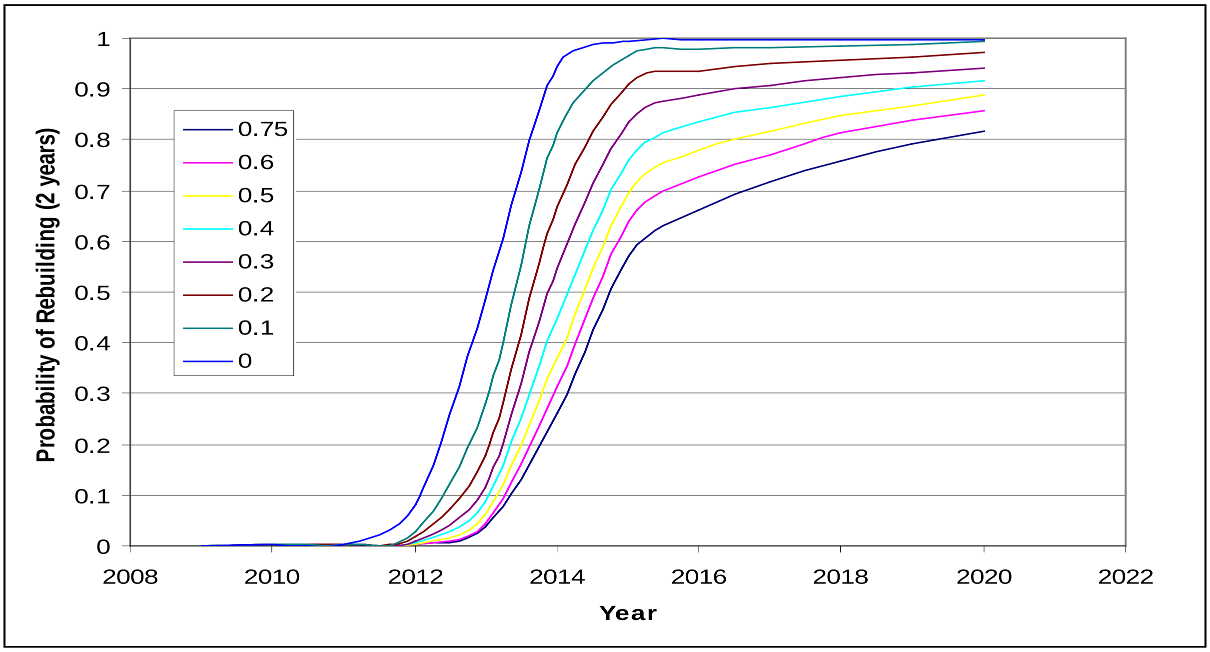


Figure 4-11 **Probability of rebuilding (2 yrs). Lines from left to right are for multipliers of 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75.**

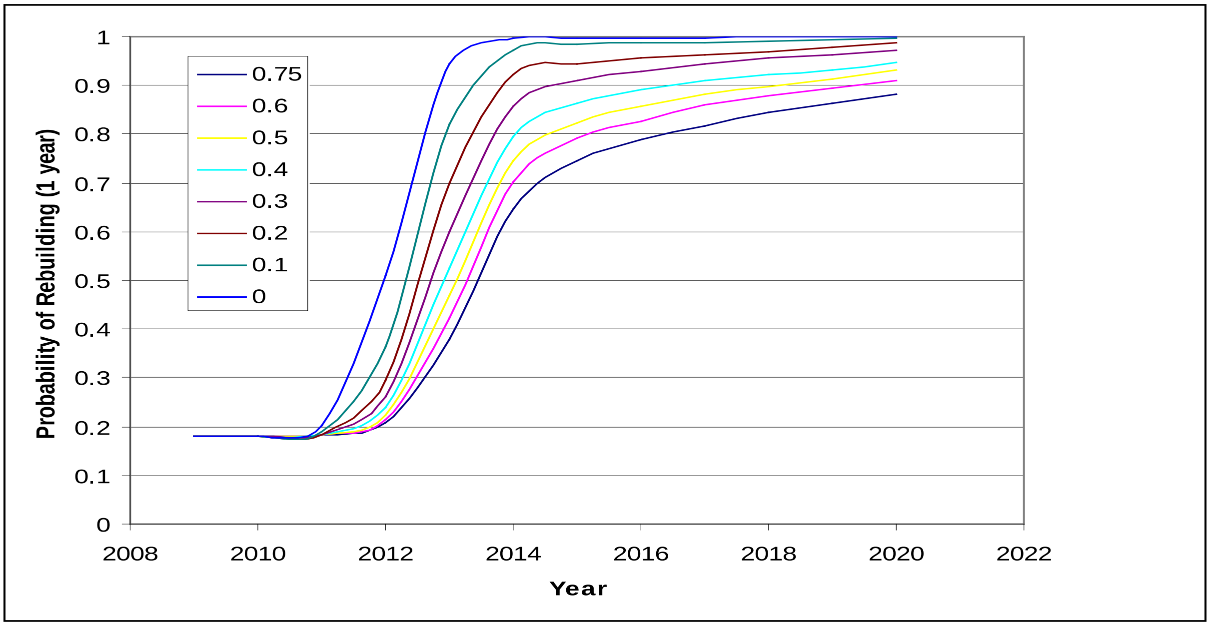


Figure 4-12 **Probability of rebuilding (1 yrs). Lines from left to right are for multipliers of 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75.**

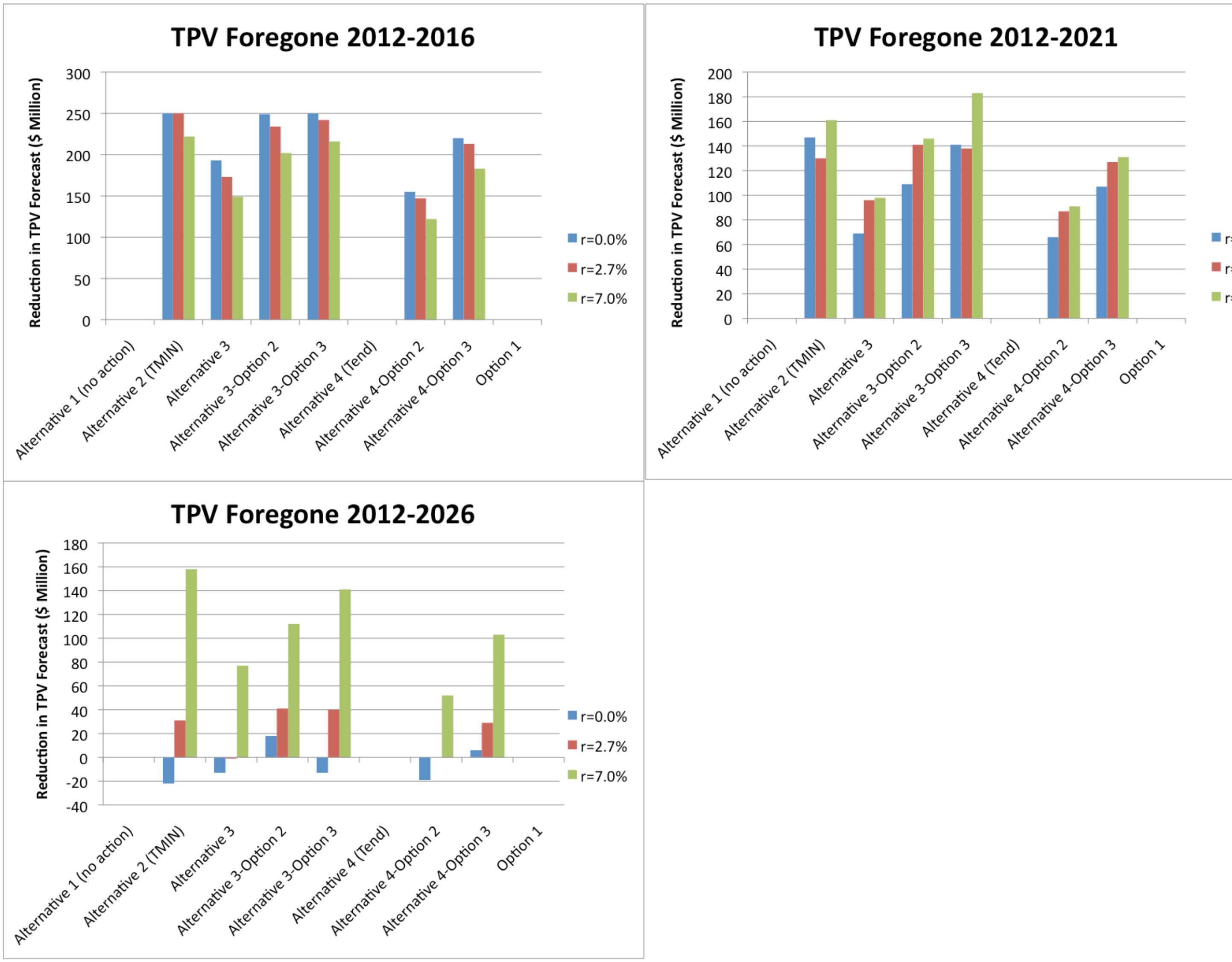


Figure 4-13 **Economic effects of rebuilding alternatives, potential total present value of gross first wholesale revenue foregone, 5, 10, and 15 Year Forecast**

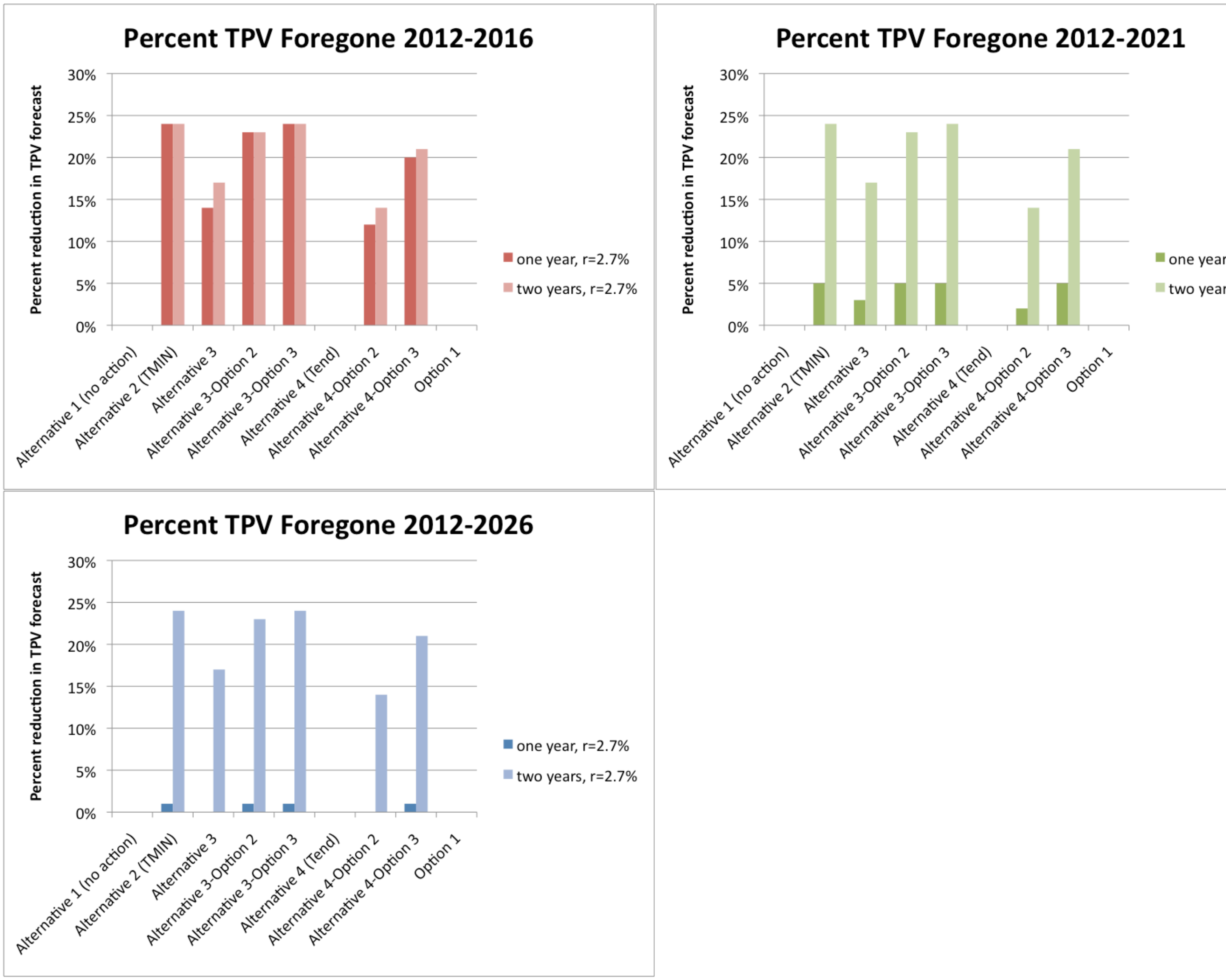


Figure 4-14 **Economic effects of rebuilding alternatives, one and two year rebuilding, percentage of gross first wholesale revenue foregone relative the no-action alternative, 5, 10, and 15 year forecast**

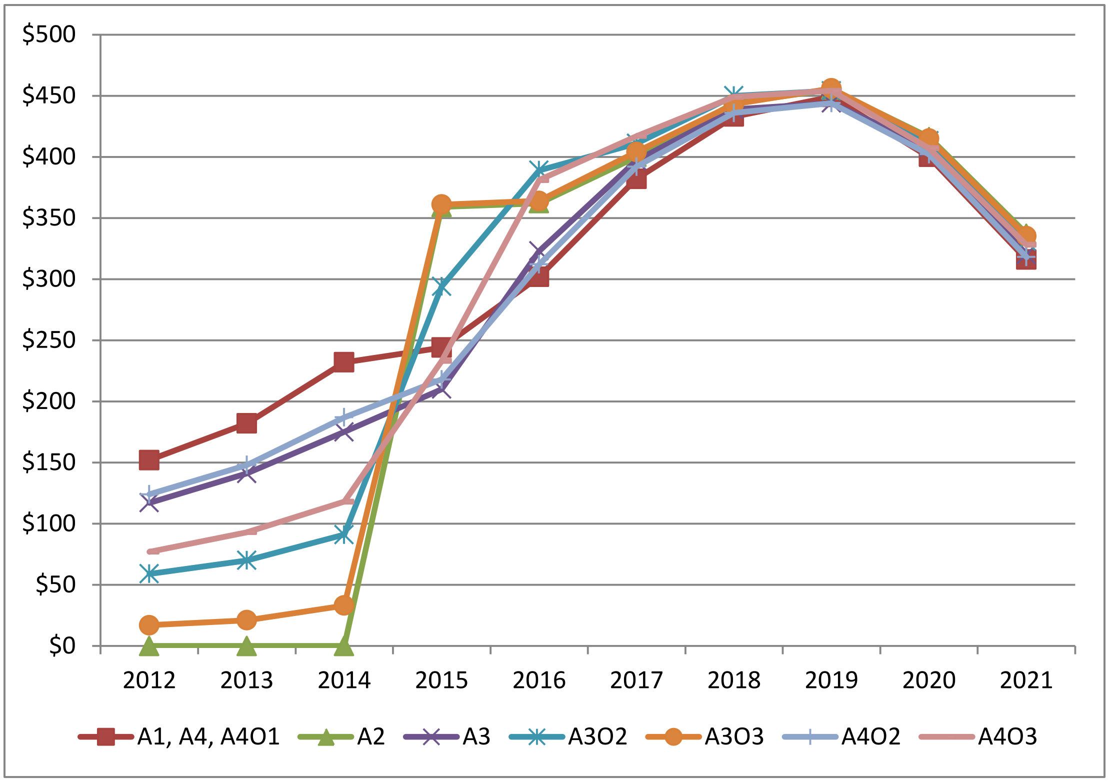


Figure 4-15 **Annual Revenue Estimates by Alternative and Option, Over Ten Rebuilding Years (S millions).**

5 EBS Tanner Crab

Tanner crab *Chionoecetes bairdi* is one of five species in the genus *Chionoecetes*. The common name for *C. bairdi* of "Tanner crab" (Williams et al. 1989) was recently modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" has also been used to refer to other members of the genus, or the genus as a whole. Hereafter, the common name "Tanner crab" will be used in reference to "southern Tanner crab".

Tanner crabs are found in continental shelf waters of the north Pacific. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974) and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east.

In the EBS, the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break where water temperatures are generally warmer. The southern range of the cold water congener the snow crab, *C. opilio*, in the EBS is near the Pribilof Islands (Turnock and Rugolo 2010a). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 58°N, and in this area, the two species hybridize (Karinen and Hoopes 1971).

Tanner crabs in the EBS are considered to be a separate stock distinct from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998)**.** The stock is assumed to be a single unit across the geographic range of the EBS continental shelf, and the status determination criteria are established for this one stock, however the stock is managed as two fisheries, east and west of 166^{o} W longitude. Differences in some biological characteristics may exist across the range of the unit stock (Somerton 1981a).

5.1 Assessment overview

For this chapter, survey biomass data through 2009 and fishery data through the 2008/09 season were included. For the purpose of performing the ACL analysis and making stock projections under the two alternative options (namely, P* and multiplier), the 2010 survey biomass estimates were set equal to those of 2009, and the 2009/10 fishery performance (retained catch, discard plus bycatch losses) set equal to the catch components projected in the 2009 SAFE (Rugolo and Turnock 2009).

As reported in Rugolo and Turnock (2009), Tanner crab MMB in 2009/10 declined substantially from previous years and it was below the minimum stock size threshold at survey time (MSST=0.5B_{REF}). Under the current plan, MMB estimated at the time of mating (mid-February) is gauged against the MSST to determine its status relative to the overfished criterion. This accounts for losses due to natural morality from the survey to the time of mating and losses due to directed and non-directed fishing in 2009/10. For the 2009/10 stock status determination, B_{REF}=86.08 thousand metric tonnes (t) and the overfished status criterion, MSST, was 43.04 thousand t. After accounting for all losses to the stock from natural mortality and the 2009/10 fisheries, the 2009/10 MMB at the time of mating (mid-February 2010) was 32.52 thousand t. This represents a ratio of 0.38 relative to B_{REF} which is below the limit that defines an overfished stock.

Tanner crab MMB at the time of the 2010 survey declined further relative to 2009 (Rugolo and Turnock 2010a). ADF&G closed the directed Tanner crab fishery for 2010/2011. However, even under a zero retained catch harvest strategy in 2010/11, there is no change in the 2010/11 stock relative to the overfished determination made in the 2010 stock assessment (Rugolo and Turnock 2010a).

In 2010, Tanner crab MMB at the time of the survey was estimated at 32.08 thousand t representing a 9.1% decrease relative to 2009. Mature male abundance fell 9.4% relative to 2009 and legal males were sparsely and patchily distributed throughout the survey range with regions of highest abundance in southwestern Bristol Bay and the Pribilof Islands. The total abundance index for legal males increased 13.7% to 8.0 million crabs between 2009 and 2010 owing largely to a high-density station in the area of the Pribilof Islands. Legal males were distributed 56.1% (4.5 million crabs) east and 43.9% (3.5 million crabs) west of 166^o west longitude which was comparable to the apportionment in 2009 (Rugolo and Turnock 2009). The 2010 abundance index for pre-recruit male crabs (110-137 mm cw) declined 15.4%, and that for small males (<110 mm cw) increased 13.9% relative to 2009. Total male abundance increased 8.5% between 2009 and 2010 which was largely driven by the increase in small males (<110 mm cw). Comparison of the male size frequency distributions between 2006 and 2010 revealed a decline in male abundance above 70 mm cw between 2009 and 2010, and a relatively increasing percentage of old shell crabs in the mature male stock. The recruit mode (20-40mm cw) seen in 2009 grew to 30-50 mm cw in 2010. The decline in male abundance in 2010 above 70 mm cw coupled with the relatively high percentage of old and very old shell males in the mature stock is an issue of concern regarding future reproductive potential (Rugolo and Turnock 2010a).

Large female (>=85 mm cw) Tanner crab revealed a substantial 49.7% decrease in abundance in 2010 relative to 2009, and mature female abundance was comprised of 79.5% old shell females. Among all female Tanner crab in 2010, 15.5% were collectively old shell and 82.7% new-hard shell. Small females (<85 mm cw) increased by 13.8% relative to 2009. Total 2010 female abundance increased 8.5% which was largely influenced by the increase in small females <85 mm cw. Total survey abundance of males and females combined increased 9.3% over that in 2009 driven by the increase in both small male and small female crabs. The survey length frequency distributions of female Tanner crab from 2006-2010 revealed consistently declining abundance across the size modes and the general failure of modes of abundance to persist inter-annually. The prominent length mode between 65-75 mm cw seen in 2006 did not persist in expected levels of abundance in 2007 through 2010. The moderate mode of female abundance above 60 mm cw seen in 2009, which was dominated by old and very old shell females, declined substantially in 2010. A modest mode of new shell recruits seen in 2009 at 25-30 mm cw persists in 2010 at 35-50 mm cw. A relatively strong recruit mode (35-50 mm cw) is apparent in the 2010 survey data (Rugolo and Turnock 2010a).

Tanner crab is managed as a Tier 4 stock. The proxy B_{MSY} for OFL-setting is the reference biomass (B_{REF})=83.80 thousand t of MMB at the time of mating estimated as the average survey male mature biomass at mating from 1969-80 inclusive. For Tier 4 stocks, the F_{OFL} is derived using an F_{OFL} Control Rule based on the relationship of current male mature biomass to B_{REF} as a proxy for B_{MSY}. Here, $F_{OFL}=\gamma M$. The Amendment 24 and its associated EA defines a default value of gamma=1.0 (NMFS 2008). Gamma is allowed to be less than or greater than unity resulting in overfishing limits more or less biologically conservative than fishing at M. Amendment 24 also cautions that γ should not be set to a value that would provide less biological conservation and more risk-prone overfishing definitions without defensible evidence that the stock could support fishing at levels in excess of M. The resultant F_{OFL} for Tier 4 stocks is specified in terms of a Total Catch OFL that includes all stock losses (retained catch, discard and bycatch mortalities) for males and females combined by the directed and all non-directed fisheries.

The value of M for Tanner crab is 0.23. In this analysis, gamma is set to 1.0. The projected 2010/11 estimate of MMB at the time of mating is 26.07 thousand t. Relative to B_{REF}, $MMB_{2010/11}/B_{REF}=0.31$. Under the OFL Control Rule, the 2010/11 $F_{OFL}=0.05$ (Rugolo and Turnock 2010a).

For the 2010/11 Tanner crab fishery, Rugolo and Turnock (2010a) estimated the Total Catch OFL=1,612.1 t for males and females combined. (Note, here the catch components are in tonnes for clarity as the values in 1000 t for some components are small at one significant digit). Total losses to MMB in the 2010/11 Total Catch OFL are 1,445.5 t. Directed and non-directed discard losses to MMB in 2010/11 are estimated to be 46.4 t and 1,312.1 t, respectively. The retained part of the catch OFL of legal-sized crabs is 87.0 t. The retained legal catch would comprise 6.4% of the total MMB losses projected in 2010/11. Thus, a significant component of MMB losses is attributed to non-targeted losses under current fishing practices.

Expected discard losses of female Tanner crab from the 2010/11 groundfish fishery and the directed pot fishery combined was estimated at 166.6 t. Estimated exploitation rates on LMB and MMB associated with these projected catches are 0.03 and 0.05 respectively (Rugolo and Turnock 2010a).

A length-based Tanner Crab stock assessment model (TCSAM) and projection model was developed for this analysis (Rugolo and Turnock 2010b). The snow crab stock assessment model (COSAM) and projection model were adapted for the Tanner crab stock. A progress report on the results of model development was presented to the CPT in March 2010 and to the SSC in April 2010. The authors' goal is to complete TCSAM development and have it approved by the CPT in May 2011 and by the SSC in June 2011 for application in 2011/12 OFL-setting. The TCSAM will incorporate population and survey performance metrics from time series survey data from 1969-2010. For this stock, the early years (1969-1975) in the survey time series are critical to deriving biological reference points and threshold stock definitions. This is being accomplished through the work of the Shellfish Assessment Program who is performing a retrospective examination of the historical time series data and re-estimating biomass and abundance for all targeted EBS crab stocks. An essential requirement to successful model development is also a consistent time series of survey population metrics, life-history parameters and biological schedules. The ultimate goal is to promote the Tanner crab stock to a Tier-3 management status, and to formulate OFLs based on the TCSAM. While the TCSAM is not yet approved by the Council for OFL-setting, the authors and CPT agreed in March 2010 that the initial model provides suitable estimates of fishery and population dynamic parameters, and stock metrics to serve the basis of this ACL analysis.

For this EA, we formulated the TCSAM and other projection models to perform stock simulations needed to evaluate ACLs and the consequences of alternative strategies on stock and fishery performance. For the estimation of the impacts of the ACLs on the 2010/11 stock and fishery, we employed the Tier 4 control rule approach (Rugolo and Turnock 2010a). For the 30th year projections, the OFL is based on the Tier-3 control rule, i.e. the proxy for F_{MSY} is taken to be $F_{35\%}$ while the proxy for B_{MSY} is taken to be B_{35} (NPFMC, 2008). Under both the Tier-3 and Tier 4 approaches, the OFL is a total-catch OFL, computed as the sum of catches by five different sources of removals: (a) the retained legal males in the directed fishery for Tanner crab, (b) discards of males and females in the directed fishery, (c) bycatch in the EBS snow crab pot fishery, (d) bycatch in the Bristol Bay red king crab pot fishery, and (e) bycatch in the EBS groundfish fisheries.

The TCSAM is specified for the unit stock distributed over the EBS shelf. Despite the custom of setting management controls for this stock east and west of 166^{o} W longitude, the unit stock of Tanner crab in the eastern Bering Sea comprises crab throughout the geographic range of the NMFS trawl survey. At the May 2010 meeting, the CPT considered genetic evidence presented in support of partitioning the EBS Tanner crab population into two stocks east and west of 166 degrees W longitude. The CPT found this evidence lacking. In developing TCSAM, Rugolo and Turnock (2010b) found no evidence to support the argument that the eastern Bering Sea shelf is member to two distinct, non-intermixing, non-interbreeding stocks of Tanner crab in which the linked population and fisheries dynamics are bifurcated east and west of 166^{o} W longitude. In one case, they examined whether the data supported differences in male and female maturity east and west of 166^{o} W longitude and found no significant differences in maturity requiring a spatially-explicit assessment model. Nevertheless, given requisite understanding of the geographic fidelity of the stock over its range, and its availability to the fisheries, partitioning the total catch OFL may be possible *a posteriori* to allow setting management controls for the Eastern and Western Districts consistent with the total catch OFL that may underlie optimum harvest strategies.

The calculation of the OFL is based on the assumptions that the F_{OFL} is the fishing mortality rate, F, from the directed Tanner crab fishery for total males plus the full-selection F for males in the snow crab and Bristol Bay red king crab pot fisheries, and groundfish fisheries (full-selection fishing mortality). The future full-selection retained fishing mortality rate for males in the directed fishery is given by the directed fishery component of the F_{OFL} multiplied by the fishery selectivity for retained males estimated from the assessment model. The future fishing mortality rate on Tanner crab in the snow and Bristol Bay red king fisheries and the groundfish fisheries equals the average value over the last three years using the respective fishery selectivity curves estimated from the assessment model. Thus, changes to F_{OFL} directly impact the predicted catches of retained males in the directed fishery as well as the predicted discard of males and females in the directed fishery, while the fishing mortality rates leading to bycatch in the snow and red king crab pot fisheries, and groundfish fisheries are constant and independent of $F_{OFL.}$

When compared to the OFL control rule adopted as part of Amendment 24, the catch of Tanner crab and the fishing mortality rates on males associated with the catches of Tanner crab have often exceeded the OFL (Rugolo and Turnock 2010b). This did not constitute overfishing in the past because Amendment 24 was not implemented until 2008.

5.1.1 Uncertainty in stock assessment

Compared to other Tier 3 crab stocks, the uncertainty associated with the estimates of stock size and OFL for Tanner crab may be relatively high. Tanner crab in the EBS is not well-studied, compared to snow crab.

The coefficient of variation for the observed survey estimate of mature male biomass for 2009 is 14.1%. A coefficient of variation of 0.05 taken from the COSAM was used in this analysis as we consider that with this initial TCSAM formulation, the model CV estimate of 0.01 was unreliable. Several potential sources of uncertainty that pertain to Tier-3 stocks are not included in the measures of uncertainty reported as part of the stock assessment. These include the following:

- Several of the key population dynamic parameters and life-history rates and schedules (natural mortality, size-weight, maturity) which are pre-specified and not estimated.
- F_{msy} is assumed to be equal to $F_{35\%}$ when applying the OFL control rule.
- B_{msy} is assumed to $B_{35\%}$ with average biomass corresponding to MSY calculated over the years 1969-1980 using observed survey mature male biomass at the time mating. Recruitment was very likely much higher before the peak stock biomass in the late-1960s to early 1970s and these are not estimated by the current model. The stock followed a 'one-way trip' from peak abundance in 1969 and recruitments during this time period were not adequate to produce higher biomass levels observed in the early time period (Rugolo and Turnock 2010b). The stock appears to not have persisted at equilibrium B_{MSY} and was exploited at rates in excess of F_{MSY} and those that we would consider biologically meaningful for this stock (Rugolo and Turnock 2010a and 2010b). Considerable uncertainty exists in the specification of B_{MSY}.

At its March 2010 meeting, the CPT recommended that the additional uncertainty level for this stock is medium. For this analysis, the value used for the medium level of additional uncertainty is 0.3, as recommended by the SSC. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different that 0.3. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

5.2 Impacts of alternatives

As described in Chapter 2, there are two alternative methods under consideration for computing an ABC for Tanner crab: (a) the total catch OFL can be multiplied by a pre-specified value or multiplier (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4).

The analysis of impacts in this chapter are based on the assumptions that the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA harvest strategy (i.e. no sector-specific ACLs are implemented), that the ACL applies to all removals of Tanner crab (a total-catch ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the groundfish fisheries and in the snow crab and Bristol Bay red king crab pot fisheries. A total catch ACL can be computed from the output of the SOA harvest strategy, which pertains to the retained catch in the directed fishery, by adding the estimates of bycatch and discard to the output from the SOA harvest strategy. See Appendix 3 for description of SOA Tanner crab harvest strategy.

The short- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by the impact of multiplier and P* values on the ABC which would be advised for the 2010/11 fishery. Short-term implications of the alternatives are based on calculations of the ABC and catch components using the Tier 4 approach (Rugolo and Turnock 2010a).

The long-term implications are evaluated by projecting the population ahead 30 years[60] under the assumptions that the catch equals the lower of the ABC and that the total catch corresponds to the TAC computed using the Tier-3 approach both with and without the SOA harvest strategy constraining the ABC, and that the catch equals the ABC. Use of the SOA harvest strategy is equivalent to assuming that the TAC is set equal to the component of the ABC which is estimated to consist of legal male crab caught by the directed fishery. The uncertainty associated with the long-term projections are necessarily higher than those associated with the short-term implications given that these projections rely on assumptions regarding the form of the stock-recruitment relationship which is very uncertain for all crab stocks, including Tanner crab.

Medium-term biological and economic implications are not assessed in this document because the necessary analysis is not possible without a more developed stock assessment model.

5.2.1 Short-term implications

The short-implications focus on the size of the ABC for the 2010/11 fishing year. Given a one-year projection, it is not feasible to assess the biological implications of the choice of an alternative.

Table 5-1 lists the ABC values for the 2010/11 fishing year for the multiplier (a) and P* (b) alternatives, along with the corresponding estimate of what the catch could have been in the directed fishery calculated using the Tier 4 approach. The difference between ABC_{tot} and ABC_{dir} reflects the losses to discard in the directed fishery, and to bycatch in the snow crab and Bristol Bay red king crab pot fisheries and groundfish fisheries. Uncertainty was incorporated in the 2010/11 ABC in the estimation of survey

[60] 30 years is sufficiently long so the resource equilibrates close to the proxy for B_{MSY} under deterministic conditions (no fluctuations in recruitment about the assumed stock-recruitment relationship).

biomass from the log-normal distribution incorporating σ_w=0.14 and σ_b=0.30 (σ_{total}=0.304), and in the estimation of B_{REF} from the distribution based on non-parametric bootstrapping of the 1969-80 survey estimates of MMB at mating.

For the 2010/2011 fishery, ADF&G closed the directed Tanner crab fishery due to low female abundance, a factor not considered in the calculation of the OFL, which is set for mature male biomass. The fact that the fishery was closed is not reflected in this analysis. Given that a stock assessment model is under development for this stock, these results should be viewed as the best available at this stage but that actual ABCs will be revised once the stock assessment model has been approved.

Under Alternative 4, once the stock assessment model is approved, the stock assessment model would be used each year to calculate an ABC with a P* of 0.49. According to Table 5-1a, a P* of 0.49 would result in a 20% buffer between the OFL and ABC.[61] As expected, a lower multiplier leads to lower ABC levels and a lower probability that the ABC is greater than the true OFL. Table 5-1a shows a linear relationship between the ABC and multiplier (with the ABC set equal to the OFL for a multiplier of 1.0 and being approximately 10% of the ABC for a multiplier of 0.1). The relationship between the multiplier and P*, in contrast, is not linearly proportional (Table 5-1b). At a multiplier of 1.0, the total ABC is 2.03 thousand t and the retained catch is 0.40 thousand t in 2010/11. Table 5-1(b) shows the corresponding values of catch components at pre-specified percentiles of the distribution of the OFL. The total ABC and directed catch decrease from 1.67 and 0.32 thousand t to 0.81 and 0.16 thousand t, respectively at P* of 0.50 and 0.25. Total ABC and retained catch values are not shown for values of P* equal to 0.20 or less since, even at a multiplier of 0.1, the probability of overfishing exceeds 0.20. Figure 5-1 through Figure 5-2 show the distributions of the various metrics used in the Tier 4 calculation of the ABC. Figure 5-1 shows the distribution of B_{REF} used in the control rule resulting from non-parametric bootstrap sampling of the 1969-80 survey estimates of male mature biomass at mating. The vertical line represents the mean B_{REF}=83.80 thousand t. The distribution of MMB at mating given the uncertainty in the OFL reveals that the majority of the distribution is less than B_{REF} which is consistent with the overfished status determination (Rugolo and Turnock 2010a) (Figure 5-2). Given the status of the 2009/10 stock, the distribution of the full-selection F_{OFL} reveals that the majority of F_{OFL} values are less than M, and approximately 25% of the F_{OFL} values estimated are zero (Figure 5-4). Figure 5-4 shows the distribution of the total catch OFL given the uncertainty incorporated in the Tier 4 approach and it reveals that a similarly high percentage (~30%) of catch OFLs are estimated to be zero.

The relationship between the probability of overfishing and the OFL multiplier from the Tier 4 calculation of the total catch OFL in 2010/11 is shown in Figure 5-5. At multiplier values from 0.1 to 0.3, the probability of overfishing varies without trend at approximately 0.24, and rises sharply at multiplier values of 0.40 and greater. The probability of overfishing is approximately 0.50 at a multiplier of 0.82 and rises to approximately 0.60 at a multiplier of 1.0. As noted above, Alternative 4 would equate to a multiplier of 0.8.

5.2.2 Long-term implications

Table 5-2 summarizes the key parameters which determine the productivity of the population for the Beverton-Holt stock-recruitment relationship used in long-term stock projections. Note that B35 (83.80 thousand t) is 27.2%, not 35% of the unfished mature male biomass at mating (308.52 thousand t). This is because recruitment is not independent of mature male biomass at mating. The extent of uncertainty captured within the stock assessment, σ_w, was set at 0.05, equivalent to the 2009 snow crab assessment.

[61] This analysis uses the mean for the probability distribution of the OFL, which provides different results than applying the median due to skewness, as discussed in section 3.2.4.2.

5.2.2.1 Long-term implications - Biological

Table 5-3 summarizes the results of the long-term consequences of the two alternatives in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period, "Prob (overfished) A", (b) the annual probability of the mature male biomass at mating dropping below the overfished level, "Prob (overfished) B", (c) the annual probability of the catch exceeding the true OFL, "Prob (overfishing)", (d) the probability of TAC being computed by adding predicted bycatch and discard to the output from the SOA harvest strategy, "Prob (SOA)", and (e) the median and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period, "C_{dir}". As expected, all tabled metrics of long-term consequences decrease with decreasing multiplier. The probability of the MMB at mating dropping below the overfished threshold at least once over the 30-year period is 1.0 for levels of multiplier both with (column 3) and without (column 8) the SOA harvest strategy constraining the total catch OFL. For multipliers 1.0 to 0.1, the annual probability of the catch exceeding the true OFL decreases from 0.445 to 0.0 (column 10). If the SOA harvest strategy is allowed to constrain the OFL, protection against the risk of overfishing is conferred to the stock with these values decreasing from 0.340 to 0.0 for multipliers 1.0 to 0.1 (column 5). The values of retained catches at multipliers 0.6 and greater are internally similar for the option with the SOA harvest strategy (column 7) and without the SOA harvest strategy constraining the OFL (column 11). This suggests that a multiplier of 0.6 to 0.7 would yield equivalent long-term value to the fishery while conferring protection against the risk of overfishing compared to fishing at higher ABC levels – i.e., higher multipliers. For example, with the SOA harvest strategy in effect, a multiplier of 0.6 yields 17.2 thousand t of retained catch versus 17.6 thousand t where the ABC=OFL (M=1.0) (column 7), whereas the probability that the catch exceeds the OFL is more than five-fold (i.e., 0.060 to 0.0.340) at these multipliers. Similarly, without the SOA harvest strategy constraining the OFL, the estimated retained catch is 18.0 and 19.5 thousand t at multipliers of 0.6 and 1.0 respectively (column 11), however, there's a greater than seven-fold increase in the probability of overfishing at a multiplier of 1.0 versus 0.6 (i.e., 0.445 versus 0.064).

Results of the P* alternative both with and without the SOA harvest strategy constraining the total catch OFL are also shown on Table 5-3. The values of the multipliers corresponding to the P* 0.05 to 0.50 are shown in column 2. The range of P* from 0.05 to 0.50 equate to multipliers 0.567 and greater. Thus, tabled stock metrics under the P* alternative represent the upper one-half of tabled values for the multiplier alternative. Figure 5-6 shows comparison of the relationship between the OFL multiplier and retained catch in the 30^{th} year both with and without the SOA harvest strategy constraining the OFL. Retained catches are similar with and without the SOA harvest strategy for multipliers 0.5 and less, and most different for multipliers 0.7 and higher (Figure 5-6, Table 5-3). The relationship between P* and the retained catch in the 30^{th} year both with and without the SOA harvest strategy constraining the total catch OFL is shown in Figure 5-7. Over the range of P* from 0.05 to 0.50, the difference in retained catch are similar and trendless between the two alternatives for P* 0.20 and greater. Application of the SOA harvest strategy equates to a P* value between 0.30 and 0.35; thus, Alternative 4 is indistinguishable from selection of a P* value in this range. Over the long-term, not much difference in retained catch is evident over the range of P* values. The stock is expected to rebuild in the long-term and, due to built-in rebuilding feature of the sloping control rule, the stock is expected to be above B_{REF} on average in the long-term which adds stability to the fishery in term of yield and a relatively low risk of overfishing at multipliers 0.6 to 0.7.

The current analyses are unable to predict the extent to which the uncertainty in terminal biomass will change over the next 30 years nor whether estimates of the extent of uncertainty not captured by the assessment will change over time. The results in Table 5-3 and Figure 5-6, and Figure 5-7 are based on pre-specified multipliers. There is, however, a direct relationship between multiplier values and choices for P* under the assumption that estimates of σ_b and σ_w do not change over time. These results provide a basis to evaluate different choices for P* and OFL multiplier for the Tanner crab stock.

5.2.2.2 Long-term implications - Economic

The long-term economic impacts of ACL alternatives are summarized in Table 5-4. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the long term. Table 5-4 (a) and (b) presents the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2038, and the comparative economic effects of alternatives in foregone revenue relative to a zero buffer (P*=0.5, multiplier=1.0). For Tanner crab, uncertainty was fixed at σ=0.3 (note that stock simulation results for σ=0 were not produced for Tanner crab). The SOA control rule represents status quo.

Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC, (Table 5-4(a)) and scenarios without the SOA control rule Table 5-4(b)). With the SOA control rule, results for P* values, with σ_b= 0.3 show minimal foregone revenue relative to a zero buffer. The estimate of total potential foregone revenues for the six years ranges from 1% to 58%, for multiplier levels 0.6 to 0.1. At multipliers above 0.6, which includes Alternative 4, the SOA control rule is a binding constraint. This reflects the fact that SOA control rule constraints are more limiting than the ABC at higher multiplier levels. This means that the impacts of Alternative 4 and the multipliers above 0.6 are the same as status quo.

Results of economic comparisons between ACL alternatives resulting from catch projections without SOA constraints (which means assuming catch = ABC) are shown in Table 4-6(b). The reduction in revenue from a zero buffer range from 2% at a multiplier of 0.9 to 85% at a multiplier of 0.1. While the SOA control rule remains in effect as the protocol for TAC-setting, the potential foregone revenues that could result from the ACL alternatives would increase substantially relative to a zero buffer if the ABC as the binding constraint on TAC rather than the SOA control rule. Note that a zero buffer does not represent the status quo alternative, but is intended to provide a representation of the effects of ACL alternatives under potential future decision-making scenarios when the SOA control rule is not binding. It should be noted that this comparison shows that the SOA rule effectively represents a buffer in itself.

5.3 Tables and Figures

Table 5-1 Values of Tanner crab catch-related quantities for 2010/11 and the relationships between the Multiplier (a) and P* (b) for each of the alternatives given the extent of additional uncertainty, σ_b=0.30. Results based on Tier 4 survey biomass methods for estimating OFL distribution.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (1000 t)	C_{dir} (1000 t)	P[Overfishing]	Revenue Millions $
M = 1.0	2.03	0.40	0.604	4.4
M = 0.9	1.83	0.36	0.549	3.96
M = 0.8	1.63	0.32	0.490	3.52
M = 0.7	1.42	0.28	0.427	3.08
M = 0.6	1.22	0.24	0.358	2.64
M = 0.5	1.02	0.20	0.295	2.2

M = 0.4	0.81	0.16	0.250	1.76
M = 0.3	0.61	0.12	0.236	1.32
M = 0.2	0.41	0.08	0.235	0.88
M = 0.1	0.20	0.04	0.235	0.44

(b) ACL defined by P* (σ_b=0.30)

Alternative	ABC_{tot} (1000 t)	C_{dir} (1000 t)	Multiplier	Revenue Millions $
P^* = 0.50	1.67	0.32	0.82	3.61
P^* = 0.45	1.48	0.29	0.73	3.21
P^* = 0.40	1.34	0.26	0.66	2.90
P^* = 0.35	1.20	0.23	0.59	2.60
P^* = 0.30	1.04	0.20	0.51	2.24
P^* = 0.25	0.81	0.16	0.40	1.76
P^* = 0.20	n/a	n/a	n/a	
P^* = 0.15	n/a	n/a	n/a	
P^* = 0.10	n/a	n/a	n/a	
P* = 0.05	n/a	n/a	n/a	

Table 5-2 Values for key parameters of the population dynamics model used for projection purposes.

Parameter	Distribution
Beverton-Holt stock-recruitment relationship	
Virgin recruitment, R_0	349,896,000
Virgin MMB (1000 t)	308.52
Steepness, h	0.726
F_{MSY} ($F_{35\%}$) y^{-1}	0.687
B_{MSY} ($B_{35\%}$) (1000 t)	83.80
σ_R	1.25

Table 5-3 Summary of the long-term consequences of the alternatives for Tanner crab. The column "C_{dir}" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2038. The results in the table are based on the extent of additional uncertainty, σ_b = 0.30.

Alternative	With SOA Control Rule						No SOA Control Rule			
	Multiplier	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	C_{dir} (2038) (1000 t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	C_{dir} (2038) (1000 t)
M = 1.0		1.0	0.050	0.340	0.220	17.6(2.9,63.5)	1.0	0.071	0.445	19.5(3.3,63.8)
M = 0.9		1.0	0.037	0.285	0.202	17.7(3.1,62.3)	1.0	0.053	0.338	19.5(3.2,62.7)
M = 0.8		1.0	0.028	0.215	0.163	17.5(3.1,60.5)	1.0	0.041	0.228	19.3(3.3,60.5)
M = 0.7		1.0	0.023	0.128	0.119	17.4(3.2,58.6)	1.0	0.027	0.137	18.8(3.3,59.1)
M = 0.6		1.0	0.017	0.060	0.075	17.2(3.3,56.9)	1.0	0.020	0.064	18.0(3.2,56.9)
M = 0.5		1.0	0.015	0.022	0.047	16.4(3.2,53.4)	1.0	0.015	0.022	16.7(3.1,53.9)
M = 0.4		1.0	0.010	0.008	0.019	14.9(3.1,49.1)	1.0	0.010	0.008	15.1(3.2,48.7)
M = 0.3		1.0	0.007	0.000	0.005	12.7(3.0,41.3)	1.0	0.007	0.001	12.7(3.0,41.3)
M = 0.2		1.0	0.003	0.000	0.000	9.2(2.5,29.8)	1.0	0.003	0.000	9.0(2.0,31.0)
M = 0.1		1.0	0.001	0.000	0.000	3.6(1.2,11.4)	1.0	0.001	0.000	3.6(1.2,11.4)
P* = 0.50	1.0	1.0	0.050	0.340	0.220	17.6(2.9,63.5)	1.0	0.071	0.445	19.5(3.3,63.8)
P* = 0.45	1.0	1.0	0.050	0.340	0.220	17.6(2.9,63.5)	1.0	0.053	0.338	19.5(3.2,62.7)
P* = 0.40	0.958	1.0	0.044	0.321	0.214	17.7(3.1,63.0)	1.0	0.065	0.400	19.6(3.3,63.0)
P* = 0.35	0.911	1.0	0.039	0.287	0.206	17.7(3.1,62.7)	1.0	0.056	0.344	19.6(3.3,62.6)
P* = 0.30	0.865	1.0	0.035	0.264	0.190	17.6(3.1,61.5)	1.0	0.049	0.297	19.5(3.3,62.0)
P* = 0.25	0.820	1.0	0.031	0.229	0.171	17.6(3.0,60.2)	1.0	0.044	0.250	19.4(3.3,60.9)
P* = 0.20	0.769	1.0	0.027	0.186	0.151	17.5(3.2,59.9)	1.0	0.035	0.193	19.2(3.3,60.0)
P* = 0.15	0.714	1.0	0.023	0.138	0.127	17.5(3.2,58.7)	1.0	0.029	0.148	18.9(3.3,59.3)
P* = 0.10	0.649	1.0	0.021	0.092	0.098	17.3(3.3,58.8)	1.0	0.023	0.093	18.4(3.3,58.1)
P* = 0.05	0.567	1.0	0.015	0.044	0.061	17.1(3.3,54.9)	1.0	0.016	0.046	17.6(3.2,55.8)

Table 5-4 Summary of long-term economic impacts of the ACL alternatives for Tanner crab. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the 30-year period 2009-2038 (2008 dollars), and differences in revenues relative to a zero buffer. Alternatives include fixed buffers (multipliers of 1.0 to 0.1) and P* levels (0.5 to 0.05), and additional uncertainty of σ= 0.3. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, ($ Million), discounted at r=0.27%	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0.3	Multiplier = 1	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	Multiplier = 0.9	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	Multiplier = 0.8	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	Multiplier = 0.7	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	Multiplier = 0.6	8829(1924,21431)	5834(1391,13681)	3358(874,7743)	NA	1
	Multiplier = 0.5	8583(1845,20721)	5669(1368,13184)	3238(844,7442)	NA	4
	Multiplier = 0.4	8072(1739,19344)	5398(1252,12423)	3038(793,6974)	NA	9
	Multiplier = 0.3	7280(1539,17136)	4850(1102,10966)	2724(713,6140)	NA	18
	Multiplier = 0.2	5917(1238,13859)	3921(872,8784)	2217(574,4926)	NA	34
	Multiplier = 0.1	3784(785,8772)	2485(556,5496)	1403(383,3091)	NA	58
0.3	P* = 0.5	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.45	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.4	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.35	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.3	8967(1986,21899)	5921(1423,14034)	3421(881,7930)	NA	0
	P* = 0.25	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	P* = 0.2	8967(1984,21885)	5921(1413,14000)	3421(879,7943)	NA	0
	P* = 0.15	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	P* = 0.1	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0
	P* = 0.05	8909(1957,21789)	5912(1406,13929)	3417(882,7930)	NA	0

(b) Results are exclusive of the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, ($ Million), discounted at r=0.27%**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.3**
0.3	Multiplier = 1	2635(462,7191)	1613(308,4247)	813(170,2074)	NA	0
	Multiplier = 0.9	2579(451,7066)	1574(293,4183)	787(163,2003)	NA	2
	Multiplier = 0.8	2516(428,6855)	1527(279,4047)	756(155,1914)	NA	5
	Multiplier = 0.7	2425(409,6576)	1463(263,3891)	716(144,1808)	NA	9
	Multiplier = 0.6	2303(375,6221)	1381(241,3671)	671(129,1710)	NA	14
	Multiplier = 0.5	2129(328,5758)	1276(219,3384)	612(113,1588)	NA	21
	Multiplier = 0.4	1893(288,5096)	1128(188,3009)	534(95,1400)	NA	30
	Multiplier = 0.3	1548(234,4274)	919(147,2459)	432(76,1147)	NA	43
	Multiplier = 0.2	1070(161,2938)	639(96,1721)	293(51,804)	NA	60
	Multiplier = 0.1	397(54,1116)	234(31,642)	104(15,295)	NA	85
0.3	P* = 0.5	2610(458,7153)	1596(302,4225)	803(167,2046)	NA	0
	P* = 0.45	2610(458,7153)	1596(302,4225)	803(167,2046)	NA	0
	P* = 0.4	2610(458,7153)	1596(302,4225)	803(167,2046)	NA	0
	P* = 0.35	2587(452,7088)	1578(294,4197)	790(164,2012)	NA	1
	P* = 0.3	2562(443,6993)	1560(288,4139)	777(160,1975)	NA	2
	P* = 0.25	2530(432,6898)	1537(282,4074)	763(157,1934)	NA	4
	P* = 0.2					
	P* = 0.15	2438(412,6612)	1473(266,3916)	723(146,1821)	NA	8
	P* = 0.1	2369(397,6414)	1423(254,3785)	694(136,1755)	NA	11
	P* = 0.05	2254(359,6074)	1350(234,3595)	654(123,1675)	NA	15

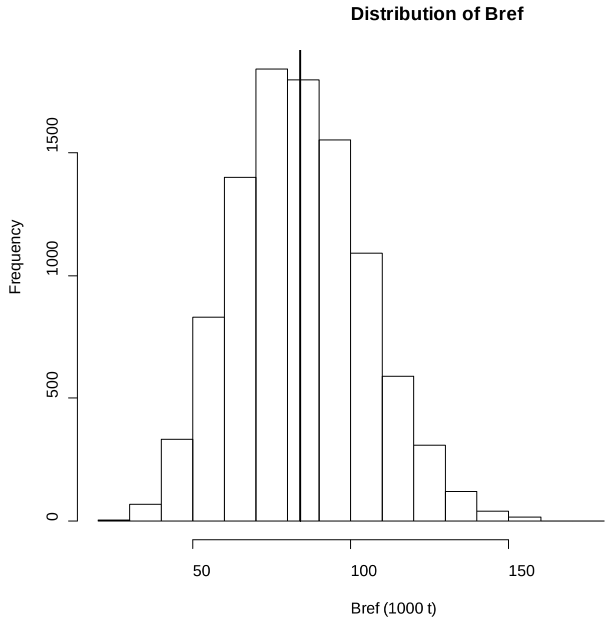


Figure 5-1 **The distribution of B_{REF} based non-parametric bootstrap sampling on the 1969-80 survey estimates of MMB at mating of n=10,000 draws with replacement. The vertical line represents the mean B_{REF}=83.80 thousand t.**

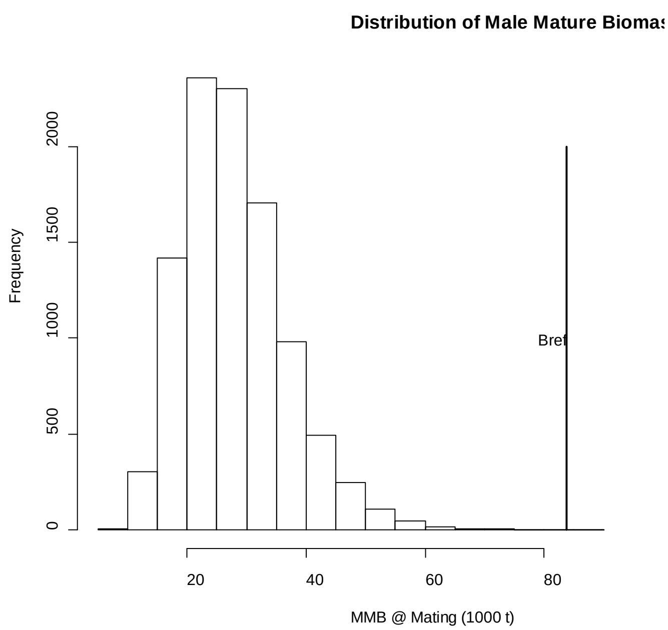


Figure 5-2 **Distribution of MMB at mating given the uncertainty in the OFL. Uncertainty components include the σb = 0.30 and σw = 0.14 for the log-normal distribution of survey biomass, and non-parametric uncertainty in B_{REF}. Vertical line is B_{REF}=83.80 thousand t.**

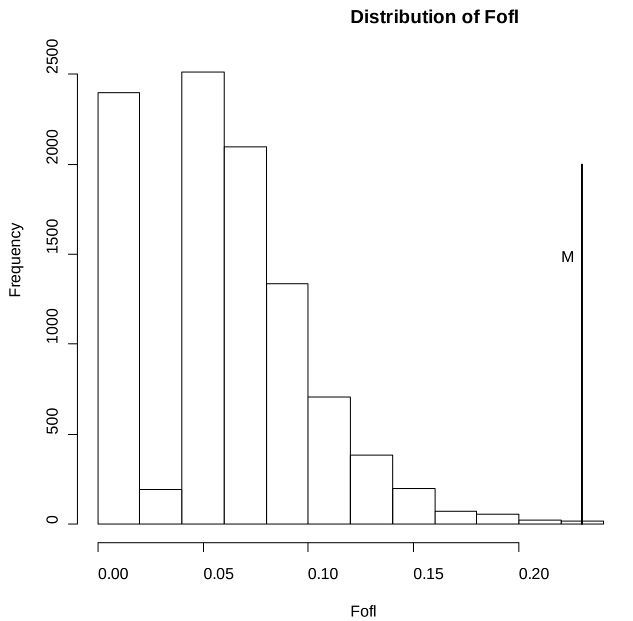


Figure 5-3 **Distribution of the full selection F_{OFL} from the Tier 4 OFL control rule given uncertainty components σ_b = 0.30 and σ_w = 0.14 for the log-normal distribution of survey biomass, and non-parametric uncertainty in B_{REF}. Vertical line is the value M=0.23.**

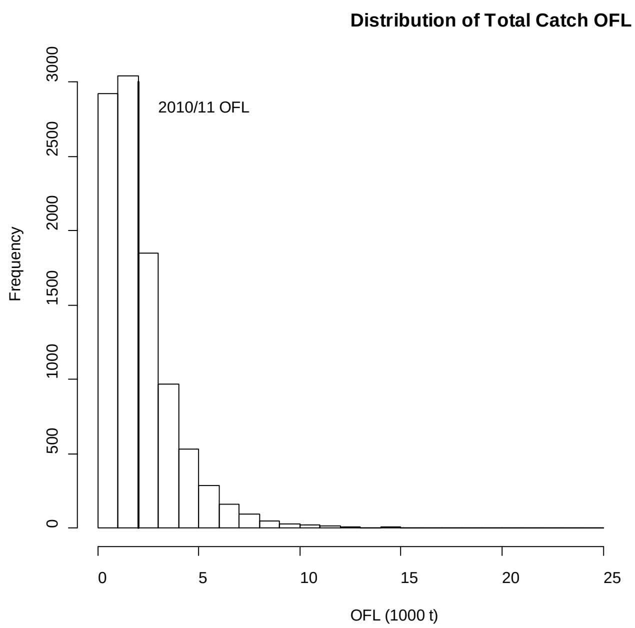


Figure 5-4 **Distribution of the total catch OFL given uncertainty components σ_b = 0.30 and σ_w = 0.14 for the log-normal distribution of survey biomass, and non-parametric uncertainty in B_{REF}. Vertical line is the mean 2010/11 OFL = 2.17 thousand t.**

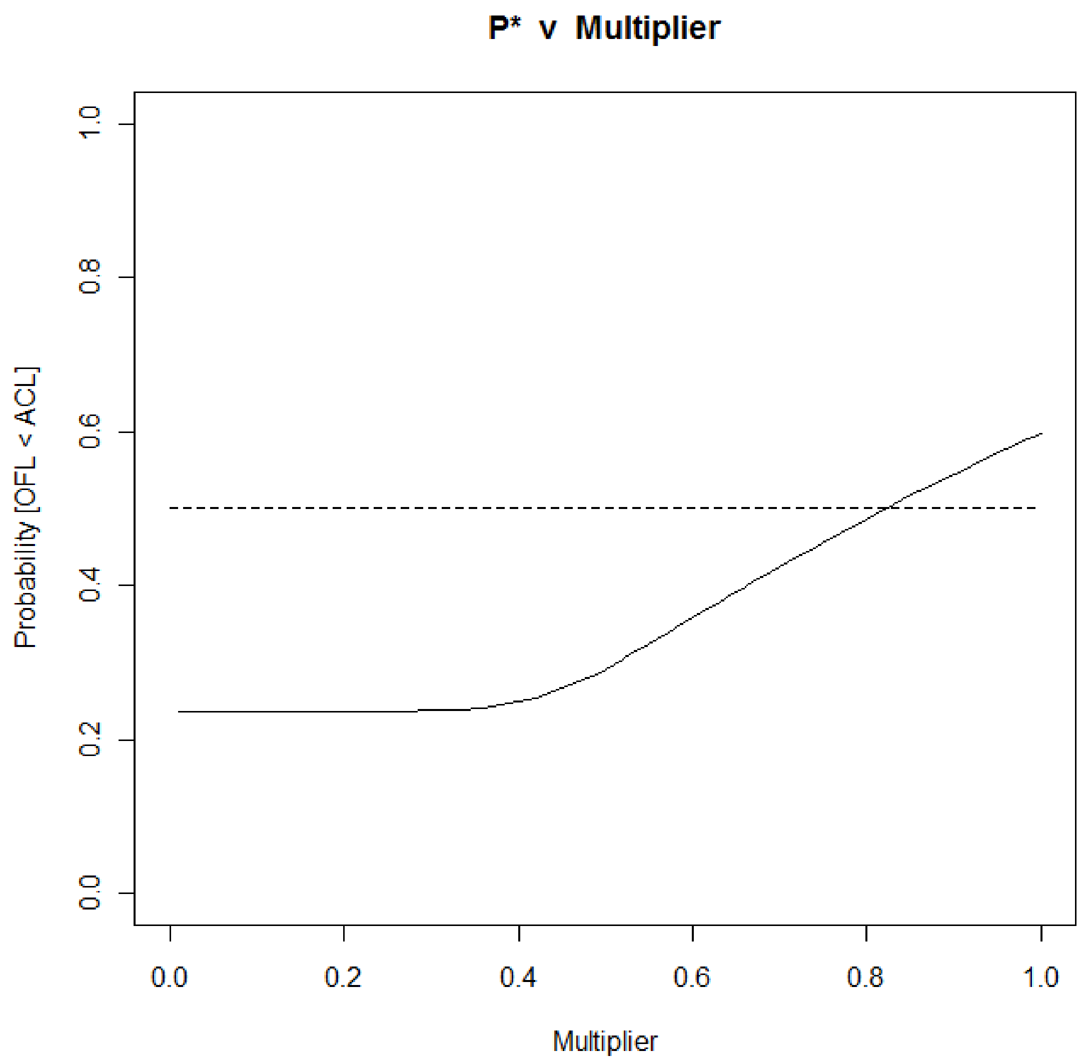


Figure 5-5 **Relationship between the probability of overfishing, P*, and the OFL multiplier for the Tier 4 calculation of total catch OFL in 2010/11. The horizontal dashed line represents a probability of 0.50. Plotted values correspond to data shown in Table 5-1 (a).**

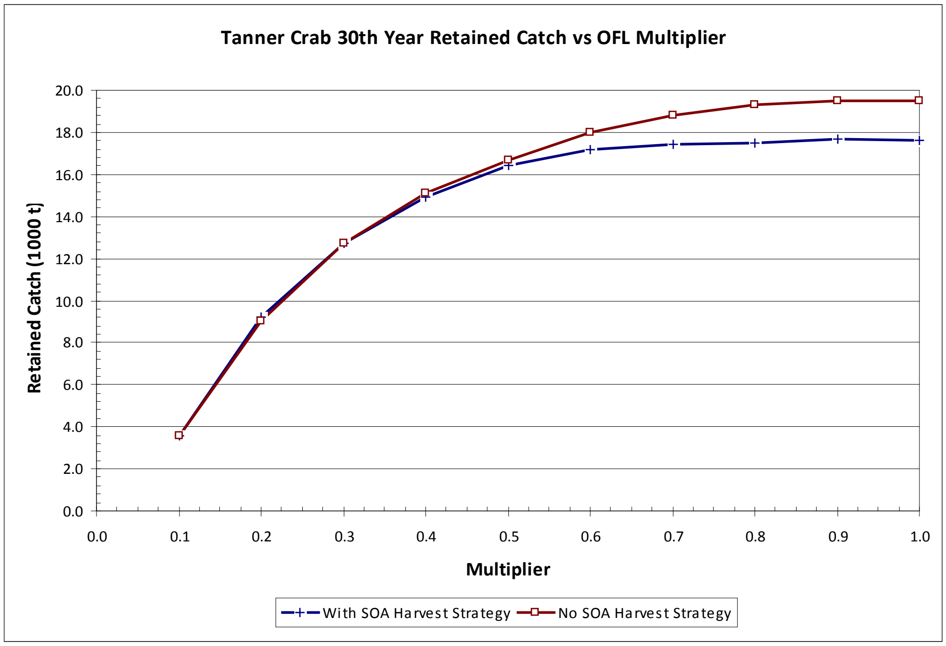


Figure 5-6 **Comparison of the relationship between the OFL Multiplier and retained catch in the 30th year with and without the SOA harvest strategy operating to constrain the total catch OFL.**

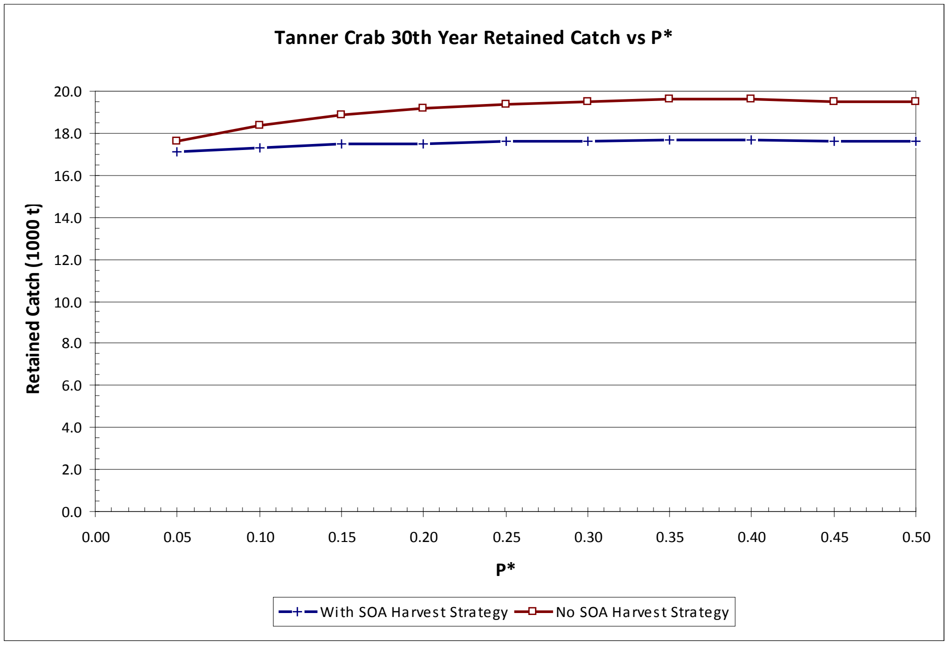


Figure 5-7 **Comparison of the relationship between P* and retained catch in the 30th year with and without the SOA harvest strategy operating to constrain the total catch OFL.**

6 Bristol Bay Red King Crab

Red king crab, *Paralithodes camtschaticus*, are found in several areas of the Aleutian Islands and eastern Bering Sea. The general distribution of red king crabs *Paralithodes camtschaticus* is summarized by NMFS (2004):

> Red king crab are widely distributed throughout the BSAI, GOA, Sea of Okhotsk, and along the Kamchatka shelf up to depths of 250 m. Red king crab are found from eastern Korea around the Pacific rim to northern British Columbia and as far north as Point Barrow (page 3-27).
>
> Most red and blue king crab fisheries occur at depths from 50-200 m, but red king crab fisheries in the Aleutian Islands sometimes extend to 300 m (page 3-41).
>
> Red king crab is native to waters of 300 m or less extending from eastern Korea, the northern coast of the Japan Sea, Hokkaido, the Sea of Okhotsk, through the eastern Kamchatkan Peninsula, the Aleutian Islands, the Bering Sea, the GOA, and the Pacific Coast of North America as far south as Alice Arm in British Columbia. They are not found north of the Kamchatkan Peninsula on the Asian Pacific Coast. In North America red king crab range includes commercial fisheries in Norton Sound and sparse populations extending through the Bering Straits as far east as Barrow on the northern coast of Alaska. Red king crab have been acclimated to Atlantic Ocean waters in Russia and northern Norway. In the Bering Sea, red king crab are found near the Pribilof Islands and east through Bristol Bay; but north of Bristol Bay (58 degrees 39 minutes) they are associated with the mainland of Alaska and do not extend to offshore islands such as St. Matthew or St. Laurence Islands (pages 3-41–42).

The State of Alaska divides the Aleutian Islands and eastern Bering Sea into three management registration areas to manage red king crab fisheries: Aleutian Islands, Bristol Bay, and Bering Sea (ADF&G 2005). The Aleutian Islands area covers two stocks, Adak and Dutch Harbor, and the Bering Sea area contains two other stocks, the Pribilof Islands and Norton Sound. The largest stock is found in the Bristol Bay area, which includes all waters north of the latitude of Cape Sarichef (54^o36' N lat.), east of 168^o W long., and south of the latitude of Cape Newenham (58^o39' N lat.) (ADF&G 2005).

6.1 Assessment overview

The Bristol Bay red king crab (BBRKC) stock biomass is above its estimated B_{MSY} (68.5 million lbs of mature male biomass, at the time of mating) with model estimated mature male biomass at mating having increased from 76.4 million lbs in 2007 to 95.2 million lbs in 2009 (Zheng *et al.* 2009; Figure 6-1). Estimates of total survey biomass increased from 177.2 million lbs in 1968 to 721.1 million lbs in 1978, decreased sharply to a low of 66.3 million lbs in 1985, then generally increased to 196.5 million lbs in 2009. Recent above-average year classes have largely recruited into the fished population with no evidence of new strong recruitment for the past three years.

The most recent assessment of BBRKC (Zheng et al. 2009) is based on a sex- and size-structured population dynamics model which also considers the dynamics of shell-condition and maturity state[62]. The values for the parameters of this model are estimated using data on catch length-compositions, survey indices of abundance (assumed to be absolute indices of the survey-selected component of the population)

[62] The analyses of this chapter are based on an updated version of the assessment model. The results are therefore not identical to those in Zheng et al. (2009).

as well as length-compositions from the surveys. The model is also fitted to discard length-frequency data, length-frequencies for the bycatch in the trawl fishery, and length frequency data for catches of red king crab in Tanner crab fishery.

The OFL for BBRKC is currently based on the Tier 3 control rule, i.e. the proxy for F_{MSY} is taken to be $F_{35\%}$ while the proxy for B_{MSY} is taken to be B_{35}[63] (NPFMC, 2008). The OFL is a total-catch OFL and is computed as the sum of catches by five different sources of removals: (a) the retained legal males in directed (pot) fishery for BBRKC, (b) discards of males and females in the directed fishery, (c) bycatch in the Tanner crab fishery, and (d) bycatch in the trawl fishery.

The calculation of the OFL is based on the assumptions that: (a) the F_{OFL} pertains to the directed fishery for legal males (full-selection fishing mortality), (b) future full-selection discard mortality (males and females) in the directed fishery is given by F_{OFL} multiplied by the average ratio of discard fishing mortality to fishing mortality on legal males over the most-recent five years (2004/05 – 2008/09 for the analyses of this chapter), (c) fishing mortality by the Tanner crab fishery equals the average value over these last five years, and (d) fishing mortality by the trawl fishery equals the average value over these five years. Thus, changes to F_{OFL} directly impact the predicted catches of legal males in the directed fishery as well as the predicted discard of males and females in the directed fishery, while the fishing mortality rates leading to bycatch in the Tanner and trawl fisheries are constant and independent of $F_{OFL.}$

When compared to the OFL control rule, adopted as part of Amendment 24, the fishing mortality rates on retained legal males associated with the catches of BBRKC (Figure 6-2) have often exceeded the OFL (Figure 6-3). This did not constitute overfishing in the past because Amendment 24 was only implemented in 2008. Moreover, the harvest strategy used to make recommendations for TACs has changed over time in response to changes in knowledge regarding the dynamics of the resource [see Appendix 3].

6.1.1 Uncertainty in stock assessment

Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for BBRKC is relatively low. BBRKC is the most well-studied of the stocks of red king crab in the BSAI. The coefficient of variation for the estimate of mature male biomass for the most recent year is only 0.05. However, several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment. These include the following:

- Several of the key parameters of the model (survey catchability and natural mortality for "normal years") are pre-specified rather than being estimated.
- F_{msy} is assumed to be equal to $F_{35\%}$ when applying the OFL control rule.
- B_{msy} is assumed to $B_{35\%}$ with average recruitment corresponding to MSY calculated over the years 1995-2009. Recruitment was, however, much higher before the 1976/77 regime shift and the selection of 1995-2009 as the basis for B_{MSY} is clearly subject to not inconsiderable uncertainty.

For BBRKC, additional uncertainty is thought to be low, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.2 to quantify this low level of additional uncertainty, which is the default value recommended by the CPT and SSC. This analysis of the short-term implications includes results for a σ_b of 0, 0.3, 0.4 and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.2. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

[63] The biomass corresponding to $F_{35\%}$ and not 35% of the average unfished biomass.

6.2 Impacts of alternatives

As described in Chapter 2, there are two alternative methods under consideration for computing a total-catch ABC for BBRKC: (a) the OFL can be multiplied by a pre-specified "multiplier" (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4).

The analyses of impacts in this chapter are based on the assumption that there are no sector-specific ACLs, that the ACL applies to all removals of BBRKC (a total-catch ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the trawl and Tanner crab fisheries. A total catch ACL can be computed from the output of the SOA control rule (which pertains to the retained catch in the directed fishery) by adding the estimates of bycatch and discard to the output from the SOA control rule. As noted in Chapter 3, two scenarios are considered related to the SOA control rule: (a) the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule, and (b) the ACL equals the ABC (i.e. the SOA control rule is ignored).

The short-, medium- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the buffer value (shown as the result of application of the multiplier by the OFL) and P* on the ABC which would have been advised for the 2009/10 fishery (assuming that ABCs had been specified for that fishery) while the medium- and long-term implications are evaluated by projecting the population ahead 30 years.[64] The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2009-2014) while the long-term implications consider the implications of the entire 30-year projection period.

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures in Sections 6.2.1 and 6.2.2.3 are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference on the evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30-year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

Revenue forecasts are based on probabilistic price forecasts for BBRKC using the time-series vector autoregression model detailed in Chapter 3. The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume by multiplying the directed catch forecasts values by the product recovery rate for Alaska red king crab. Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and product recovery rate (mean and standard errors for both are presented in Chapter 3), and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

[64] 30 years is sufficiently long so the resource equilibrates close to the proxy for B_{MSY} under deterministic conditions (no fluctuations in recruitment about the assumed stock-recruitment relationship).

It should be noted that economic impacts presented below provide a coarse basis for evaluation of ACL alternatives. Ideally, this analysis would provide an evaluation of the net economic effects of ACL alternatives. However, insufficient information on costs of production in the harvest and processing sectors is available to estimate the net economic value of crab production.

6.2.1 Short-term implications

The short-term implications focus on the size of the ABC for the 2009/10 fishing year. The biological implications of the choice of an alternative are addressed in Section 6.2.2.1 and 6.2.2.2.

Table 6-2 lists summaries for the breakdown of the OFL to each source of removals. The estimated gross revenue from the directed fishery associated with each of the alternatives and the percentage reduction in revenues relative to the zero buffer or P*=0.5 is also shown in Table 6-1.

As expected, a larger buffer (lower multiplier) leads to lower ABC levels and a lower probability that the ABC is less than the true (but unknown) OFL. For BBRKC, the output of the SOA control rule is 8,442t which is lower than the retained catch for (9,559t) when there is no buffer so, in this case, the ABC would not constrain the fishery if TACs continue to be based on the SOA control rule. In contrast, the retained component of the ABC for buffer values of 20% and higher (multipliers of 0.8 or less) are less than the output of the SOA control rule. If a buffer value of 20% or higher was selected, the ABC would constrain the SOA control rule. Therefore, the impacts of Alternative 4 and buffer values greater that 20% are indistinguishable from status quo.

There is a linear relationship between the ABC and the buffer (Table 6-1a, Figure 6-4a) with the ABC set equal to the OFL when there is no buffer and being 10% of the ABC for a buffer of 90% (a multiplier of 0.1). The relationship between the buffer and P* is, however, not simple linear proportionality (Table 6-1b-e, Figure 6-4b). Moreover, the impact of the (assumed) extent of additional uncertainty is substantial given that the uncertainty of the OFL estimated from the assessment is low (Figure 6-5). Specifically, the buffer gets larger (and hence the ABC decreases for 2009/10) for the same value for P* as the value for σ_b (additional uncertainty not captured in the assessment) is increased. For example, the buffer for a P* of 0.4 (40% probability that the ABC will exceed the true OFL) is 1% if there is no uncertainty that is not captured by the stock assessment, but is 6%, 16% and 28% if σ_b is 0.2, 0.4 or 0.6 (Table 6-1b-e, Figure 6-4b). The relationship between P* and the buffer (as indicated by the result of multiplying the OFL by the multiplier) based on the OFL calculated for 2009/10 is given in the "P* (additional uncertainty)" column of Table 6-1a.

As of this analysis, final wholesale price data for king crab are available only through 2008. Estimated revenue under for alternative multiplier- and σ_b -levels presented in Table 6-1 use an estimated 2009/10 price from red king crab price model (see Chapter 3). In the single-year short term results, the incremental change in revenues associated with a 0.1 increment in the multiplier is approximately $15 million (Table 6-1a), or 10% of baseline revenue levels. For the P* alternative, at σ=0.2, each 0.1 incremental decrease in P* is associated with an increasing marginal decline in gross revenues, with the change from 0.5 to 0.4 producing a $7 million, or 5% decrease in gross revenues relative to a zero buffer, and assuming that catch equals the ACL, and the marginal revenue decline increasing by approximately $1 million for each increment in P* from 0.4 to 0.1. This corresponds to the linear relationship between the ABC and the multiplier, and nonlinear relationship between the multiplier and P* depicted in Figure 6-4.

6.2.2 Medium- and long-term implications

Table 6-2 lists summaries of the posterior distributions for the key parameters which determine the productivity of the population. B_{35} is not 35% of the unfished mature male biomass at mating. This is because recruitment is not independent of mature male biomass at mating. The extent of uncertainty captured within the stock assessment, σ_w, is 0.05 based on the 2009 assessment.

6.2.2.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized in Table 6-4 by the projected values for the ABC (which includes all sources of catches), "ABC_{tot}", the retained directed component of ABC_{tot}, "ABC_{dir},", the output of the SOA control rule (which pertains to retained catches in the directed fishery), "SOA", the retained catch in the directed fishery, "C_{dir}", the ratio of the mature male biomass at the time of mating to that the mature male biomass at which MSY is achieved, expressed as a percentage, "MMB/B_{MSY}", the probability of overfishing occurring. Results are shown in Table 6-4 for analyses based on the extent of additional uncertainty recommended by the CPT (0.2), and for four multiplier levels (1, 0.8, 0.6 and 0.4) and choices for P* (0.4, 0.3, 0.2 and 0.1). These multiplier levels correspond to buffer values of 0, 20%, 40% and 60% respectively.

As expected from Table 6-1, the retained catch in the directed fishery is equal to the output from the SOA control rule when there is no buffer (a multiplier of 1) and generally the same as the output of the SOA control rule for a buffer of 20% or lower (a multiplier of 0.8 or greater) or a P* of 0.2 and higher (

Table 6-4b,d,j). However, the ABC is less than the output from the SOA control rule for buffers of 40% and greater (multipliers of 0.6 or less), and P* values of 0.2 or lower. Thus, in terms of its impact, Alternative 4 is most similar to Alternative 3 with a P* value of 0.20 and additional uncertainty equal to 0.2.

The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) decreases as the size of the buffer in increased (the multiplier is decreased) or P* is reduced. However, this reduction is at a cost of substantially lower annual catches if the ABC is based on the buffer (particularly during the earlier years of the projection period). For example, the retained catch in the directed fishery in 2009/10 drops from 8,300t to 3,900t as the buffer is increased from 0 to 60% (multipliers from 1 to 0.4;

Table 6-4 a-d). One consequence of larger buffers is, however, larger stock sizes. The probability of overfishing is higher for small buffer values (or values for P*) and if the SOA control rule is ignored. The impact of different choices for P* is less than for different choices for the buffer because the range of buffers for P* in the range 0.05 to 1 is only 29%-0, a much more narrow range than the range of buffers under consideration.

The mature male biomass at the time of mating is predicted to decrease in all cases (including to slightly below B_{MSY}). This occurs in part because the OFL (and hence ABC) control rule aim to move the stock to B_{MSY} (100 in the fourth column of

Table 6-4), but also because recent recruitment upon which these projections depend has not been strong.

6.2.2.2 Long-term implications - Biological

Table 6-5 summarizes the results of the 30-year projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column

"Prob (overfished) A"),(b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B") (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of TAC being computed by adding predicted bycatch and discard to the output from the SOA control rule (column "Prob (SOA)"), and (e) the median and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period.

Figure 6-6 shows the time-trajectories of catch and mature male biomass at mating relative to B_{35} for two illustrative choices for the buffer (0; ABC=OFL; 40%; the ABC is 60% of the OFL). As expected, the mature male biomass is larger when the buffer is larger (multiplier is smaller). As noted above the mature male biomass drops over the early years of the projection period because the current mature male biomass is substantially larger than B_{MSY} at present and setting the ABC to the OFL (no buffer) would be expected to drive the stock back (down) to B_{MSY}. The decline in mature male biomass also occurs owing to some poorer-than-average recruitments in recent years.

Figure 6-9 and Figure 6-10 evaluate the implications of different buffer values between the ABC and the OFL in terms of metrics (a), (b), (c) and (e) in

Table 6-5, except that results are shown for all four values of the extent of additional uncertainty instead of only the value recommended by the CPT. As expected, higher values for P* and smaller buffers (larger multipliers) lead to higher probabilities of the stock becoming overfished, with this effect exacerbated when the extent of additional uncertainty is high. The annual probability of being overfished is lower than the probability of being overfished at least once during the 30-year projection period. The probabilities if being overfished are lower for lower values for the extent of additional uncertainty and larger buffers when the SOA control rule is imposed (Figure 6-8, upper left panel).

In contrast the probability of overfishing occurred is high when there is no buffer (a multiplier of 1) for all levels of additional uncertainty if the SOA control rule is not imposed (Figure 6-8, upper right panel). The median catch in 2038 is highest for when there is no buffer and for the lowest extent of additional uncertainty (Figure 6-8, lower panels) and Figure 6-9 and Figure 6-10 illustrate the differences among the 10 buffer values and choices for P* in terms of the median time-trajectory of mature male biomass at mating relative to B_{MSY} and the median time-trajectory of the catch of legal males in the directed fishery. The ratio of mature male biomass to B_{MSY} increases essentially continuously with changes in the buffer irrespective of whether the SOA control rule is imposed or not while this ratio also increases with P* if the SOA control rule is not imposed. The rate at which catch drops with decreasing buffers (increasing multipliers) is, however, not the same as that at which biomass increases (Figure 6-9 and Figure 6-10), with the catch in 2038 essentially the same for buffers between 30% and 0 (multipliers between 0.7 and 1) and for all choices for P*. The probability of overfishing is lower than P* when the SOA control rule is imposed. However, there is a reasonably close correspondence between P* and the probability of overfishing when the SOA control rule is not imposed (

Table 6-5 lower).

As before, the catch is constrained not by the ABC for the smallest buffers (20% and 0) (multipliers between 0.8 and 1), but rather by the output of the SOA control rule (e.g. there is 88% probability that the retained-directed component of ABC is larger than the output from the SOA control rule when there is no buffer between the ACL and the OFL). Therefore, the impacts under Alternative 4 and buffers less that 20% would be indistinguishable from status quo.

Table 6-5).

6.2.2.3 Medium- and Long-term implications - Economic

The medium and long-term impacts of ACL alternatives are summarized in Table 6-6 and

Table 6-7. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term. Table 6-6 (a) and (b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to two scenarios, 1) zero buffer (multiplier=1.0) and no additional uncertainty (σ=0), and 2) zero buffer, but holding the value of σ constant across compared alternatives.

Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC (Table 6-6 (a)) and scenarios without the SOA control rule (Table 6-6 (b)). Under the SOA control rule, the median estimate of all foregone revenue over the 2009-2014 period associated with decreasing buffer size under alternative levels of additional uncertainty ranges from $9 million (buffer=0.8 and σ=0.0 additional uncertainty) to $303 million (buffer=0.4 and σ=0.4 additional uncertainty), discounted to present value at 2.7%. This represents a range of 1% to 46% potential reduction in gross revenues from the fishery. At the recommended level of additional uncertainty for BBRKC (σ= 0.2), the estimate of total potential foregone revenues for the six years ranges from $10 million to $226 million, for buffer level 0.8 to 0.4, a range of 2-35% relative to zero buffer. Results for P* alternatives are shown for σ= 0.2, with potential foregone revenue relative to zero buffer (~P*=.5) ranging from $29 million (3%) to $140 million (17%). SOA control rule constraints are more limiting than the ABC at lower ACL buffer levels (multiplier 0.08-1.0). Results of economic comparisons between ACL alternatives resulting from catch projections without SOA constraints are not shown in Table 6-6 (b). The SOA control rule remains in effect as the protocol for TAC-setting, however, the potential foregone revenues that could result from the ACL alternatives would increase substantially relative to a zero buffer, with the ABC as the binding constraint on TAC rather than the SOA control rule. Note that a zero buffer does not represent the status quo alternative, but is intended to provide a representation of the effects of ACL alternatives under potential future decision-making scenarios where the SOA control rule is no longer binding. It should be noted that this comparison does not indicate that costs of ACLs would be higher in the event that the SOA rule was not applied, rather that the SOA rule effectively represents a buffer in itself, and results in foregone catch and revenues relative to the least conservative ACL alternatives under consideration.

Economic results of ACL alternatives over the long term (2009-2038) are represented in

Table 6-7. The range of potential foregone revenues relative to a zero buffer are of similar range as the mid-term results, with percentage reduction from baseline ranging from 2% (multiplier = .8 and σ= 0) to 37% (multiplier = 0.4 and σ= 0.6). At the recommended level of additional uncertainty for BBRKC (σ= 0.2), the estimate of percentage reduction in total potential foregone revenues for the 30-year period ranges from 2% for buffer level 0.8 to 27% for a buffer level of 0.4. As with the mid-term results, the relative effects of the ACL alternatives are more pronounced when the effective constraint of the SOA rule is removed from the analysis. It should be noted that the relative economic effects of the ACLs are not qualitatively different between the mid- and long-term, nor do alternative discount rates appreciably change the relative ranking of alternatives in terms of economic outcomes. This is largely due to the effect of the constancy of the buffer in the model projections, in both the buffer and P* scenarios. With fixed buffers, which are not responsive to changes in the stock status, there is little change in the timing of harvest over the period of analysis. That is, none of the alternatives under consideration implement different buffers over time according to stock conditions, and thus the timing of relative economic benefits from the fishery across the time horizon are not appreciably different under the alternatives analyzed.

6.3 Tables and Figures

Table 6-1 Values for catch-related quantities for BBRKC for 2009/10 for each of the alternatives. The column P* in Table 6-1a shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The SSC recommended additional uncertainty is shaded. The TAC under the SOA control rule is 8,442t. Estimated gross economic revenue associated with first wholesale value of directed catch is reported for $\sigma_b = 0.2$ **model results.**

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	P * (additional uncertainty					Revenue	
			None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	10,774	9,559	0.5	0.50	0.50	0.50	0.50	144	0%
Multiplier = 0.9	9,697	8,603	0.00	0.25	0.36	0.43	0.50	129	10%
Multiplier = 0.8	8,619	7,647	0.00	0.11	0.21	0.32	0.44	115	20%
Multiplier = 0.7	7,542	6,691	0.00	0.04	0.12	0.20	0.35	100	31%
Multiplier = 0.6	6,464	5,735	0.00	0.00	0.05	0.12	0.26	86	40%
Multiplier = 0.5	5,387	4,780	0.00	0.00	0.01	0.05	0.16	71	51%
Multiplier = 0.4	4,310	3,824	0.00	0.00	0.00	0.01	0.09	57	60%
Multiplier = 0.3	3,232	2,868	0.00	0.00	0.00	0.00	0.04	42	71%
Multiplier = 0.2	2,155	1,912	0.00	0.00	0.00	0.00	0.00	28	81%
Multiplier = 0.1	1,077	956	0.00	0.00	0.00	0.00	0.00	13	91%

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$	10,774[&]	9,559	1.0
$P^* = 0.4$	11,126	9884	0.99
$P^* = 0.3$	10,985	9712	0.98
$P^* = 0.2$	10,815	9577	0.96
$P^* = 0.1$	10,620	9366	0.94

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier	Revenue	
				Millions $	% Change
$P^* = 0.5$	10,774[&]	9,559	1.0	142	0%
$P^* = 0.4$	10,544	9380	0.94	135	5%
$P^* = 0.3$	9,952	8821	0.89	127	11%
$P^* = 0.2$	9,370	8306	0.83	119	16%
$P^* = 0.1$	8,565	7559	0.76	109	23%

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$	10,774&	9,559	1.0
$P^* = 0.4$	10,020	8,879	0.89
$P^* = 0.3$	9,225	8,168	0.82
$P^* = 0.2$	8,450	7,477	0.75
$P^* = 0.1$	7,371	6,541	0.66

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$	10,774&	9,559	1.0
$P^* = 0.4$	9,439	8,356	0.84
$P^* = 0.3$	8,492	7,489	0.76
$P^* = 0.2$	7,503	6,562	0.67
$P^* = 0.1$	6,264	5,563	0.56

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier
$P^* = 0.5$	10,774&	9,559	0.84
$P^* = 0.4$	8,091	7166	0.72
$P^* = 0.3$	6,927	6142	0.62
$P^* = 0.2$	5,810	5147	0.52
$P^* = 0.1$	4,434	3913	0.39

& - set to the point estimate

Table 6-2 Breakdown of the 2009/10 OFL for BBRKC among the sources of mortality included in the OFL

Component	Catch (t)
Directed fishery	9,559
Male discard in the directed fishery	942
Female discard in the direct fishery	152
Bycatch in the trawl fishery	108
Bycatch in the Tanner fishery	13
Total	10,774

Table 6-3 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes for BBRKC.

Parameter	Distribution
Virgin recruitment, R_0	15,971 (15,303; 16,639)
Virgin MMB	125.8 (120.7; 130.8)
Steepness, h	0.701 (0.700; 0.702)
F_{MSY} ($F_{35\%}$)	0.323 (0.318; 0.329)
B_{MSY} ($B_{35\%}$)	34.3 (32.9; 35.6)
σ_R	1.009 (0.925; 1.100)

Table 6-4 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for BBRKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on $\sigma_b = 0.2$.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	11.0 (7.8-15.9)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	136 (125-146)	0.198
2010	14.1 (9.8-20.1)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	13.5 (10.1-18.2)	8.0 (5.0-10.8)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	11.8 (9.6-14.5)	6.6 (4.4- 8.4)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	8.8 (7.7-10.3)	5.5 (3.7- 6.8)	5.5 (3.7- 6.8)	5.5 (3.6- 6.8)	94 (71-118)	0.076
2014	6.9 (5.6- 9.8)	5.0 (3.4- 7.6)	5.0 (3.4- 7.6)	5.0 (3.3- 7.6)	85 (59-119)	0.226

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	8.8 (6.2-12.7)	7.8 (5.5-11.2)	8.3 (4.8-11.9)	7.8 (4.8-11.2)	138 (127-147)	0.131
2010	11.3 (7.9-16.0)	10.4 (7.3-14.9)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	10.8 (8.1-14.5)	10.2 (7.7-13.8)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	9.5 (7.7-11.5)	9.0 (7.4-11.0)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	7.0 (6.1- 8.2)	6.6 (5.8- 7.7)	5.5 (3.7- 6.8)	5.4 (3.6- 6.7)	94 (71-118)	0.083
2014	5.3 (4.3- 7.7)	5.0 (4.0- 6.6)	4.9 (3.3- 7.7)	4.5 (3.3- 6.6)	84 (61-119)	0.144

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2009	6.6 (4.7- 9.5)	5.9 (4.1- 8.4)	8.3 (4.8-11.9)	5.9 (4.1- 8.4)	143 (135-150)	0.005
2010	8.4 (5.9-12.0)	7.8 (5.5-11.2)	9.1 (5.3-13.0)	7.8 (5.3-11.1)	159 (147-167)	0.005
2011	8.3 (6.1-11.2)	7.9 (5.8-10.6)	8.1 (5.0-11.2)	7.8 (4.9-10.6)	141 (123-156)	0.010
2012	7.3 (5.8- 9.2)	7.0 (5.6- 8.7)	6.8 (4.4- 8.7)	6.7 (4.3- 8.5)	118 (97-138)	0.006
2013	5.5 (4.7- 6.4)	5.2 (4.5- 6.0)	5.6 (3.7- 7.1)	5.1 (3.6- 6.0)	97 (78-118)	0.005
2014	4.2 (3.5- 6.1)	3.9 (3.3- 5.3)	5.1 (3.4- 7.9)	3.9 (3.2- 5.3)	88 (68-125)	0.006

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2009	4.4 (3.1- 6.3)	3.9 (2.8- 5.6)	8.3 (4.8-11.9)	3.9 (2.7- 5.6)	149 (142-155)	0.000
2010	5.6 (3.9- 8.0)	5.2 (3.7- 7.4)	9.1 (5.3-13.0)	5.2 (3.6- 7.4)	166 (158-173)	0.000
2011	5.8 (4.2- 8.1)	5.5 (4.0- 7.7)	8.5 (5.1-11.9)	5.4 (3.9- 7.6)	155 (142-164)	0.000
2012	5.4 (4.0- 7.3)	5.2 (3.9- 7.0)	7.4 (4.6- 9.9)	5.1 (3.8- 6.9)	134 (118-146)	0.000
2013	4.5 (3.5- 5.6)	4.3 (3.4- 5.3)	6.3 (3.9- 8.4)	4.3 (3.3- 5.3)	114 (97-128)	0.000
2014	3.6 (2.8- 5.0)	3.4 (2.7- 4.5)	5.9 (3.6- 8.9)	3.4 (2.6- 4.5)	103 (85-142)	0.000

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	11.0 (7.8-15.8)	9.8 (6.9-14.0)	8.3 (4.8-11.9)	9.8 (6.9-14.0)	132 (119-141)	0.477
2010	14.1 (9.8-20.0)	13.1 (9.2-18.6)	9.1 (5.3-13.0)	13.1 (9.1-18.6)	143 (126-156)	0.459
2011	12.5 (9.5-16.1)	11.8 (9.0-15.1)	7.4 (4.7- 9.7)	11.8 (8.9-15.1)	116 (91-134)	0.475
2012	8.9 (7.6-10.3)	8.5 (7.3- 9.7)	5.6 (3.8- 6.8)	8.5 (7.3- 9.8)	89 (69-108)	0.461
2013	5.7 (4.8- 6.7)	5.3 (4.5- 6.2)	4.2 (2.9- 5.2)	5.3 (4.5- 6.2)	71 (54- 89)	0.470
2014	4.2 (3.2- 7.3)	3.8 (3.0- 6.2)	3.3 (2.5- 6.5)	3.8 (3.0- 6.2)	65 (48- 98)	0.476

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	8.8 (6.2-12.7)	7.8 (5.5-11.2)	8.3 (4.8-11.9)	7.8 (5.5-11.2)	138 (127-146)	0.131
2010	11.3 (7.9-16.0)	10.4 (7.3-14.9)	9.1 (5.3-13.0)	10.4 (7.3-14.9)	151 (137-161)	0.130
2011	10.5 (7.9-14.0)	10.0 (7.5-13.2)	7.8 (4.8-10.5)	9.9 (7.4-13.2)	128 (107-143)	0.135
2012	8.5 (7.0-10.0)	8.1 (6.7- 9.5)	6.2 (4.1- 7.7)	8.1 (6.7- 9.5)	102 (81-119)	0.125
2013	5.7 (4.9- 6.7)	5.3 (4.6- 6.2)	4.9 (3.2- 6.1)	5.3 (4.6- 6.2)	82 (64- 99)	0.126
2014	4.2 (3.4- 6.8)	3.9 (3.2- 5.7)	4.1 (2.9- 7.2)	3.9 (3.2- 5.7)	74 (56-109)	0.144

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	6.6 (4.7- 9.5)	5.9 (4.1- 8.4)	8.3 (4.8-11.9)	5.9 (4.1- 8.4)	143 (135-150)	0.005
2010	8.4 (5.9-12.0)	7.8 (5.5-11.2)	9.1 (5.3-13.0)	7.8 (5.4-11.1)	159 (147-167)	0.005
2011	8.3 (6.1-11.2)	7.9 (5.8-10.6)	8.1 (5.0-11.2)	7.8 (5.7-10.6)	141 (123-153)	0.010
2012	7.3 (5.7- 9.2)	7.0 (5.5- 8.7)	6.8 (4.3- 8.7)	7.0 (5.4- 8.7)	117 (97-132)	0.006
2013	5.4 (4.5- 6.4)	5.1 (4.3- 6.0)	5.6 (3.5- 7.1)	5.1 (4.2- 6.0)	96 (78-113)	0.005
2014	4.1 (3.3- 6.1)	3.8 (3.1- 5.3)	5.0 (3.2- 7.9)	3.8 (3.1- 5.3)	86 (68-124)	0.006

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	4.4 (3.1- 6.3)	3.9 (2.8- 5.6)	8.3 (4.8-11.9)	3.9 (2.7- 5.6)	149 (142-155)	0.000
2010	5.6 (3.9- 8.0)	5.2 (3.7- 7.4)	9.1 (5.3-13.0)	5.2 (3.6- 7.4)	166 (158-173)	0.000
2011	5.8 (4.2- 8.1)	5.5 (4.0- 7.7)	8.5 (5.1-11.9)	5.4 (3.9- 7.6)	155 (142-164)	0.000
2012	5.4 (4.0- 7.3)	5.2 (3.9- 7.0)	7.4 (4.6- 9.9)	5.1 (3.8- 6.9)	134 (118-146)	0.000
2013	4.5 (3.5- 5.6)	4.3 (3.4- 5.3)	6.3 (3.9- 8.4)	4.3 (3.3- 5.3)	114 (97-128)	0.000
2014	3.6 (2.8- 5.0)	3.4 (2.7- 4.5)	5.9 (3.6- 8.9)	3.4 (2.6- 4.5)	103 (85-142)	0.000

(i) P*=0.4; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	11.0 (7.8-15.8)	9.8 (6.9-14.0)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	136 (125-146)	0.198
2010	14.1 (9.8-20.0)	13.1 (9.2-18.6)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	13.5 (10.1-18.2)	12.8 (9.6-17.2)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	11.8 (9.6-14.4)	11.3 (9.2-13.7)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	8.8 (7.6-10.2)	8.3 (7.2- 9.6)	5.5 (3.7- 6.8)	5.4 (3.6- 6.8)	94 (71-118)	0.083
2014	6.6 (5.3- 9.6)	6.2 (5.0- 8.3)	4.9 (3.3- 7.7)	4.8 (3.3- 7.6)	84 (58-118)	0.237

(j) P*=0.3; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	10.5 (7.4-15.0)	9.3 (6.6-13.3)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	136 (125-146)	0.198
2010	13.4 (9.3-19.0)	12.4 (8.7-17.6)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	12.8 (9.6-17.2)	12.1 (9.1-16.3)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	11.2 (9.1-13.7)	10.7 (8.7-13.0)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	8.3 (7.2- 9.7)	7.9 (6.8- 9.1)	5.5 (3.7- 6.8)	5.4 (3.6- 6.8)	94 (71-118)	0.083
2014	6.3 (5.1- 9.1)	5.9 (4.7- 7.9)	4.9 (3.3- 7.7)	4.8 (3.3- 7.5)	84 (59-118)	0.234

(k) P*=0.2; Impose SOA control rule

Year	**ABC_{tot} ('000t)**	**ABC_{Dir} ('000t)**	**SOA ('000t)**	**C_{dir} ('000t)**	**MMB $/B_{MSY}$**	**Prob (overfishing)**
2009	9.9 (7.0-14.2)	8.8 (6.2-12.6)	8.3 (4.8-11.9)	8.3 (4.8-11.9)	136 (125-146)	0.198
2010	12.6 (8.8-18.0)	11.7 (8.2-16.7)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	12.1 (9.1-16.3)	11.5 (8.7-15.4)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	10.6 (8.6-12.9)	10.1 (8.3-12.3)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	7.9 (6.8- 9.2)	7.5 (6.5- 8.6)	5.5 (3.7- 6.8)	5.4 (3.6- 6.8)	94 (71-118)	0.083
2014	6.0 (4.8- 8.6)	5.6 (4.5- 7.4)	4.9 (3.3- 7.7)	4.8 (3.3- 7.3)	84 (60-118)	0.229

(l) P*=0.1; Impose SOA control rule

Year	**ABC_{tot} ('000t)**	**ABC_{Dir} ('000t)**	**SOA ('000t)**	**C_{dir} ('000t)**	**MMB $/B_{MSY}$**	**Prob (overfishing)**
2009	9.3 (6.6-13.3)	8.2 (5.8-11.8)	8.3 (4.8-11.9)	8.2 (4.8-11.7)	137 (125-146)	0.186
2010	11.8 (8.3-16.9)	11.0 (7.7-15.6)	9.1 (5.3-13.0)	9.1 (5.3-13.0)	155 (142-166)	0.045
2011	11.3 (8.5-15.3)	10.8 (8.1-14.5)	8.0 (5.0-10.8)	7.9 (4.9-10.8)	137 (118-156)	0.015
2012	9.9 (8.0-12.1)	9.5 (7.7-11.6)	6.6 (4.4- 8.4)	6.6 (4.3- 8.4)	115 (93-137)	0.022
2013	7.4 (6.4- 8.6)	7.0 (6.0- 8.1)	5.5 (3.7- 6.8)	5.4 (3.6- 6.8)	94 (71-118)	0.083
2014	5.6 (4.5- 8.1)	5.2 (4.2- 7.0)	4.9 (3.3- 7.7)	4.6 (3.3- 6.9)	84 (61-118)	0.183

(m) P*=0.4; No SOA control rule

Year	**ABC_{tot} ('000t)**	**ABC_{Dir} ('000t)**	**SOA ('000t)**	**C_{dir} ('000t)**	**MMB $/B_{MSY}$**	**Prob (overfishing)**
2009	11.0 (7.8-15.8)	9.8 (6.9-14.0)	8.3 (4.8-11.9)	9.8 (6.9-14.0)	132 (119-141)	0.477
2010	14.1 (9.8-20.0)	13.1 (9.2-18.6)	9.1 (5.3-13.0)	13.1 (9.1-18.6)	143 (126-156)	0.459
2011	12.5 (9.5-16.1)	11.8 (9.0-15.1)	7.4 (4.7- 9.7)	11.8 (8.9-15.1)	116 (91-134)	0.475
2012	8.9 (7.6-10.3)	8.5 (7.3- 9.7)	5.6 (3.8- 6.8)	8.5 (7.3- 9.8)	89 (69-108)	0.461
2013	5.7 (4.8- 6.7)	5.3 (4.5- 6.2)	4.2 (2.9- 5.2)	5.3 (4.5- 6.2)	71 (54- 89)	0.470
2014	4.2 (3.2- 7.3)	3.8 (3.0- 6.2)	3.3 (2.5- 6.5)	3.8 (3.0- 6.2)	65 (48- 98)	0.476

(n) P*=0.3; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	10.5 (7.4-15.0)	9.3 (6.6-13.3)	8.3 (4.8-11.9)	9.3 (6.5-13.3)	133 (121-143)	0.373
2010	13.4 (9.3-19.0)	12.4 (8.7-17.6)	9.1 (5.3-13.0)	12.4 (8.7-17.6)	145 (129-157)	0.367
2011	12.0 (9.1-15.6)	11.4 (8.6-14.7)	7.5 (4.7- 9.9)	11.4 (8.6-14.7)	119 (95-136)	0.369
2012	8.8 (7.6-10.2)	8.4 (7.2- 9.7)	5.8 (3.9- 7.0)	8.4 (7.2- 9.7)	92 (72-111)	0.362
2013	5.7 (4.8- 6.7)	5.3 (4.6- 6.2)	4.4 (3.0- 5.4)	5.3 (4.6- 6.2)	74 (56- 92)	0.371
2014	4.2 (3.3- 7.2)	3.8 (3.1- 6.1)	3.4 (2.6- 6.6)	3.8 (3.1- 6.1)	67 (50-100)	0.371

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	9.9 (7.0-14.2)	8.8 (6.2-12.6)	8.3 (4.8-11.9)	8.8 (6.2-12.6)	135 (123-144)	0.269
2010	12.6 (8.8-18.0)	11.7 (8.2-16.7)	9.1 (5.3-13.0)	11.7 (8.2-16.7)	147 (131-159)	0.274
2011	11.5 (8.7-15.1)	10.9 (8.2-14.2)	7.6 (4.8-10.1)	10.9 (8.2-14.2)	122 (99-139)	0.266
2012	8.8 (7.5-10.2)	8.3 (7.1- 9.6)	5.9 (3.9- 7.3)	8.3 (7.1- 9.6)	95 (75-114)	0.266
2013	5.7 (4.9- 6.7)	5.3 (4.6- 6.2)	4.6 (3.1- 5.6)	5.3 (4.6- 6.2)	77 (59- 94)	0.270
2014	4.2 (3.4- 7.1)	3.8 (3.1- 5.9)	3.5 (2.7- 6.8)	3.8 (3.1- 5.9)	69 (52-103)	0.258

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	9.3 (6.6-13.3)	8.2 (5.8-11.8)	8.3 (4.8-11.9)	8.2 (5.8-11.8)	136 (125-145)	0.190
2010	11.8 (8.3-16.9)	11.0 (7.7-15.6)	9.1 (5.3-13.0)	11.0 (7.7-15.6)	150 (134-160)	0.184
2011	11.0 (8.2-14.4)	10.4 (7.8-13.6)	7.7 (4.8-10.3)	10.4 (7.7-13.6)	125 (103-141)	0.181
2012	8.6 (7.3-10.1)	8.2 (6.9- 9.6)	6.1 (4.0- 7.5)	8.2 (6.9- 9.6)	99 (78-117)	0.185
2013	5.7 (4.9- 6.7)	5.3 (4.6- 6.2)	4.7 (3.2- 5.9)	5.3 (4.6- 6.2)	80 (62- 97)	0.188
2014	4.2 (3.4- 6.9)	3.9 (3.2- 5.8)	3.8 (2.8- 7.0)	3.8 (3.2- 5.8)	72 (55-106)	0.188

Table 6-5 **Summary of the long-term consequences of the alternatives for BBRKC. The column "directed catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2038. The results in the table are based on $\sigma_b = 0.2$.**

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Directed catch (2038) ('000 t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Directed catch (2038) ('000 t)
Multiplier = 1		0.092	0.010	0.208	0.883	7.1 (3.4-13.9)	0.198	0.023	0.466	7.2 (3.1-16.0)
Multiplier = 0.9		0.066	0.006	0.174	0.788	7.1 (3.4-14.1)	0.120	0.012	0.273	7.3 (3.1-15.6)
Multiplier = 0.8		0.040	0.003	0.106	0.615	7.2 (3.4-14.4)	0.063	0.005	0.133	7.2 (3.1-15.2)
Multiplier = 0.7		0.021	0.002	0.043	0.402	7.1 (3.3-14.4)	0.028	0.002	0.046	7.1 (3.2-14.9)
Multiplier = 0.6		0.010	0.001	0.007	0.138	6.8 (3.2-14.1)	0.011	0.001	0.007	6.8 (3.2-14.1)
Multiplier = 0.5		0.001	0.000	0.000	0.027	6.5 (3.1-13.1)	0.003	0.000	0.000	6.5 (3.1-13.1)
Multiplier = 0.4		0.000	0.000	0.000	0.001	5.8 (2.9-11.7)	0.000	0.000	0.000	5.8 (2.9-11.7)
Multiplier = 0.3		0.000	0.000	0.000	0.000	4.9 (2.7- 9.6)	0.000	0.000	0.000	4.9 (2.7- 9.6)
Multiplier = 0.2		0.000	0.000	0.000	0.000	3.7 (2.1- 7.1)	0.000	0.000	0.000	3.7 (2.1- 7.1)
Multiplier = 0.1		0.000	0.000	0.000	0.000	2.1 (1.2- 4.0)	0.000	0.000	0.000	2.1 (1.2- 4.0)
P* = 0.5	1.0	0.092	0.010	0.208	0.883	7.1 (3.4-13.9)	0.198	0.023	0.466	7.2 (3.1-16.0)
P* = 0.45	0.974	0.086	0.009	0.203	0.863	7.1 (3.4-13.9)	0.166	0.020	0.414	7.3 (3.1-15.9)
P* = 0.4	0.949	0.083	0.008	0.196	0.841	7.1 (3.4-14.0)	0.151	0.017	0.367	7.3 (3.1-15.8)
P* = 0.35	0.924	0.075	0.007	0.186	0.816	7.2 (3.4-14.0)	0.128	0.015	0.318	7.3 (3.1-15.7)
P* = 0.3	0.898	0.066	0.006	0.173	0.786	7.1 (3.4-14.1)	0.117	0.012	0.270	7.3 (3.1-15.6)
P* = 0.25	0.870	0.059	0.005	0.156	0.749	7.1 (3.4-14.2)	0.099	0.009	0.224	7.3 (3.1-15.5)
P* = 0.2	0.841	0.054	0.004	0.137	0.692	7.1 (3.4-14.3)	0.085	0.008	0.186	7.2 (3.1-15.4)
P* = 0.15	0.808	0.043	0.003	0.112	0.629	7.2 (3.4-14.5)	0.066	0.006	0.143	7.2 (3.1-15.2)
P* = 0.1	0.768	0.034	0.003	0.084	0.558	7.1 (3.4-14.6)	0.046	0.004	0.099	7.2 (3.1-15.2)
P* = 0.05	0.712	0.022	0.002	0.050	0.439	7.1 (3.3-14.3)	0.031	0.002	0.054	7.1 (3.2-15.0)

Table 6-6 Summary of medium-term economic impacts of a subset of the ACL alternatives for BBRKC. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the five year period 2009-2014, and percentage differences in revenues relative to a zero baseline. Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty ($\sigma_b = 0.2$). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2014 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, ($ Million), discounted at r=0.27%	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0	Multiplier = 1	703(338,1030)	665(322,973)	614(300,894)	0	0
	Multiplier = 0.8	693(334,1018)	656(318,960)	605(296,880)	1	0
	Multiplier = 0.6	625(303,915)	591(288,862)	542(267,790)	11	0
	Multiplier = 0.4	456(216,672)	429(204,630)	390(188,573)	35	0
0.2	Multiplier = 1	682(304,1132)	646(291,1071)	596(270,984)	3	0
	Multiplier = 0.8	672(303,1104)	636(287,1044)	588(269,958)	4	2
	Multiplier = 0.6	610(283,979)	577(269,927)	529(248,848)	13	11
	Multiplier = 0.4	446(207,730)	420(197,690)	384(182,627)	37	35
0.2	P* = 0.5	682(304,1132)	646(291,1071)	596(270,984)	3	0
	P* = 0.4	681(304,1131)	646(291,1069)	596(270,983)	3	0
	P* = 0.3	680(304,1128)	645(291,1067)	596(270,979)	3	0
	P* = 0.2	679(304,1121)	642(290,1059)	594(270,970)	3	1
	P* = 0.1	667(301,1092)	631(286,1032)	582(266,946)	5	2

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, ($ Million), discounted at r=0.27%**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0	Multiplier = 1	892(449,1287)	847(430,1221)	784(402,1129)	0	0
	Multiplier = 0.8	774(384,1119)	733(365,1060)	675(340,978)	13	0
	Multiplier = 0.6	631(305,920)	595(290,868)	546(269,796)	30	0
	Multiplier = 0.4	456(216,672)	429(204,630)	390(188,573)	49	0
0.2	Multiplier = 1	892(437,1356)	847(416,1288)	783(388,1195)	0	0
	Multiplier = 0.8	769(371,1189)	727(353,1126)	670(329,1035)	14	14
	Multiplier = 0.6	621(293,981)	587(280,927)	540(261,848)	31	31
	Multiplier = 0.4	446(207,730)	420(197,690)	384(182,627)	50	50
0.2	P* = 0.5	892(437,1356)	847(416,1288)	783(388,1195)	0	0
	P* = 0.4	863(421,1316)	818(401,1248)	756(373,1157)	3	3
	P* = 0.3	832(404,1275)	788(385,1208)	727(358,1117)	7	7
	P* = 0.2	796(385,1226)	753(366,1161)	695(341,1070)	11	11
	P* = 0.1	747(359,1159)	707(341,1096)	651(319,1007)	17	17

Table 6-7 Summary of long-term economic impacts of the ACL alternatives for BBRKC. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the 30-year period 2009-2038 (2008 dollars), and percentage differences in revenues relative to a zero buffer, with and without σ_b = 0.2. Alternatives include fixed buffers (multipliers of 1.0 to 0.4) and P* levels (0.5 to 0.1), for additional uncertainty of σ_b = 0.2. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives Discount rate: r=0.27%	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b=**0.0**	Baseline B: Multiplier=**1**, σ_b=**0.2**
0	Multiplier = 1	3206(969,6247)	2259(734,4227)	1429(523,2577)	0	0
	Multiplier = 0.8	3168(959,6181)	2220(719,4138)	1403(511,2535)	2	0
	Multiplier = 0.6	2939(886,5783)	2030(665,3827)	1273(464,2318)	10	0
	Multiplier = 0.4	2366(699,4630)	1618(516,3054)	994(352,1809)	28	0
0.2	Multiplier = 1	3129(904,6197)	2196(666,4229)	1400(474,2595)	3	0
	Multiplier = 0.8	3080(892,6150)	2159(664,4172)	1372(470,2553)	4	2
	Multiplier = 0.6	2870(824,5669)	1989(627,3837)	1256(440,2321)	12	9
	Multiplier = 0.4	2336(664,4644)	1602(495,3072)	989(346,1831)	29	27
0.2	P* = 0.5	3129(904,6197)	2196(666,4229)	1400(474,2595)	3	0
	P* = 0.4	3125(903,6196)	2190(666,4222)	1395(474,2591)	3	0
	P* = 0.3	3117(902,6194)	2184(666,4214)	1391(474,2581)	3	1
	P* = 0.2	3100(899,6181)	2174(666,4200)	1383(474,2570)	4	1
	P* = 0.1	3061(885,6094)	2144(664,4132)	1359(467,2536)	5	2

(b) Results are exclusive of SOA control rule effect.

σ_b	Alternative	Present Value of Total Revenue, 2009-2038 ($ Million) r=0	r=2.7%	r=7.0%	Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, Discount rate: r=0.27% — Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0	Multiplier = 1	4364(2171,6657)	2990(1522,4476)	1840(981,2738)	0	0
	Multiplier = 0.8	3859(1909,5901)	2618(1324,3936)	1597(847,2371)	12	0
	Multiplier = 0.6	3201(1575,4890)	2152(1086,3246)	1300(687,1929)	28	0
	Multiplier = 0.4	2369(1159,3616)	1577(793,2384)	941(495,1401)	47	0
0.2	Multiplier = 1	4195(1911,6745)	2860(1322,4642)	1763(834,2871)	4	0
	Multiplier = 0.8	3690(1640,6138)	2504(1139,4207)	1531(716,2558)	16	12
	Multiplier = 0.6	3055(1332,5347)	2065(916,3571)	1247(577,2141)	31	28
	Multiplier = 0.4	2273(971,4036)	1522(668,2686)	904(414,1595)	49	47
0.2	P* = 0.5	4195(1911,6745)	2860(1322,4642)	1763(834,2871)	4	0
	P* = 0.4	4024(1813,6593)	2743(1253,4506)	1677(793,2776)	8	4
	P* = 0.3	3841(1720,6359)	2608(1200,4336)	1595(750,2661)	13	9
	P* = 0.2	3621(1617,6117)	2451(1111,4150)	1502(701,2510)	18	14
	P* = 0.1	3329(1478,5736)	2255(1004,3872)	1375(635,2313)	25	21

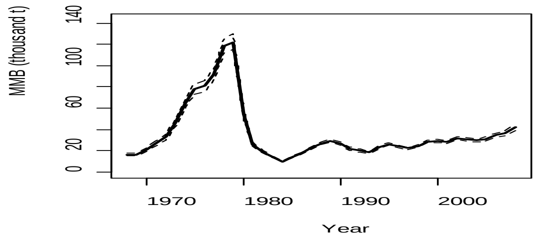


Figure 6-1 Time-trajectory of mature male biomass at the time of mating for BBRKC (thousand t).

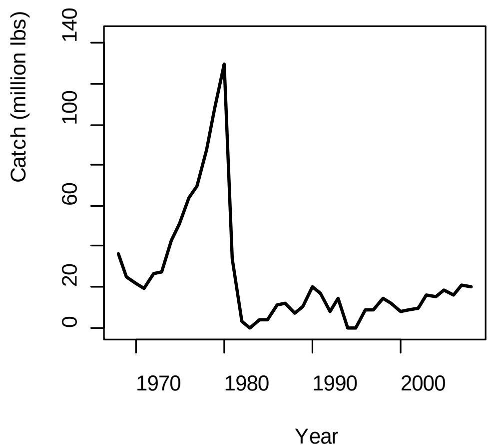


Figure 6-2 Total retained catches of BBRKC (million lbs) [source: Zheng *et al.* (2009)].

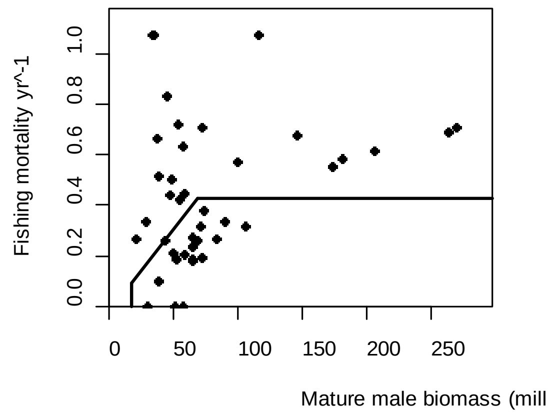


Figure 6-3 **Fully-selected fishing mortality by the directed (pot) fishery on legal males and the mature male biomass on Feb 15 (dots). The solid line denotes the Tier 3 OFL control rule.**

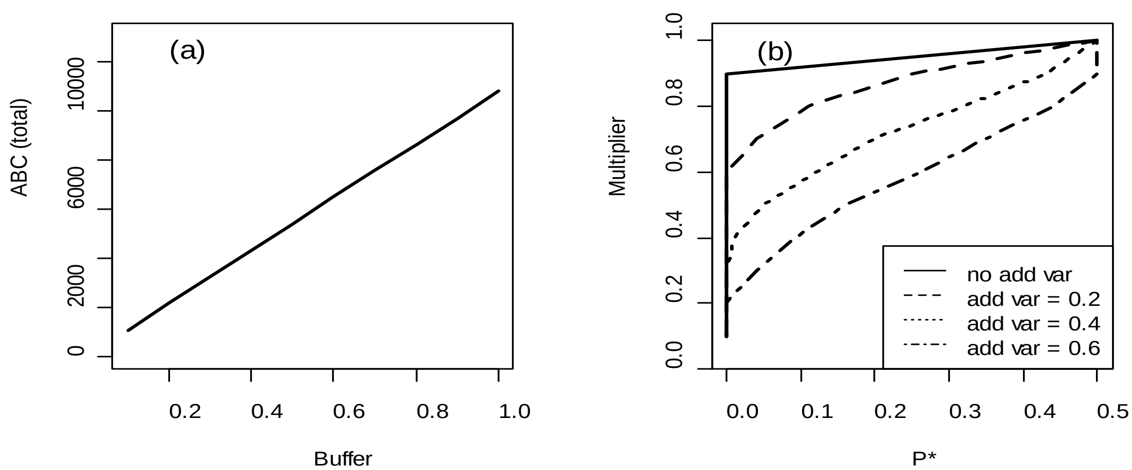


Figure 6-4 **Relationship between the multiplier and the ABC (a), and the relationships between P* and the multiplier for four values for the extent of additional uncertainty (b).**

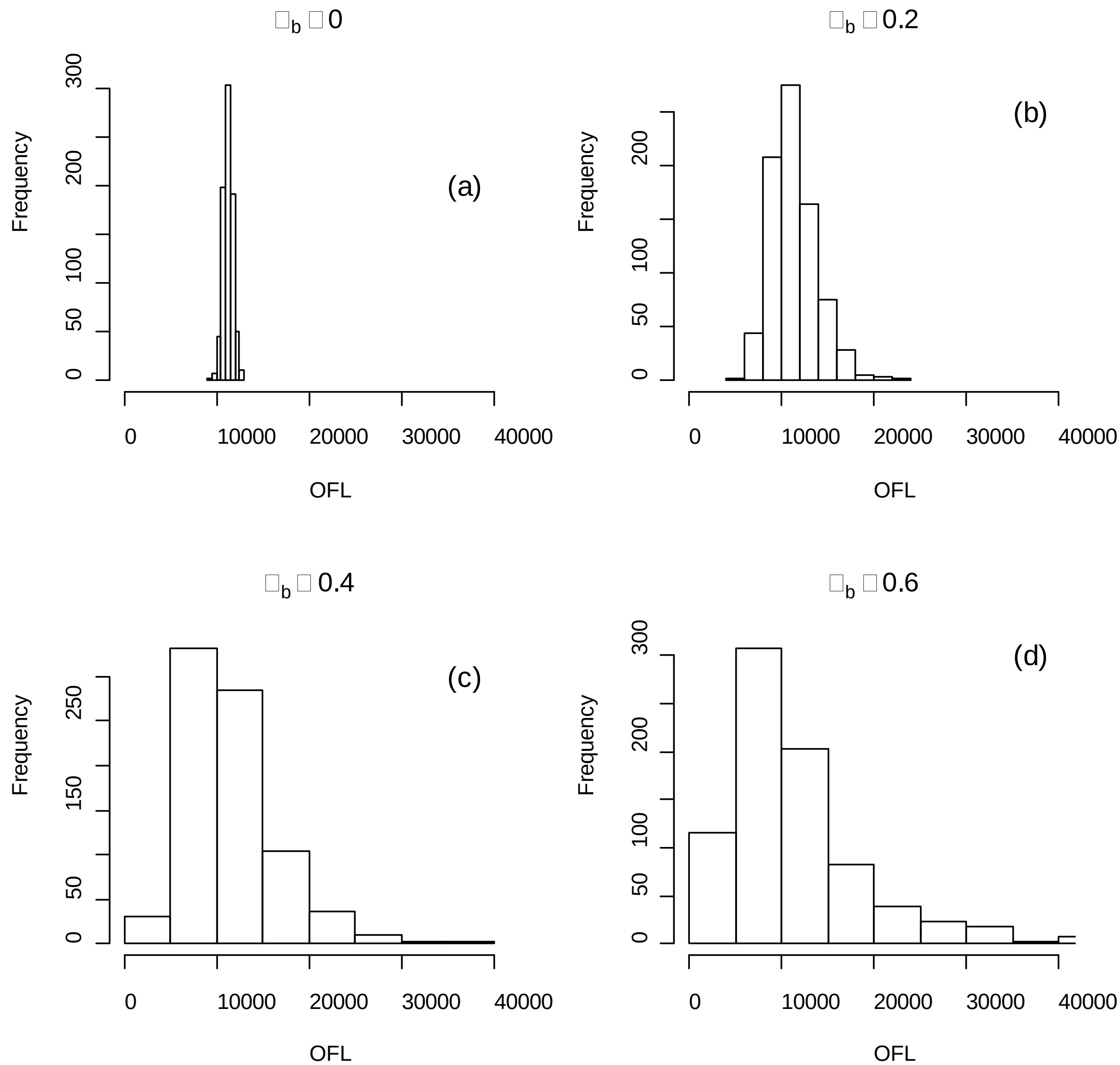


Figure 6-5 **Distribution of OFL values for BBRKC as a function of the assumed extent of additional uncertainty (σ_b).**

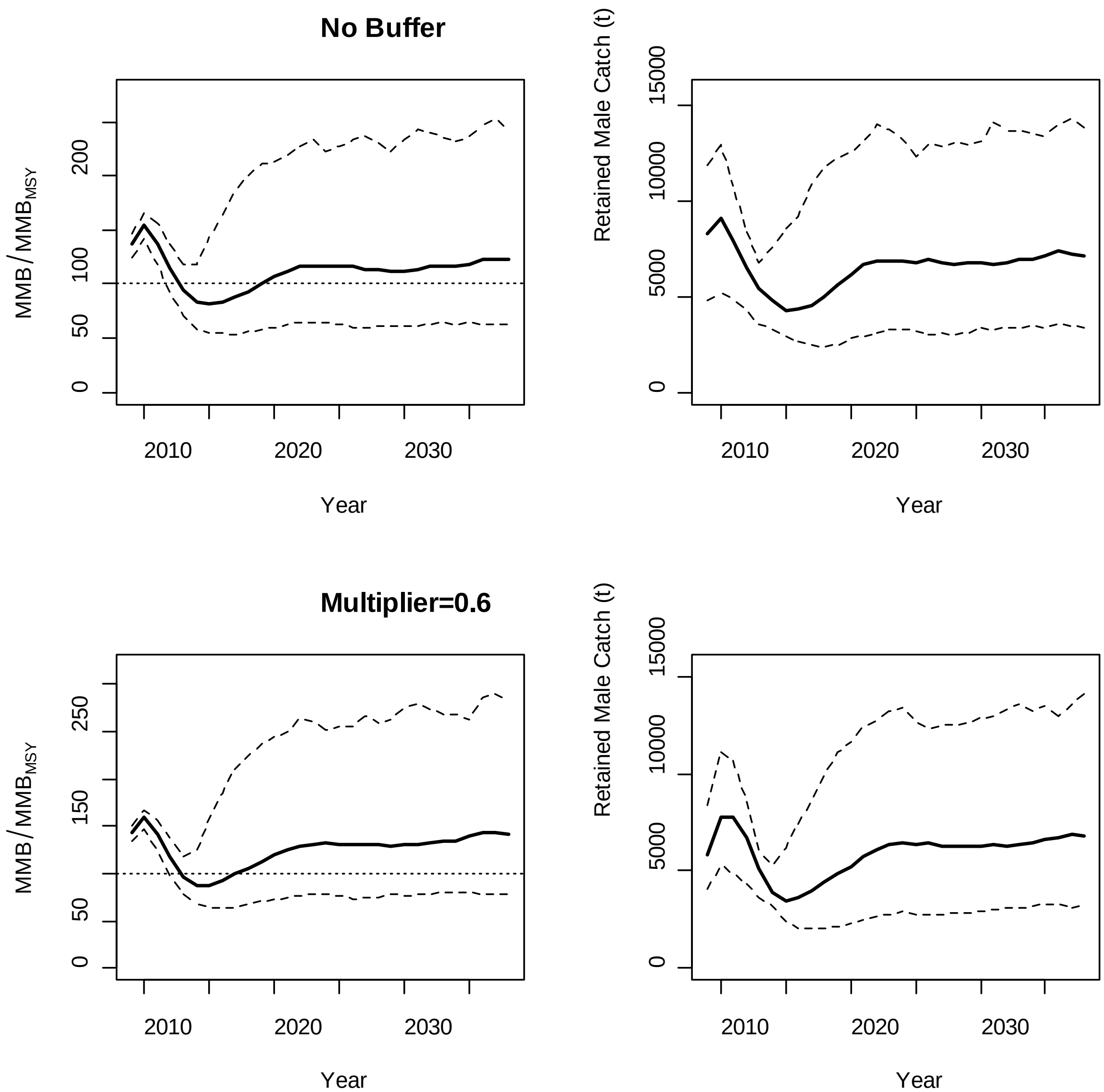


Figure 6-6 **Time-trajectories of mature male biomass at mating relative to B_{35} (the proxy for B_{MSY}) and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the table are based on $\sigma_b = 0.2$. The results in this figure are based on applying the SOA control rule.**

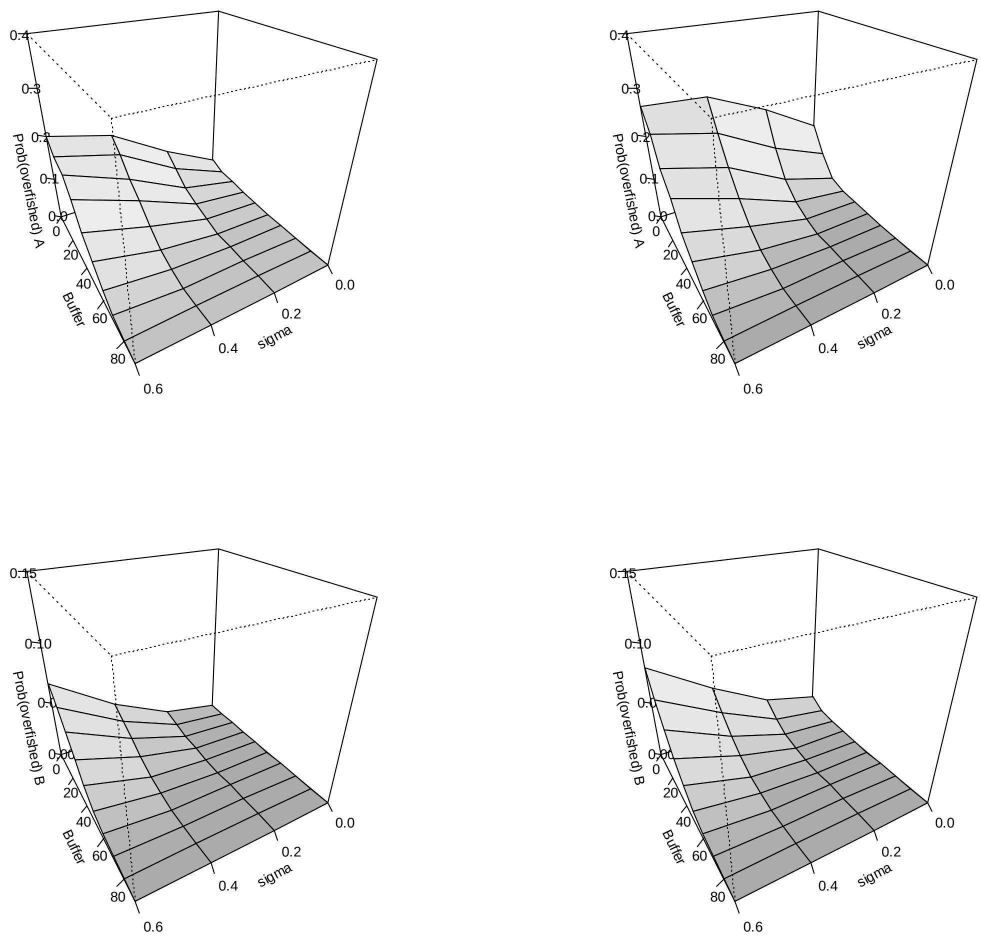


Figure 6-7 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for BBRKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

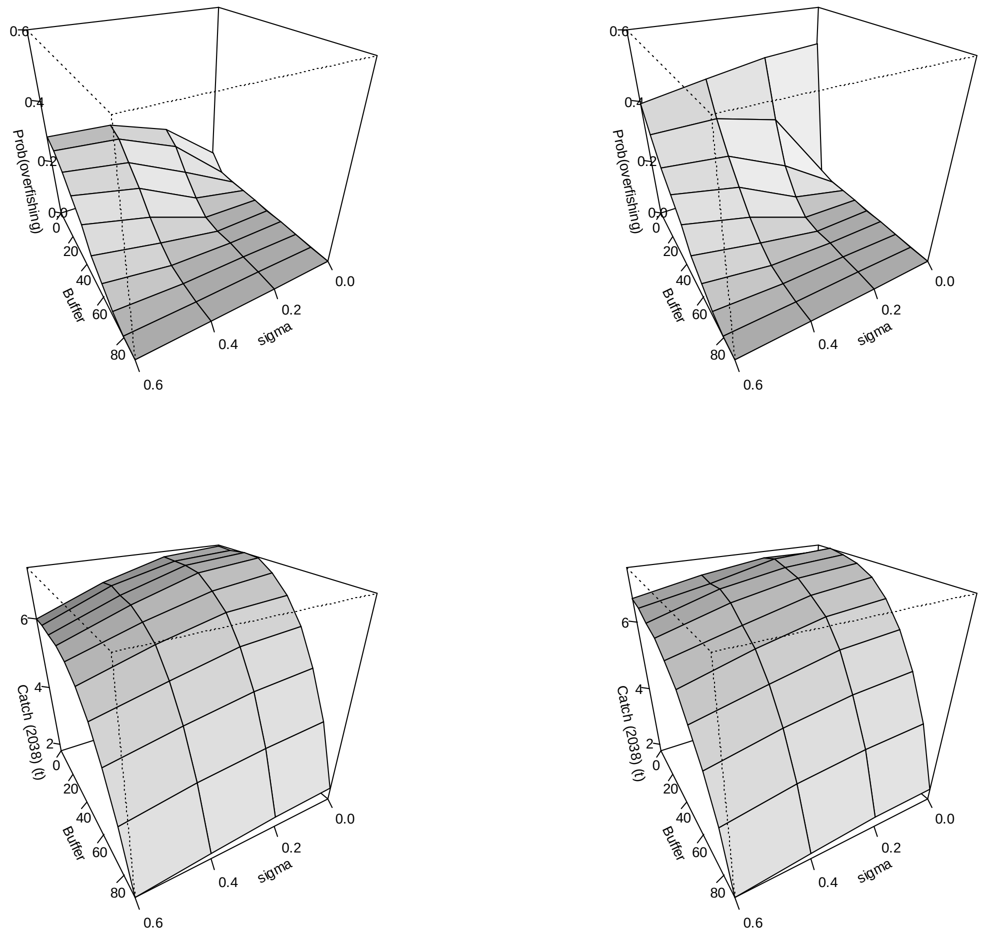


Figure 6-8 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for BBRKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

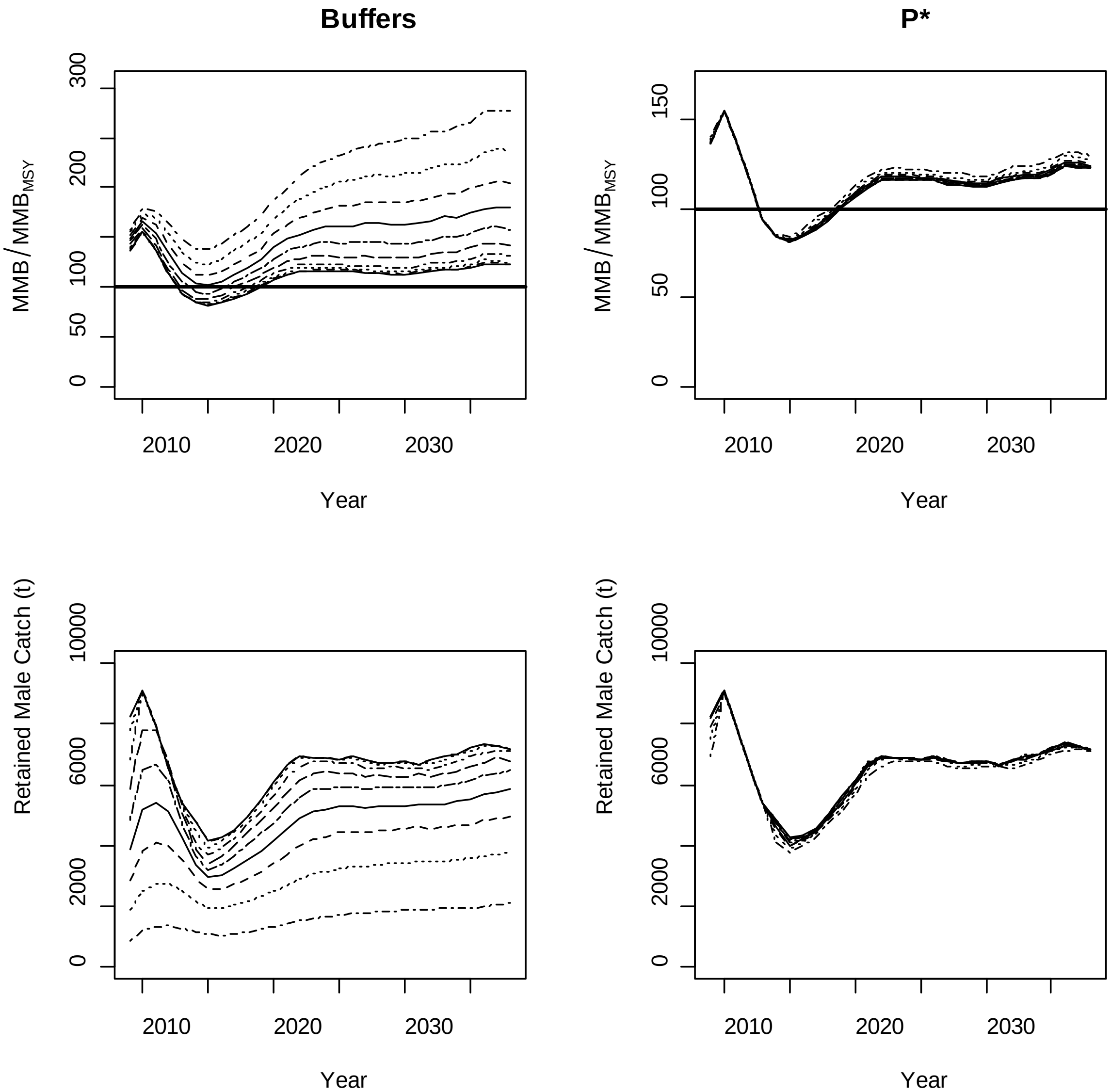


Figure 6-9 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (B_{35}) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the table are based on $\sigma_b = 0.2$ and imposing the SOA control rule.**

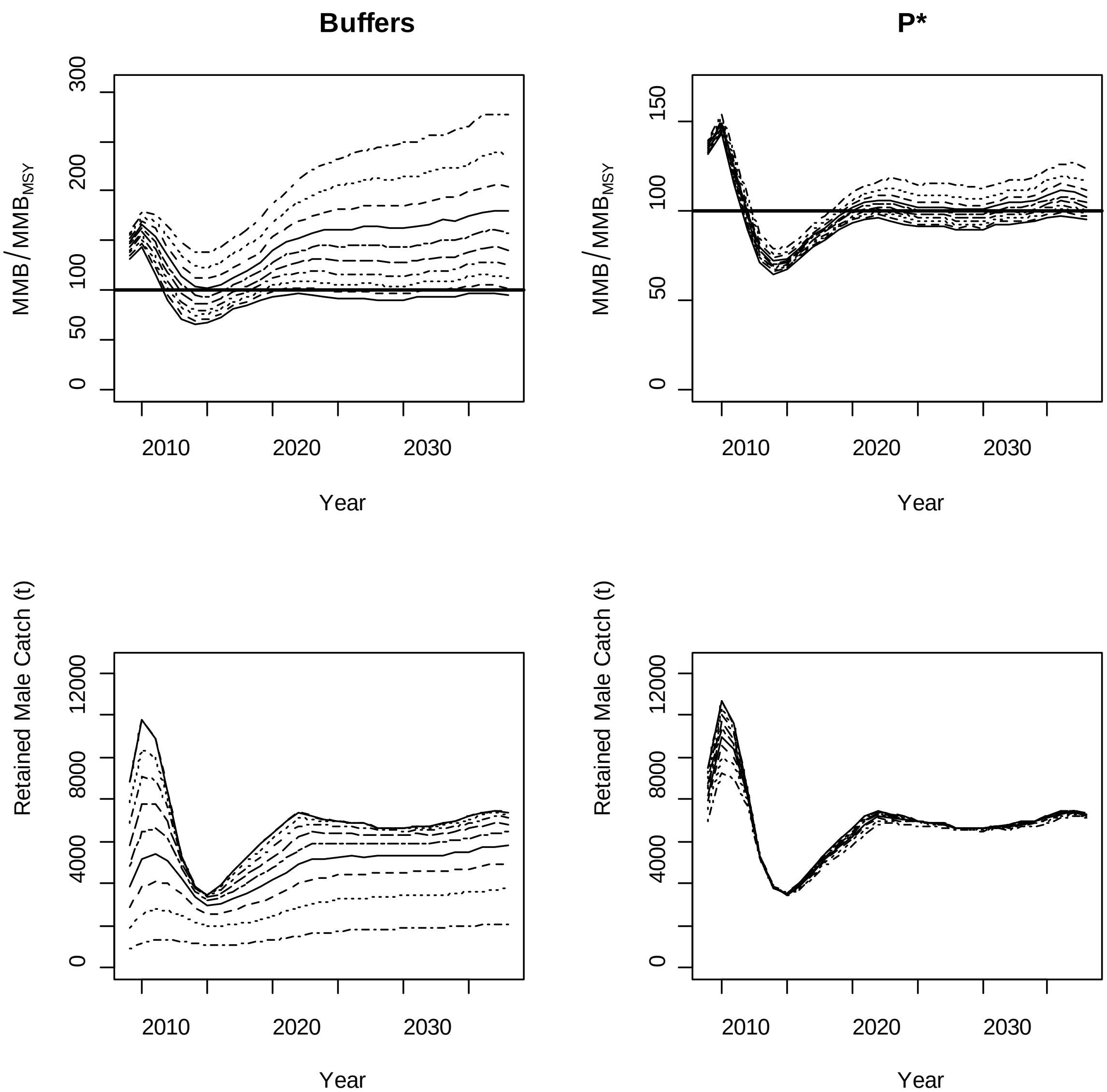


Figure 6-10 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (B_{35}) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the table are based on $\sigma_b = 0.2$ and not imposing the SOA control rule.**

7 Pribilof Islands Red King Crab

Red king crab, *Paralithodes camtschaticus*, are found in several areas of the Aleutian Islands and eastern Bering Sea. The State of Alaska divides the Aleutian Islands and eastern Bering Sea into three management registration areas to manage red king crab fisheries: Aleutian Islands, Bristol Bay, and Bering Sea (ADF&G 2005). The Aleutian Islands area covers two stocks, Adak and Dutch Harbor, and the Bering Sea area contains two other stocks, the Pribilof Islands and Norton Sound. The largest stock is found in the Bristol Bay area, which includes all waters north of the latitude of Cape Sarichef (54°36' N lat.), east of 168° W long., and south of the latitude of Cape Newenham (58°39' N lat.) (ADF&G 2005).

7.1 Assessment overview

The Pribilof Islands red king crab (PIRKC) stock biomass is below its estimated B_{MSY} (8.78 million lbs of mature male biomass, at the time of mating) with survey-estimated mature male biomass at mating having decreased from 11.06 million lbs in 2008 to 4.46 million lbs in 2009 (Foy and Rugolo 2009). Model-estimated mature male biomass was near 3,000t in 2008 and 2009 (Figure 7-1). Survey estimates of total biomass increased to 68 million pounds in 1995, fluctuated between 8.8 and 21.9 million pound between 1996 and 2007, and then decreased to 6.7 million pounds in 2009. Pre-recruit biomass has followed similar patterns as total biomass with no indication of above average recruitment in the past three years.

The most recent assessment of PIRKC (Foy and Rugolo 2009) is based on survey estimates using area swept methods[65]. Survey abundance in specified length bins is summed across strata defined by single or multiple tows. Weight and maturity schedules are applied to these abundances and summed to calculate biomass.

The OFL for PIRKC is currently based on the Tier 4 control rule, i.e. the proxy for F_{MSY} is taken to be the product of natural mortality (M) and a scalar, γ (NPFMC, 2008). The proxy for B_{MSY} is taken to be the average biomass over a specified time period (currently 1991 to 2008). The OFL is a male total-catch OFL and is computed as the sum of catches by three different sources of removals: (a) the retained legal males in directed (pot) fishery for PIRKC, (b) discards of males in the directed fishery, and (c) bycatch in the groundfish pot and trawl fisheries.

The harvest strategy has incorporated protection measures for Pribilof Island blue king crab so TACs have been zero in recent years.

Methods for economic projections are described in Chapter 3.

7.1.1 Uncertainty in stock assessment

Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for PIRKC is high due to insufficient data and the small distribution of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass for the most recent year is 0.637 and has ranged between 0.357 and 0.786 since the 1995 peak in biomass. The coefficient of variation for the estimate of mature male biomass for the most recent year from the stock assessment used for the projections is 0.180.

However, several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:

[65] The analyses of this chapter are based on a new assessment model. The results are therefore not identical to those in Foy and Rugolo (2009).

- Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.
- F_{msy} is assumed to be equal to γM when applying the OFL control rule while γ is assumed to be equal to 1 and M is assumed to be known.
- The model on which the projections are based is still in development and has yet to be reviewed by the CPT.
- The coefficients of variation for the survey estimates of abundance for this stock are very high.
- B_{msy} is assumed to be equivalent to average mature male biomass between 1991 and 2008. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1981-1988 and 1993-1999, so considerable uncertainty exists with this estimate of B_{msy}.

For PIRKC, additional uncertainty is thought to be high, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.4 to quantify this high level of additional uncertainty, which is the value recommended by the CPT and SSC. This analysis of the short-term implications also includes results for a σ_b of 0, 0.2, 0.3, and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.4. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

7.2 Impacts of alternatives

As described in Chapter 2, there are two methods under consideration for computing an ABC for PIRKC: (a) the OFL can be multiplied by a pre-specified "multiplier" (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4). The analyses of this chapter consider two approaches to computing OFLs using the Tier 4 control rule: (a) based on the results of the assessment model, and (b) based on the survey estimates of abundance. The results from the model used determine the OFL have a CV of 0.18 while the CV for the survey data is set to the square root of the average of the CV^2 for 2000-09 (0.574). The large difference in CVs is not unexpected because the model-estimate of current biomass essentially reflects an average over multiple years.

The implications of the alternatives for calculating the ABC are evaluated in this chapter. The analyses of impacts in this chapter are based on the assumption that there are no sector-specific ACLs, that the ACL applies to all removals of PIRKC (a total-catch ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the groundfish and other crab fisheries.

7.2.1 Short-term Implications

The short-term implications are assessed by the impacts of the alternative buffers and P* values on the ABC which would have been advised for the 2010/11 fishery relative to a zero buffer (assuming that ABCs had been specified for that fishery and assuming catch equals the ABC). These values are shown in Table 7-1. Under Alternative 4, a P* of 0.49 would result in a buffer of approximately 40% between the OFL and ABC.[66] For this fishery, this does not reflect status quo because ADF&G has closed this fishery and, therefore, under status quo, retained catch would be zero. Given a one-year projection, it is

[66] This analysis uses the mean for the probability distribution of the OFL, which provides different results than applying the median due to skewness, as discussed in section 3.2.4.2.

not feasible to assess the short-term biological implications of the choice of an alternative because no alternative would have changed that fact that the fishery is closed for the near future.

7.2.2 Medium- and long-term implications

The medium- and long-term implications are evaluated by projecting the population ahead 30 years under the assumption that the catch equals the ABC.[67] The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2010-2015) while the long-term implications consider the implications of the entire 30-year projection period.

Table 7-3 lists summaries of the posterior distributions for the key parameters which determine the productivity of the population. For medium- and long-term projections, the implications of the alternatives were analyzed based on projections from a model-based Tier 4 control rule and a non-model-based Tier 4 control rule.

7.2.2.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized by the model-based projected values for the ABC (which includes all sources of male catch), "ABC_{tot}", the retained catch in the directed fishery, "C_{dir}", the ratio of the mature male biomass at the time of mating to that the mature male biomass at which MSY is achieved, "MMB/B_{MSY}", and the probability of overfishing occurring. Results are shown in Table 7-4 and Table 7-5 for analyses based on the model-based and non-model-based Tier 4 control rules for additional uncertainty (0.4), and for four multiplier levels (1, 0.8, 0.6 and 0.4) and choices for P* (0.4, 0.3, 0.2 and 0.1). These multiplier levels correspond to buffer values of 0, 20%, 40% and 60% respectively.

The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) decreases as the size of the buffer is increased (the multiplier is decreased) and P* is reduced. However, this reduction is at a cost of substantially lower annual catches (particularly in the earlier years of the projection period) relative to fishing at the OFL. One consequence of larger buffer is, however, larger stock sizes.

The same basic patterns of overfishing probability relative to buffer and of the effects on annual catches were observed when applying a non-model based Tier 4 control rule. Except when there is no buffer between the OFL and the ABC, the probability of overfishing is higher when the non-model-based approach is applied (Table 7-4 and Table 7-5). However, the extent of uncertainty is higher for the simulations based on the non-based approach (an "assessment" CV of 0.574 compared to 0.18).

7.2.2.2 Long-term implications - Biological

Table 7-6 summarizes the results of the modeled long-term projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"), (b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B"), (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), and (d) the mean and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period.

Figure 7-5 and Figure 7-6 show the time-trajectories of catch and mature male biomass at mating relative to the proxy for B_{MSY} for two illustrative choices for the buffer (0: ABC=OFL; 40%: the ABC is 60% of

[67] The analysis in this chapter does not incorporate State management regulations because there is no harvest strategy in regulation or formally developed for PIRKC. However, the State has closed this fishery due to concerns with bycatch of blue king crab.

the OFL). These choices assume that catch equals the ACL, which is not status quo. Status quo catch would be zero or, if catch was allowed, it would be below the ACL. Therefore, the projected catch and probability of overfishing for each buffer are greater than would occur under status quo. As expected, the mature male biomass is larger when the buffer is lower.

Figure 7-7 evaluates the implications of different buffer values between the ABC and the OFL in terms of metrics (c) and (d) in Table 7-6, except that results are shown for all four values of the extent of additional uncertainty instead of only the value recommended by the CPT. Results are not shown for metrics (a) and (b) because the probability of being overfished is high (essentially 1) for all cases. As expected from Table 7-4 to Table 7-6, the catches under the non-model-based Tier 4 control rule are much lower than under the model-based approach (Figure 7-7, lower panels) but the risk of overfishing (Figure 7-7, upper panels) is not markedly different between the two approaches. The probability of overfishing and of catch in 2039 are maximized for the smallest buffer and are not markedly impacts by the extent of additional uncertainty (especially when the OFL is based on the non-model-based approach).

Figure 7-5 and Figure 7-6 illustrate the differences among the 10 buffers and choices for P* in terms of the model-based median time-trajectory of mature male biomass at mating relative to the proxy for B_{MSY} and the median time-trajectory of the catch of legal males in the directed fishery. The ratio of mature male biomass to B_{MSY} increases essentially continuously with changes in the buffer. The rate at which catch drops with increasing buffer sizes is, however, not the same as that at which biomass increases.

7.2.2.3 Medium and long-term implications - Economic

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference on the evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30- year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

Revenue forecasts are based on probabilistic price forecasts using the time-series vector autoregression model for Alaskan red king crab, adjusted by a factor of 0.86 to account for the mean difference between Alaskan blue king and red king crab over the period 1991 to 2003 when the fishery was open (see Chapter 3 for details). The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume using the average product recovery rate for Alaska red king crab (0.64%). Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

The medium and long-term impacts of ACL alternatives are summarized in Table 7-7 and Table 7-8. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term, assuming that catch equal the ACL, however, in reality, catch would be zero or below the ACL. Table 7-7(a) and Table 7-7(b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to 1) zero buffer (multiplier=1.0) and no additional uncertainty (σ=0), and 2) zero buffer, but holding the value of σ constant across compared alternatives. Results are shown for scenarios that apply the model based [Table 7-7(a)] and non-model based [Table 7-7(b)] OFL control rule. Table 7-8(a) and Table 7-8(b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2038, and the comparative economic effects of alternatives in foregone revenue relative to 1) zero buffer (multiplier=1.0) and no additional uncertainty (σ=0), and 2) zero buffer, but holding the value of σ constant across compared alternatives. Results are shown for scenarios that apply the model based [Table 7-8(a)], and non-model based control rule (Table 7-8(b)].

7.3 Tables and Figures

Table 7-1 Values for catch-related quantities for PIRKC for 2010/11 for each of the alternatives. The column P* in (a) shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The SSC recommended additional uncertainty is shaded. Revenues reported are median and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009. The results in this table are based on applying the Tier 4 control rule to the survey data (non-model-based OFL).

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (t)	P * (additional uncertainty)					Revenue	
		None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	227	>0.50	>0.50	>0.50	>0.50	>0.50	5	0
Multiplier = 0.9	204	>0.50	>0.50	>0.50	>0.50	>0.50	4	20
Multiplier = 0.8	181	>0.50	>0.50	>0.50	>0.50	>0.50	4	20
Multiplier = 0.7	159	0.48	>0.50	>0.50	>0.50	>0.50	3	40
Multiplier = 0.6	136	0.43	0.47	0.46	0.49	>0.50	3	40
Multiplier = 0.5	113	0.38	0.41	0.41	0.44	0.49	2	60
Multiplier = 0.4	91	0.32	0.35	0.35	0.39	0.44	2	60
Multiplier = 0.3	68	0.25	0.29	0.28	0.33	0.39	1	80
Multiplier = 0.2	45	0.18	0.21	0.22	0.26	0.32	1	80
Multiplier = 0.1	23	0.14	0.17	0.19	0.22	0.29	0	100

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot} (t)	Multiplier
P^* = 0.5	227[&]	1
P^* = 0.4	114	0.50
P^* = 0.3	79	0.35
P^* = 0.2	52	0.23
P^* = 0.1	0	0.00

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot} (t)	Multiplier
P^* = 0.5	227[&]	1
P^* = 0.4	113	0.50
P^* = 0.3	77	0.34
P^* = 0.2	45	0.20
P^* = 0.1	0	0.00

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot} (t)	Multiplier	Revenue	
			Millions $	Millions $
$P^* = 0.5$	227&	1	4	0
$P^* = 0.4$	104	0.46	3	25
$P^* = 0.3$	69	0.30	3	25
$P^* = 0.2$	37	0.16	2	50
$P^* = 0.1$	0	0.00	1	75

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot} (t)	Multiplier
$P^* = 0.5$	227&	1
$P^* = 0.4$	95	0.42
$P^* = 0.3$	60	0.27
$P^* = 0.2$	0	0.00
$P^* = 0.1$	0	0.00

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot} (t)	Multiplier
$P^* = 0.5$	227&	1
$P^* = 0.4$	71	0.31
$P^* = 0.3$	24	0.11
$P^* = 0.2$	0	0.00
$P^* = 0.1$	0	0.00

& - set to the point estimate

Table 7-2 Breakdown of the model-based estimate of the 2010/11 OFL for PIRKC among the sources of mortality included in the OFL.

Component	Catch (t)
Directed fishery	392
Male discard in the directed fishery	5
Bycatch in the trawl fishery	13
Bycatch in the Fixed gear fishery	1
Total	413

Table 7-3 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes.

Parameter	Distribution
Virgin MMB	12.0 (1.4, 12.6)
Steepness, h	0.530, (0.526, 0.534)
FMSY (M)	0.18
BMSY	3.8 (3.6, 4.1)
σ_R	4.055 (3.695, 4.358)*

* σ_R was set to 1.5 for the projections

Table 7-4 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for PIRKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on $\sigma_b = 0.4$. These projections apply the Tier 4 control rule (model based OFL).

(a) Multiplier = 1

Year	ABC_{tot} (t)	C_{dir} (‘t)	MMB/B_{MSY}	Prob (overfishing)
2010	454 (183-1082)	423 (156-1045)	70 (60- 76)	0.439
2011	363 (158- 764)	330 (132- 728)	65 (52- 73)	0.427
2012	317 (140- 768)	286 (116- 688)	62 (48- 119)	0.395
2013	327 (136-1283)	295 (112-1153)	64 (44- 153)	0.409
2014	361 (119-1633)	323 (102-1497)	66 (40- 196)	0.399
2015	366 (101-2002)	333 (81-1944)	67 (38- 213)	0.405

(b) Multiplier = 0.8

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	363 (147- 865)	334 (119- 831)	71 (63- 76)	0.276
2011	306 (131- 645)	275 (105- 611)	68 (57- 75)	0.302
2012	272 (122- 641)	241 (97- 579)	65 (52- 122)	0.249
2013	286 (118-1096)	256 (94- 977)	66 (47- 162)	0.245
2014	313 (106-1362)	279 (86-1252)	71 (43- 209)	0.258
2015	321 (92-1713)	292 (71-1640)	72 (42- 228)	0.263

(c) Multiplier = 0.6

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	272 (110- 649)	244 (83- 617)	73 (66- 77)	0.133
2011	242 (103- 521)	210 (75- 479)	71 (62- 77)	0.139
2012	219 (98- 529)	188 (73- 479)	68 (57- 126)	0.094
2013	235 (96- 873)	203 (71- 796)	70 (52- 170)	0.085
2014	257 (89-1094)	223 (67-1038)	75 (47- 219)	0.095
2015	269 (78-1365)	239 (56-1288)	77 (45- 242)	0.110

(d) Multiplier = 0.4

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	182 (73- 433)	154 (46- 402)	74 (69- 78)	0.024
2011	167 (71- 367)	138 (44- 333)	73 (67- 79)	0.018
2012	159 (70- 380)	129 (44- 342)	71 (62- 130)	0.024
2013	169 (67- 607)	141 (44- 544)	74 (56- 178)	0.021
2014	189 (66- 816)	157 (44- 741)	80 (51- 235)	0.013
2015	201 (58- 970)	166 (35- 887)	82 (49- 254)	0.022

(e) P* = 0.4

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	372 (53-1562)	341 (27-1516)	71 (51- 78)	0.404
2011	285 (8-1480)	256 (0-1401)	65 (43- 77)	0.403
2012	231 (6-1192)	202 (0-1111)	62 (40- 119)	0.356
2013	278 (6-1572)	249 (0-1462)	62 (36- 159)	0.380
2014	334 (6-1980)	294 (0-1786)	65 (35- 200)	0.416
2015	341 (6-2678)	300 (0-2398)	65 (33- 204)	0.395

(f) P* = 0.3

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	298 (42-1250)	268 (16-1207)	72 (56- 79)	0.310
2011	239 (8-1196)	213 (0-1145)	68 (50- 78)	0.331
2012	198 (6- 985)	172 (0- 916)	65 (46- 121)	0.295
2013	247 (5-1284)	220 (0-1194)	66 (41- 165)	0.287
2014	297 (6-1627)	255 (0-1481)	69 (39- 212)	0.315
2015	302 (5-2183)	261 (0-1957)	70 (37- 220)	0.299

(g) P* = 0.2

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	223 (32- 937)	194 (6- 899)	74 (62- 79)	0.230
2011	188 (26- 926)	160 (4- 875)	70 (56- 79)	0.240
2012	161 (5- 770)	136 (0- 721)	68 (52- 127)	0.184
2013	207 (4- 997)	181 (0- 925)	70 (48- 172)	0.200
2014	253 (5-1277)	213 (0-1150)	74 (44- 229)	0.205
2015	247 (4-1680)	216 (0-1524)	75 (42- 241)	0.200

(h) P* = 0.1

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	149 (21- 625)	120 (0- 591)	75 (67- 80)	0.111
2011	131 (19- 627)	104 (0- 586)	73 (63- 80)	0.125
2012	119 (3- 530)	92 (0- 489)	71 (59- 131)	0.095
2013	155 (3- 698)	125 (0- 632)	74 (54- 179)	0.092
2014	186 (4- 874)	153 (0- 752)	79 (49- 240)	0.090
2015	187 (3-1160)	154 (0-1072)	81 (48- 254)	0.075

Table 7-5 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for PIRKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on $\sigma_b = 0.4$. These projections apply the Tier 4 control rule (non-model based OFL).

(a) Multiplier = 1

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	406 (164- 968)	376 (137- 932)	71 (61- 76)	0.350
2011	334 (144- 707)	300 (118- 666)	67 (54- 74)	0.359
2012	293 (132- 696)	264 (107- 630)	64 (50- 121)	0.321
2013	308 (128-1196)	276 (102-1078)	65 (45- 157)	0.326
2014	337 (114-1494)	302 (95-1338)	68 (42- 203)	0.329
2015	344 (96-1869)	312 (76-1795)	69 (40- 222)	0.323

(b) Multiplier = 0.8

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	361 (146- 860)	331 (118- 825)	71 (63- 76)	0.274
2011	305 (130- 642)	273 (104- 608)	68 (57- 75)	0.299
2012	271 (122- 638)	240 (96- 576)	65 (52- 122)	0.245
2013	284 (118-1089)	255 (93- 972)	67 (47- 162)	0.237
2014	311 (105-1355)	278 (86-1244)	71 (43- 209)	0.253
2015	320 (91-1703)	291 (70-1631)	72 (42- 228)	0.259

(c) Multiplier = 0.6

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	314 (127- 747)	285 (100- 714)	72 (65- 77)	0.194
2011	273 (116- 575)	243 (88- 544)	69 (60- 76)	0.209
2012	246 (110- 585)	212 (84- 527)	67 (55- 123)	0.168
2013	259 (107- 973)	228 (82- 899)	68 (50- 166)	0.151
2014	285 (95-1206)	251 (76-1141)	73 (45- 214)	0.164
2015	296 (84-1527)	264 (63-1457)	74 (43- 235)	0.177

(d) Multiplier = 0.4

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	259 (104- 617)	230 (77- 584)	73 (67- 78)	0.115
2011	230 (99- 502)	199 (70- 457)	71 (62- 77)	0.117
2012	211 (95- 505)	180 (69- 459)	68 (57- 127)	0.076
2013	226 (92- 835)	194 (67- 754)	71 (53- 171)	0.074
2014	247 (87-1050)	215 (64-1003)	75 (48- 222)	0.079
2015	260 (75-1310)	229 (53-1228)	77 (45- 248)	0.096

(e) P* = 0.4

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	282 (32-1489)	252 (5-1447)	72 (52- 79)	0.320
2011	227 (8-1225)	201 (0-1181)	68 (45- 78)	0.336
2012	189 (6-1051)	163 (0- 988)	65 (41- 122)	0.275
2013	238 (5-1393)	208 (0-1261)	67 (38- 165)	0.276
2014	277 (7-1815)	240 (0-1677)	69 (35- 210)	0.299
2015	276 (5-2206)	237 (0-2120)	69 (35- 228)	0.300

(f) P* = 0.3

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	233 (26-1232)	203 (0-1192)	73 (56- 79)	0.266
2011	197 (10-1052)	169 (0-1004)	70 (50- 79)	0.275
2012	169 (6- 928)	143 (0- 877)	67 (46- 123)	0.221
2013	217 (5-1176)	182 (0-1076)	69 (42- 170)	0.224
2014	245 (6-1622)	210 (0-1463)	72 (40- 218)	0.245
2015	245 (5-1885)	215 (0-1819)	73 (38- 235)	0.251

(g) P* = 0.2

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	187 (21- 986)	158 (0- 949)	74 (61- 79)	0.196
2011	161 (14- 854)	136 (0- 821)	72 (55- 80)	0.212
2012	143 (6- 788)	117 (0- 700)	69 (51- 127)	0.164
2013	183 (5- 970)	153 (0- 872)	71 (47- 174)	0.165
2014	209 (6-1320)	177 (0-1214)	75 (43- 228)	0.175
2015	213 (4-1575)	183 (0-1501)	77 (42- 245)	0.183

(h) P* = 0.1

Year	ABC_{tot} (t)	C_{dir} ('t)	MMB/B_{MSY}	Prob (overfishing)
2010	137 (15- 725)	109 (0- 691)	75 (65- 80)	0.123
2011	126 (15- 674)	100 (0- 632)	73 (61- 80)	0.144
2012	112 (5- 604)	88 (0- 562)	71 (57- 130)	0.099
2013	146 (4- 735)	116 (0- 665)	74 (52- 180)	0.092
2014	165 (5-1021)	132 (0- 917)	79 (48- 238)	0.091
2015	174 (3-1229)	140 (0-1161)	81 (46- 252)	0.096

Table 7-6 Summary of the long-term consequences of the alternatives for PIRKC. The column "retained catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2039. The results in the table are based on $\sigma_b = 0.4$

Alternative	Multiplier for P*	Model-based				Multiplier for P*	Non-Model-based			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Retained catch (2039) (t)		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Retained catch (2039) (t)
Multiplier = 1		1.000	1.000	0.399	405 (65-1928)		1.000	1.000	0.353	282 (0-2367)
Multiplier = 0.9		1.000	1.000	0.322	401 (64-1798)		1.000	1.000	0.313	288 (0-2298)
Multiplier = 0.8		1.000	1.000	0.247	397 (65-1675)		1.000	1.000	0.272	287 (0-2177)
Multiplier = 0.7		1.000	1.000	0.172	391 (62-1602)		1.000	1.000	0.228	285 (0-2020)
Multiplier = 0.6		1.000	1.000	0.103	370 (59-1501)		1.000	1.000	0.180	271 (0-1885)
Multiplier = 0.5		1.000	1.000	0.052	334 (55-1318)		1.000	1.000	0.132	254 (0-1745)
Multiplier = 0.4		1.000	1.000	0.018	293 (47-1143)		1.000	1.000	0.084	226 (0-1464)
Multiplier = 0.3		1.000	1.000	0.003	235 (37- 929)		1.000	1.000	0.041	182 (0-1161)
Multiplier = 0.2		1.000	1.000	0.000	160 (21- 666)		1.000	1.000	0.011	126 (0- 830)
Multiplier = 0.1		1.000	1.000	0.000	66 (0- 305)		1.000	1.000	0.000	47 (0- 428)
P* = 0.5	1.0	1.000	1.000	0.399	405 (65-1928)	1.0	1.000	1.000	0.353	282 (0-2367)
P* = 0.45	0.974	1.000	1.000	0.357	400 (64-1859)	0.916	1.000	1.000	0.319	286 (0-2316)
P* = 0.4	0.949	1.000	1.000	0.319	400 (64-1791)	0.838	1.000	1.000	0.287	291 (0-2231)
P* = 0.35	0.924	1.000	1.000	0.280	402 (65-1722)	0.764	1.000	1.000	0.255	287 (0-2157)
P* = 0.3	0.898	1.000	1.000	0.242	396 (65-1668)	0.693	1.000	1.000	0.225	285 (0-2005)
P* = 0.25	0.870	1.000	1.000	0.204	393 (63-1631)	0.624	1.000	1.000	0.192	275 (0-1911)
P* = 0.2	0.841	1.000	1.000	0.164	389 (63-1600)	0.555	1.000	1.000	0.159	266 (0-1828)
P* = 0.15	0.808	1.000	1.000	0.127	378 (60-1538)	0.484	1.000	1.000	0.125	250 (0-1718)
P* = 0.1	0.768	1.000	1.000	0.086	360 (57-1450)	0.408	1.000	1.000	0.087	229 (0-1490)
P* = 0.05	0.712	1.000	1.000	0.045	329 (53-1291)	0.316	1.000	1.000	0.047	191 (0-1206)

Table 7-7 Summary of medium-term economic impacts of a subset of the ACL alternatives for PIRKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2009-2014, and percentage differences in revenues relative to a zero buffer, with and without the effects of additional uncertainty (σ). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4), and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b =0.4. Point estimates are medians and ranges are 90% confidence intervals.

(a) These projections apply the Tier 4 control rule (model based OFL).

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	36(16,83)	34(16,76)	31(15,67)	0	0
	Multiplier = 0.8	30(14,69)	28(13,63)	26(12,56)	18	0
	Multiplier = 0.6	23(10,53)	22(10,49)	20(9,44)	35	0
	Multiplier = 0.4	16(7,36)	15(7,33)	14(6,30)	56	0
0.4	Multiplier = 1	33(12,89)	31(11,82)	29(11,73)	9	0
	Multiplier = 0.8	28(10,75)	26(9,70)	24(9,62)	24	16
	Multiplier = 0.6	22(7,60)	20(7,56)	19(6,50)	41	35
	Multiplier = 0.4	15(5,42)	14(4,39)	13(4,35)	59	55
0.4	P* = 0.5	33(12,89)	31(11,82)	29(11,73)	9	0
	P* = 0.4	30(11,81)	29(10,76)	26(10,68)	15	6
	P* = 0.3	28(10,75)	26(9,69)	24(9,62)	24	16
	P* = 0.2	24(9,67)	23(8,62)	21(7,56)	32	26
	P* = 0.1	21(7,58)	20(7,53)	18(6,48)	41	35

(b) These projections apply the Tier 4 control rule (non-model based OFL).

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	38(12,91)	36(12,84)	32(11,76)	0	0
	Multiplier = 0.8	32(10,76)	29(9,71)	27(8,63)	19	0
	Multiplier = 0.6	24(7,60)	23(7,55)	21(6,49)	36	0
	Multiplier = 0.4	16(5,41)	15(4,38)	14(4,34)	58	0
0.4	Multiplier = 1	35(10,96)	33(10,88)	30(9,79)	8	0
	Multiplier = 0.8	29(8,82)	27(8,75)	25(7,67)	25	18
	Multiplier = 0.6	22(6,64)	21(5,59)	19(5,53)	42	36
	Multiplier = 0.4	15(4,44)	14(3,41)	13(3,37)	61	58
0.4	P* = 0.5	35(10,96)	33(10,88)	30(9,79)	8	0
	P* = 0.4	30(9,84)	28(8,77)	26(7,69)	22	15
	P* = 0.3	25(7,72)	24(6,67)	22(6,60)	33	27
	P* = 0.2	21(5,60)	19(5,55)	18(5,49)	47	42
	P* = 0.1	15(4,45)	14(3,42)	13(3,38)	61	58

Table 7-8 Summary of long-term economic impacts of a subset of the ACL alternatives for PIRKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the 30-year period 2010-2039, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ_b). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b =0.4. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2010-2039 ~~2009-2014~~ ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives Discount rate: r=0.27%	
σ_b	Alternative	r=0	r=2.7%	r=7.0%	Baseline A :Multiplier=**1**, σ_b=**0.0**	Baseline B: Multiplier=**1**, σ_b=**0.4**
0	Multiplier = 1	230(58,656)	158(42,424)	99(30,250)	0	0
	Multiplier = 0.8	207(51,580)	141(36,375)	87(26,218)	11	0
	Multiplier = 0.6	175(42,485)	118(30,312)	71(21,178)	25	0
	Multiplier = 0.4	133(30,361)	88(22,228)	52(15,128)	44	0
0.4	Multiplier = 1	214(54,656)	146(39,427)	89(26,249)	8	0
	Multiplier = 0.8	189(48,585)	128(35,381)	78(23,221)	19	12
	Multiplier = 0.6	158(38,490)	106(28,317)	65(18,185)	33	27
	Multiplier = 0.4	117(27,359)	79(19,234)	47(12,138)	50	46
0.4	P* = 0.5	214(54,656)	146(39,427)	89(26,249)	8	0
	P* = 0.4	202(51,622)	137(37,409)	83(25,235)	13	6
	P* = 0.3	188(47,583)	128(34,380)	78(23,221)	19	12
	P* = 0.2	172(43,533)	117(31,349)	71(20,204)	26	20
	P* = 0.1	153(37,472)	103(27,307)	62(17,177)	35	29

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2010-2039 ~~2009-2014~~ ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives Discount rate: r=0.27%	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b = 0.4
0	Multiplier = 1	235(59,640)	164(44,416)	100(30,249)	0	0
	Multiplier = 0.8	212(52,585)	146(38,377)	87(25,218)	11	0
	Multiplier = 0.6	179(43,490)	122(31,323)	71(20,181)	26	0
	Multiplier = 0.4	133(30,360)	89(22,239)	52(14,131)	46	0
0.4	Multiplier = 1	213(56,624)	148(41,433)	93(27,256)	10	0
	Multiplier = 0.8	189(49,574)	130(36,387)	81(23,227)	21	12
	Multiplier = 0.6	157(40,497)	108(28,315)	67(18,184)	34	27
	Multiplier = 0.4	118(27,371)	78(19,234)	47(12,138)	52	47
0.4	P* = 0.5	213(56,624)	148(41,433)	93(27,256)	10	0
	P* = 0.4	194(51,587)	134(37,396)	83(24,232)	18	9
	P* = 0.3	173(44,538)	120(31,351)	74(21,208)	27	19
	P* = 0.2	150(37,469)	101(26,301)	63(17,174)	38	32
	P* = 0.1	119(28,376)	79(20,238)	48(12,139)	52	47

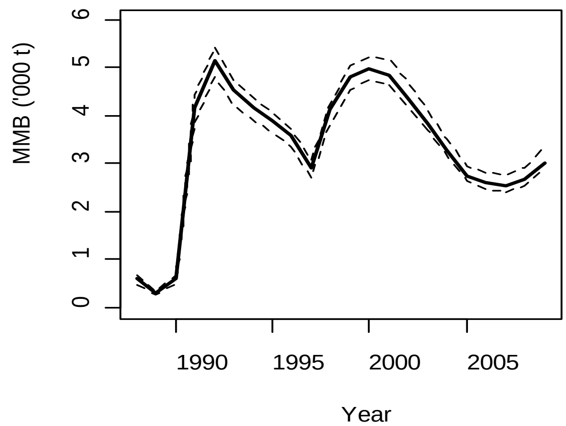


Figure 7-1 Time-trajectory of model estimated mature male biomass at the time of mating for PIRKC (thousand t).

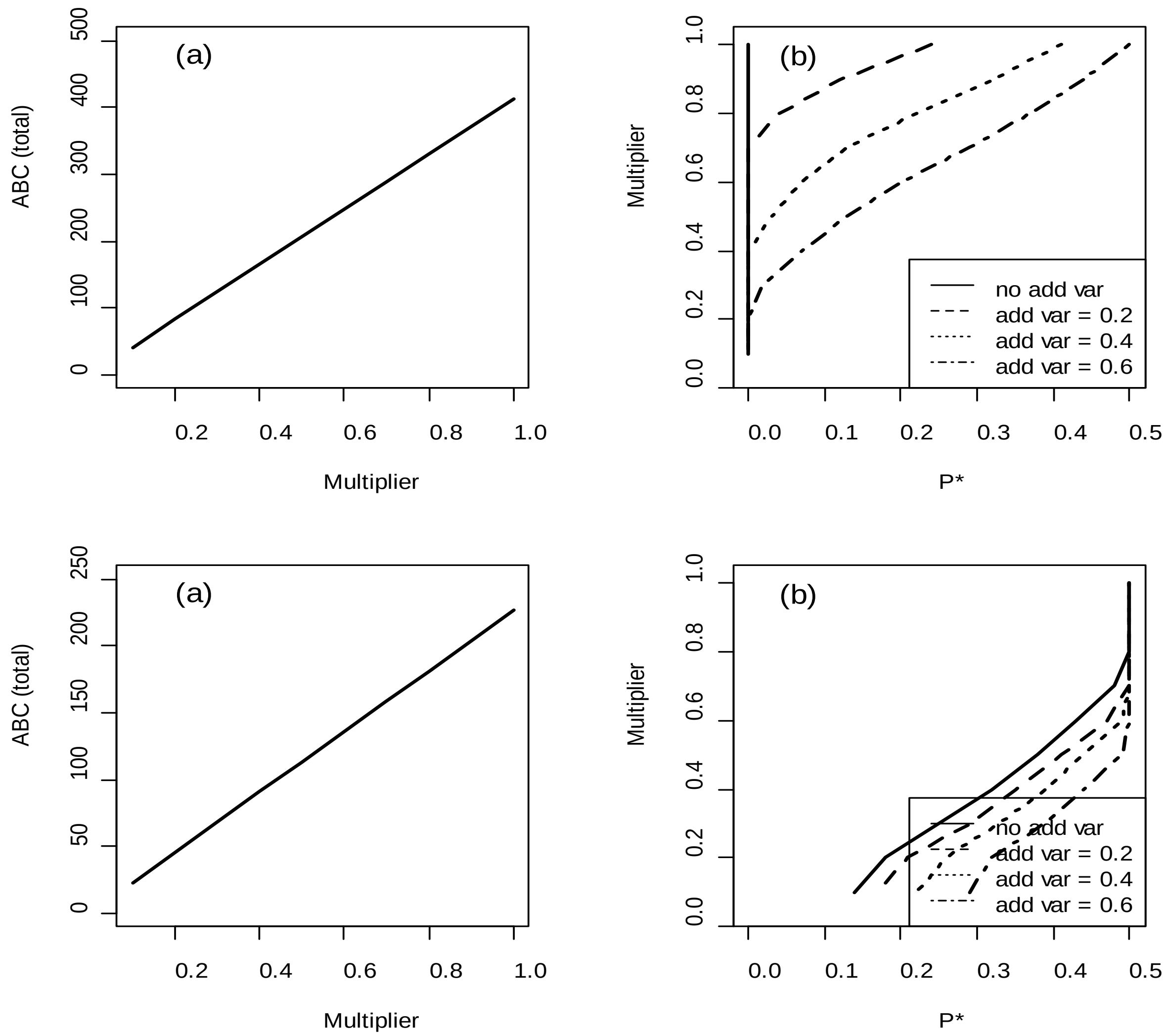


Figure 7-2 **Relationship between the buffer and the ABC (a), and the relationships between P* and the buffer for four values for the extent of additional uncertainty (b). Results are shown in the upper panels when the OFL is based on the assessment model (model-based OFL) and in the lower panels when the OFL is based on the survey data (non-model-based OFL).**

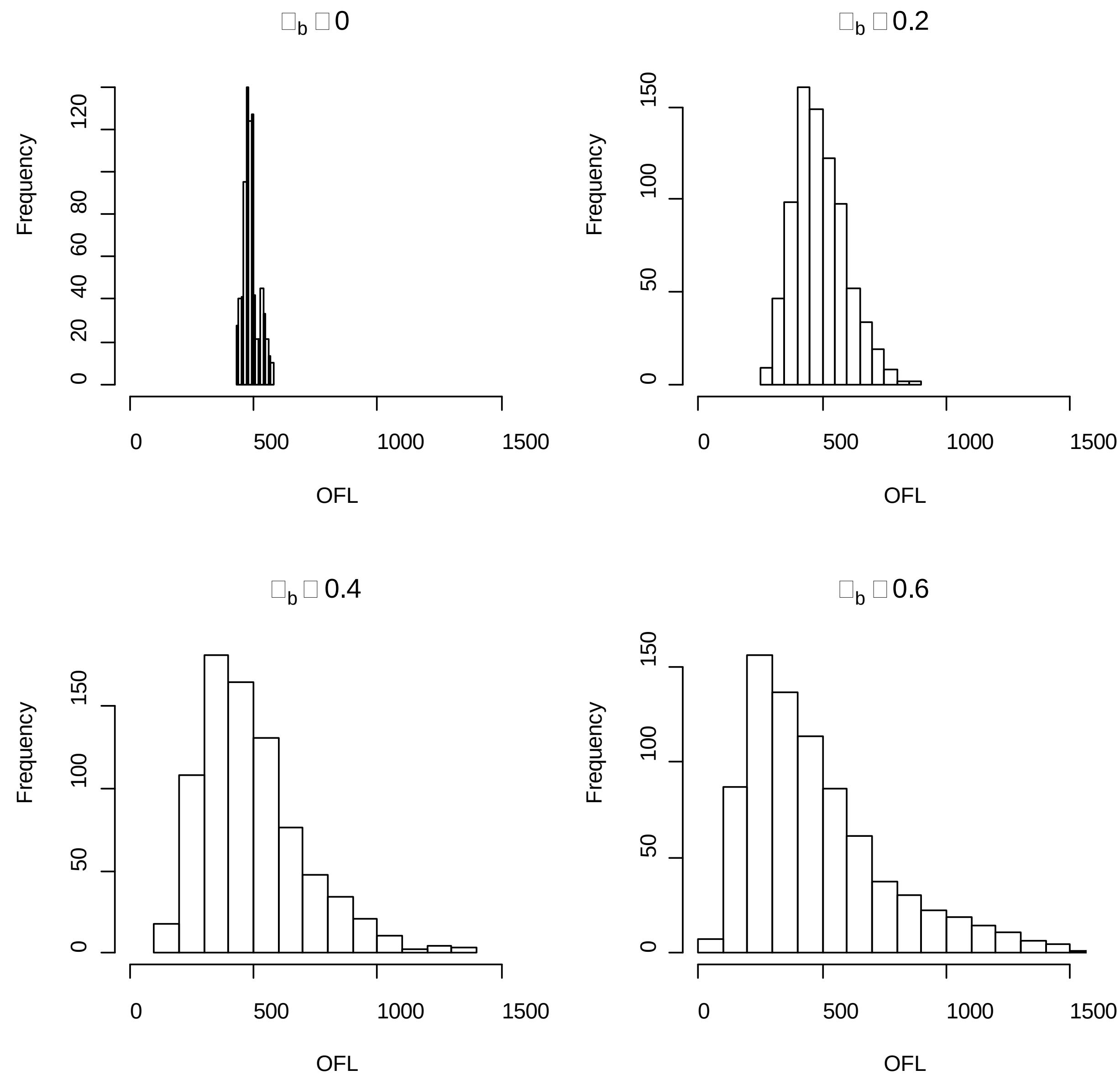


Figure 7-3 **Distribution of OFL values as a function of the assumed extent of additional uncertainty (σ_b). The results in this figure are based on the model-based approach to applying the Tier 4 control rule.**

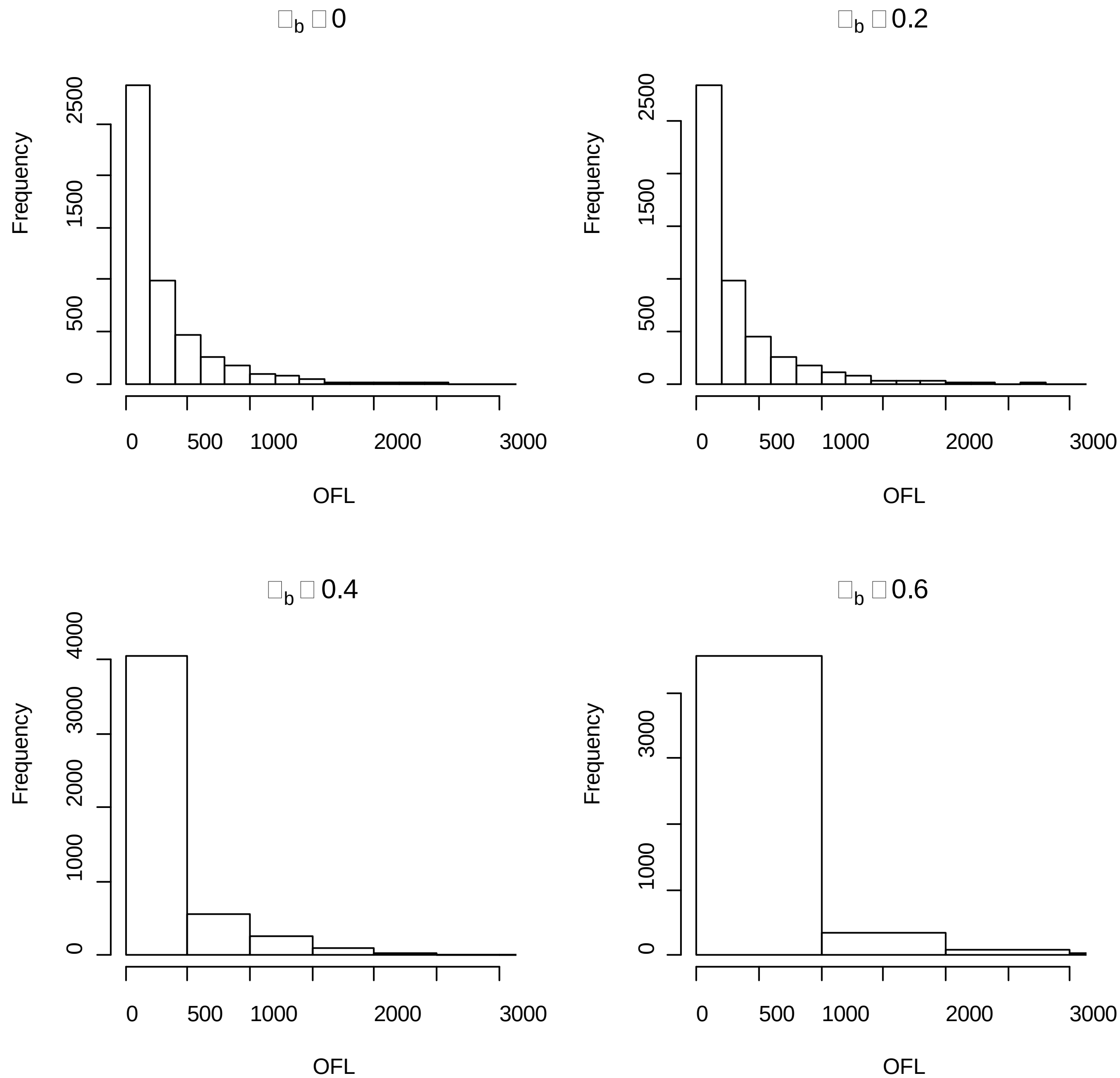


Figure 7-4 Distribution of OFL values as a function of the assumed extent of additional uncertainty (σ_b). The results in this figure are based on using the survey data when applying the Tier 4 control rule (non-model-based approach).

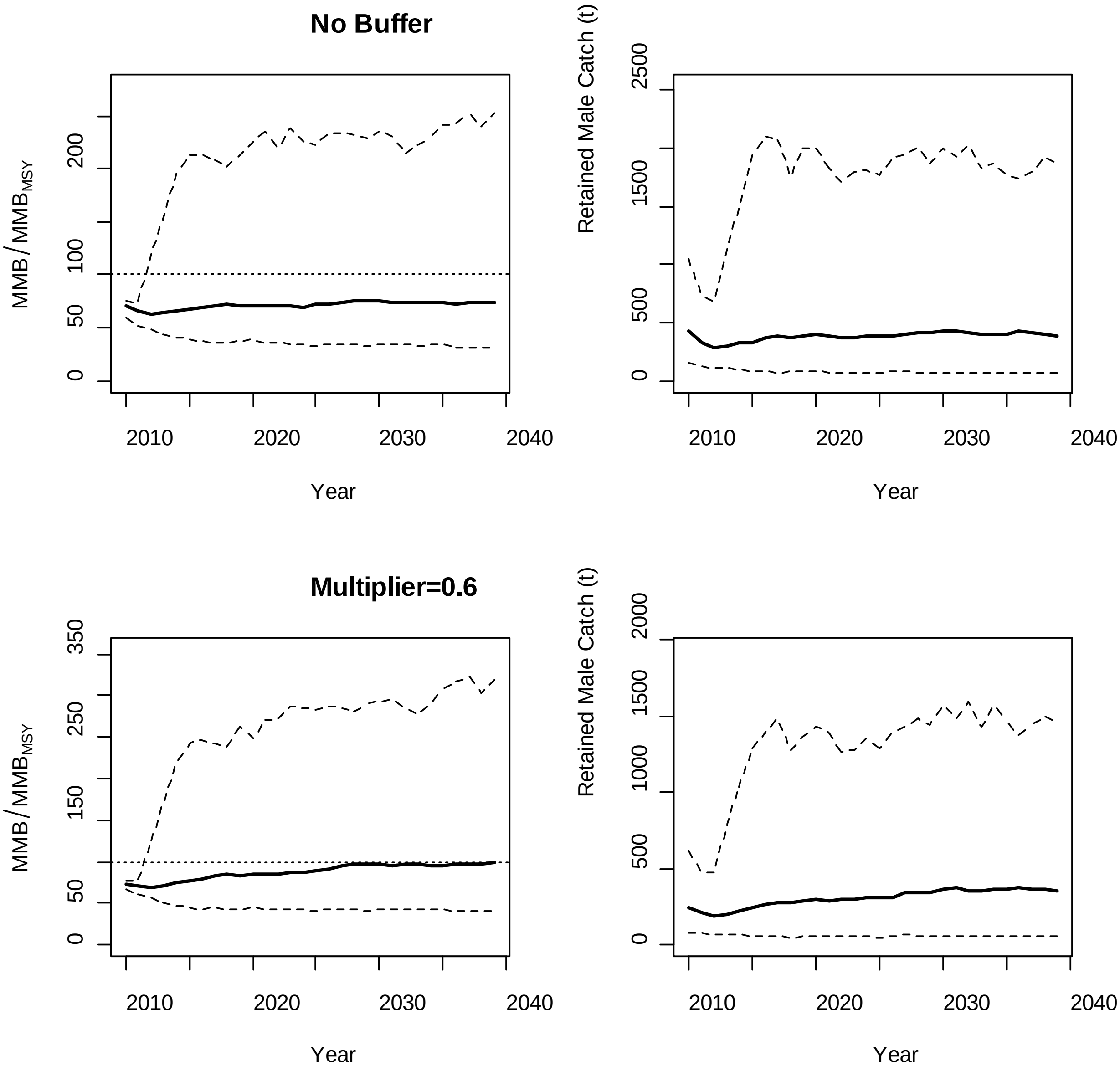


Figure 7-5 Time-trajectories of mature male biomass at mating relative to the proxy for B_{MSY} and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the table are based on σ_b=0.4 and the Tier 4 control rule (model based OFL).

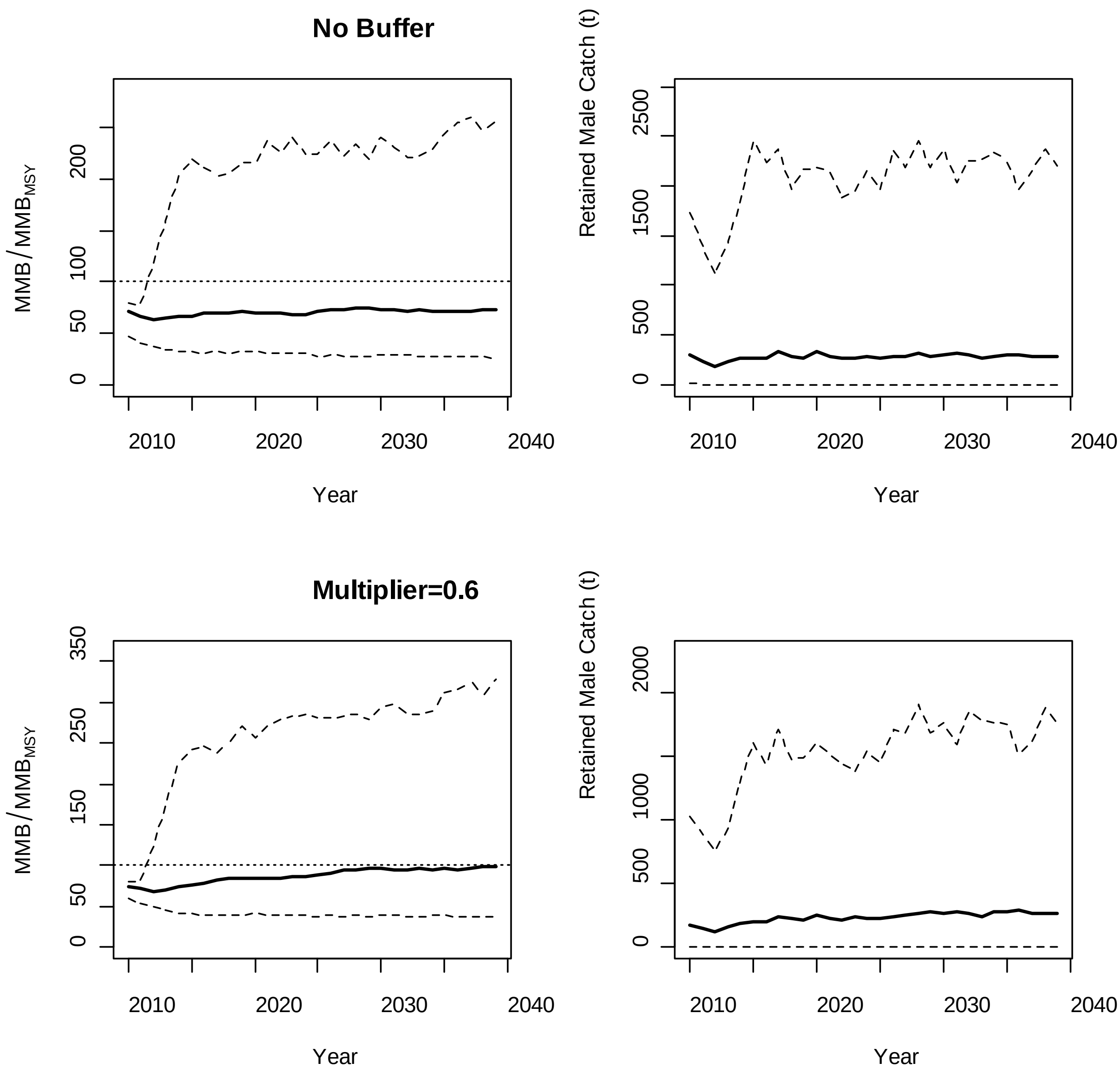


Figure 7-6 Time-trajectories of mature male biomass at mating relative to the proxy for B_{MSY} and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the table are based on σ_b=0.4 and the Tier 4 control rule (non-model based OFL).

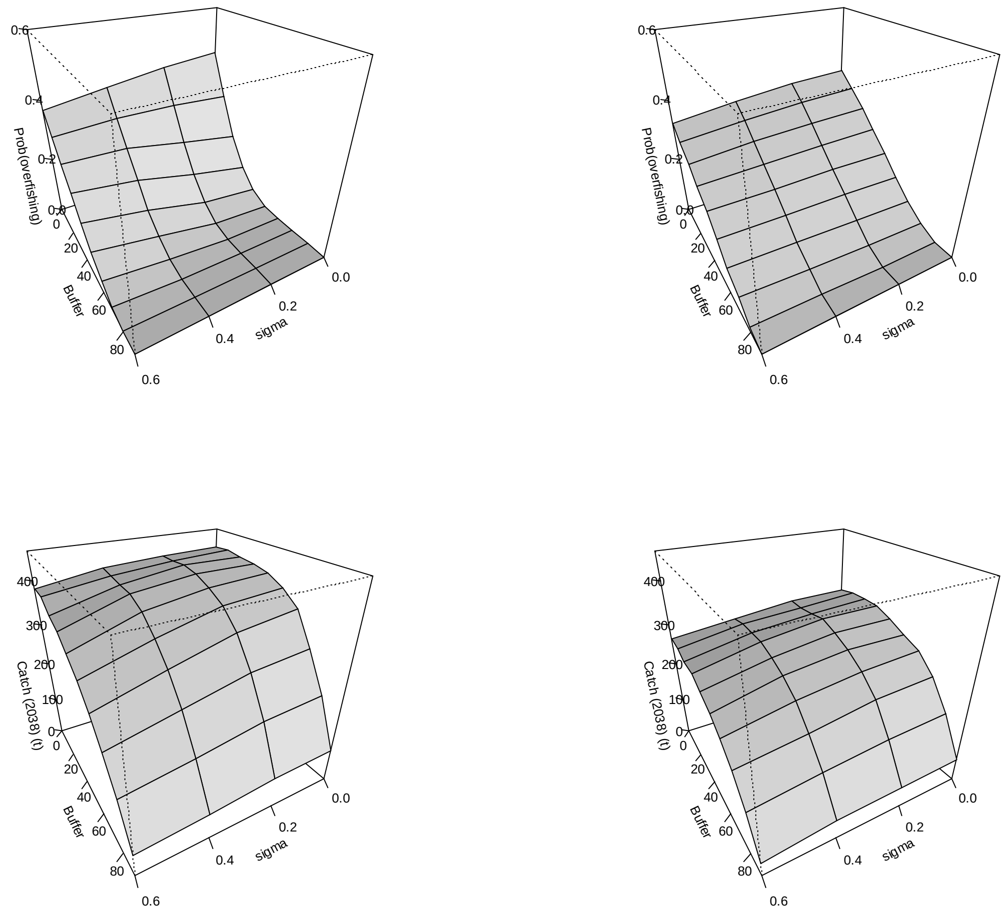


Figure 7-7 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for PIRKC. Results are shown in the left panels for the model-based OFL and in the right columns for the non-model-based OFL.**

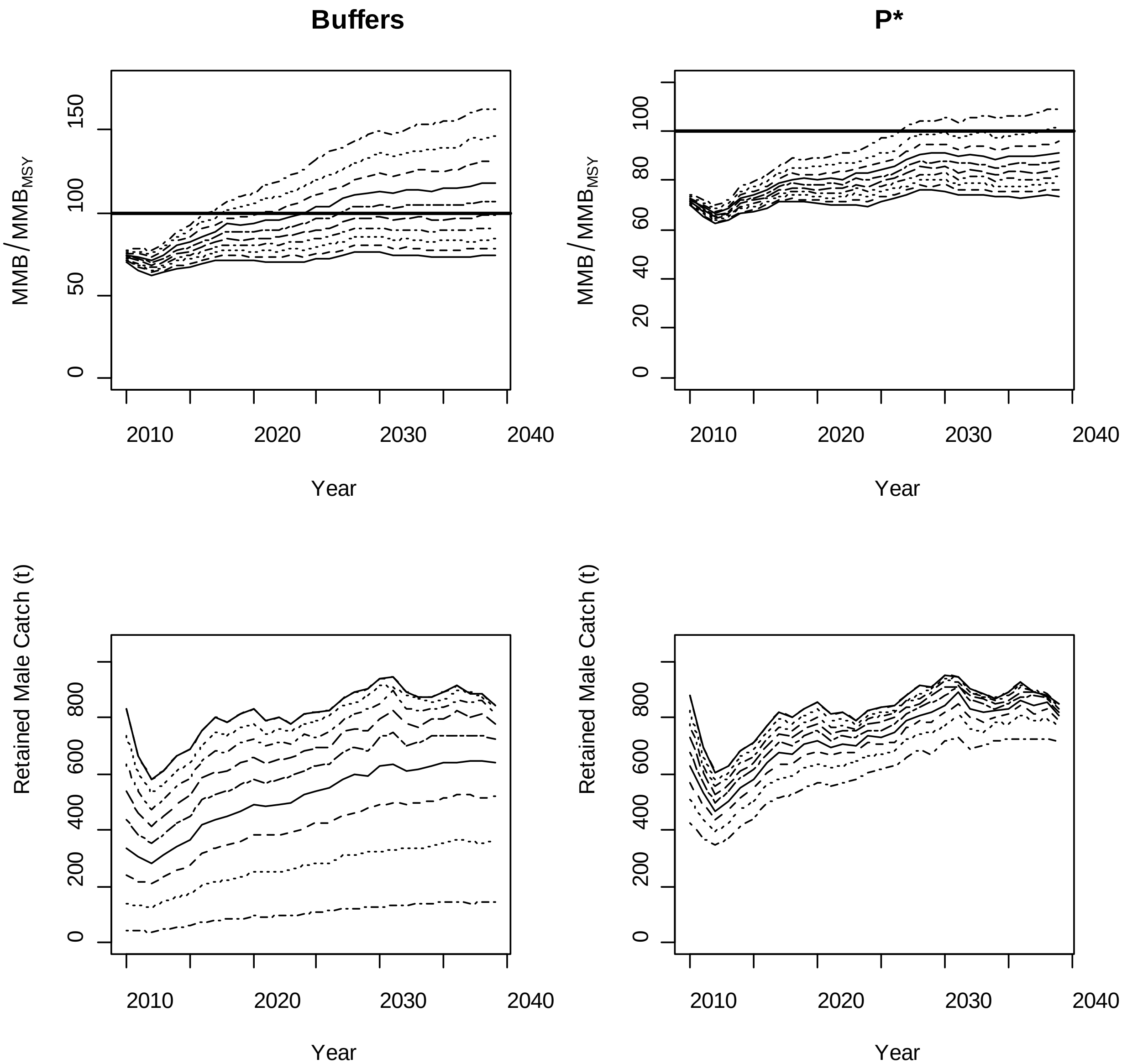


Figure 7-8 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.4 and the model-based Tier 4 control rule.**

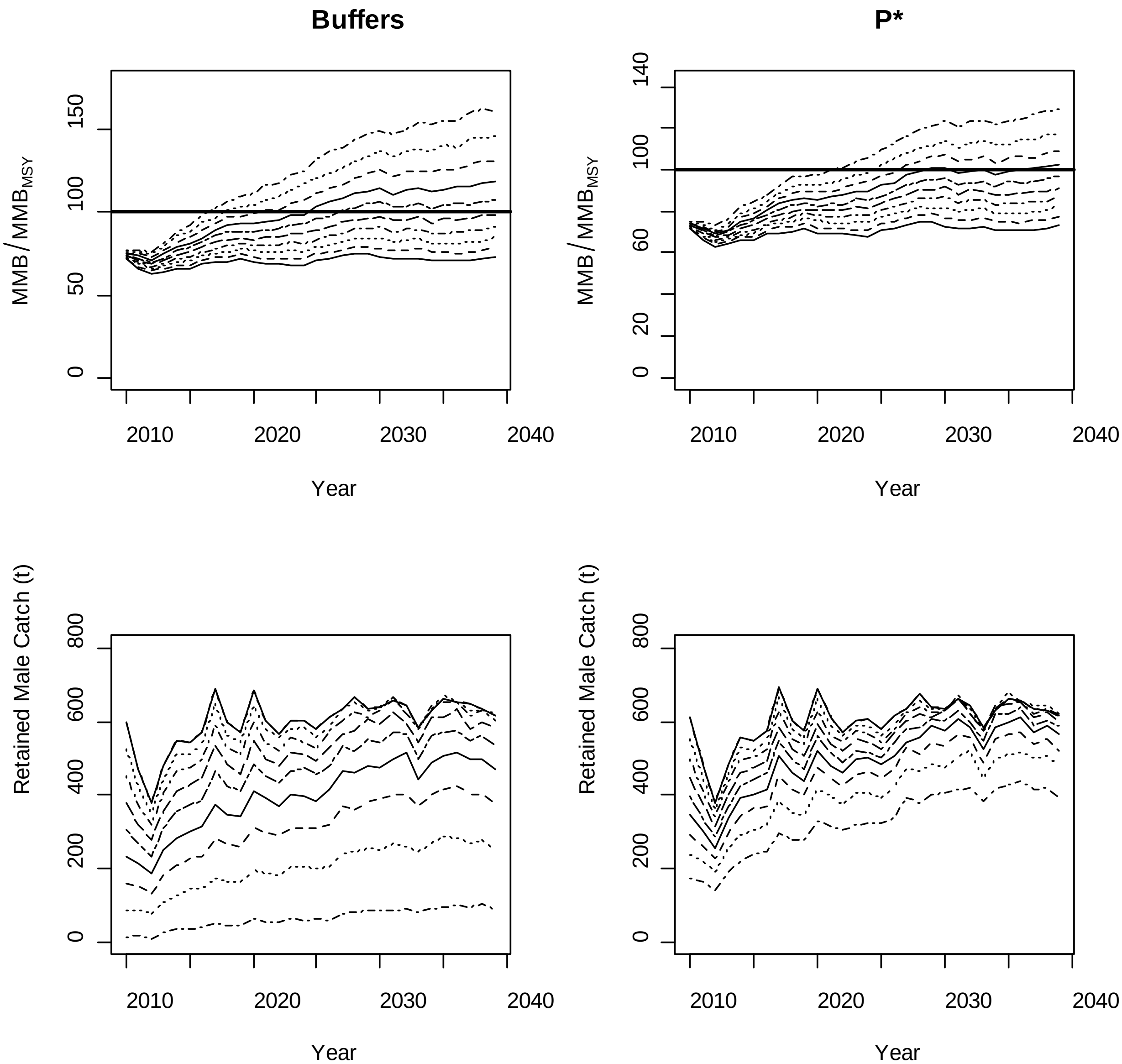


Figure 7-9 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.4 and the non-model-based Tier 4 control rule.**

8 Pribilof Islands Blue King Crab

Blue king crab, *Paralithodes platypus*, are sporadically distributed throughout their range in the North Pacific Ocean from Hokkaido in Japan to southeast Alaska, with disjunct populations occurring in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are known from the Diomede Islands, Point Hope, outer Kotzebue Sound, King Island, and the outer parts of Norton Sound. In the remainder of the Bering Sea, they are found in the waters off St. Matthew Island and the Pribilof Islands. In more southerly areas as far as southeastern Alaska in the Gulf of Alaska, blue king crabs are found in widely-separated populations that are frequently associated with fjord-like bays. Adult blue king crabs are found at depths less than 180 meters and at average bottom water temperatures of 0.6° C (NPFMC 1998).

The State of Alaska divides the Aleutian Islands and eastern Bering Sea blue king crab into the Pribilof Islands and St. Matthew management registration areas (ADF&G 2006). The Pribilof Islands blue king crab (PIBKC) are managed under the Bering Sea king crab Registration Area Q Pribilof District, which has as its southern boundary a line from 54° 36’ N lat., 168° W long., to 54° 36’ N lat., 171° W long., to 55° 30’ N lat., 171° W. long., to 55° 30’ N lat., 173° 30’ E long., as its northern boundary the latitude of Cape Newenham (58° 39’ N lat.), as its eastern boundary a line from 54° 36’ N lat., 168° W long., to 58° 39’ N lat., 168° W long., to Cape Newenham (58° 39’ N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991 (ADF&G 2008).

8.1 Assessment overview

The PIBKC stock biomass is below its estimated B_{MSY} (9.28 million lbs of mature male biomass, at the time of mating) with survey estimated mature male biomass at mating having increased from 0.25 million lbs in 2008 to 1.13 million lbs in 2009 (Foy and Rugolo 2009). Model-estimated mature male biomass was near 1,000t in 2008 and 2009 (Figure 8-1). Survey estimates of total biomass were highest at the beginning of the time series with a peak of 176.5 million lbs in 1980, dropped dramatically to 3.3 million lbs, increased again to 29.5 million lbs in 1995 and then steadily decreased to a low of 0.5 million lbs in 2004. Pre-recruit biomass has followed similar patterns as total biomass with no indication of above average recruitment in the past three years, although small male and female recruits have been noted.

The most recent assessment of PIBKC (Foy and Rugolo 2009) is based on survey estimates using area swept methods.[68] Survey abundance in specified length bins is summed across strata defined by single or multiple tows. Weight and maturity schedules are applied to these abundances and summed to calculate biomass.

The OFL for PIBKC is currently based on the Tier 4 control rule, i.e. the proxy for F_{MSY} is taken to be the product of natural mortality (M) and a scalar, γ (NMFS 2008). The proxy for B_{MSY} is taken to be the average biomass over a specified time period (currently 1980-1984 and 1990-1997). The OFL is a male total-catch OFL and is computed as the sum of catches by three different sources of removals: (a) the retained legal males in directed (pot) fishery for PIBKC, (b) discards of males in the directed fishery, and (c) bycatch in the groundfish pot and trawl fisheries.

The harvest strategy has incorporated protection measures for PIBKC due to its overfished status so TACs have been zero in recent years.

[68] The analyses of this chapter are based on a new assessment model. The results are therefore not identical to those in Foy and Rugolo (2009).

8.1.1 Uncertainty in stock assessment

Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for PIBKC is very high due to insufficient data and the small distribution of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass from the surveys for the most recent year is 0.713 and has ranged between 0.168 and 0.799 in since the 1980 peak in biomass. The coefficient of variation for the estimate of mature male biomass for the most recent year from the stock assessment used for the projections is 0.271.

However, several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:

- Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.
- F_{msy} is assumed to be equal to γM when applying the OFL control rule while γ is assumed to be equal to 1 and M is assumed to be known.
- The model on which the projections are based is still in development and has yet to be reviewed by the CPT.
- The coefficients of variation for the survey estimates of abundance for this stock are very high.
- B_{msy} is assumed to be equivalent to average mature male biomass between 1991 and 2008. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1973-1987 and 1995-1998 so considerable uncertainty exists with this estimate of B_{msy}.

For PIBKC, additional uncertainty is thought to be high, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.4 to quantify this high level of additional uncertainty, which is the value recommended by the SSC. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.4. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

8.2 Impacts of alternatives

As described in Chapter 2, there are two methods under consideration for computing an ABC for PIBKC: (a) the OFL can be multiplied by a pre-specified “multiplier” (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4). A total catch ACL can be computed from the output of the SOA control rule (which pertains to the retained catch in the directed fishery) by adding the estimated bycatch and discard to the output from the SOA control rule. As noted in Chapter 3, two scenarios are considered related to the SOA control rule: (a) the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule, and (b) the ACL equals the ABC (i.e. the SOA control rule is ignored).

The analyses of impacts in this chapter are based on the assumption that there are no sector-specific ACLs, that the ACL applies to all removals of PIBKC (a total-catch ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the groundfish and other crab fisheries.

The implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications would be assessed by impacts of the alternatives for the buffer and P* on the ABC which would have been advised for the 2009/10 fishery (assuming that ABCs had been specified for that fishery). However, the OFL, ABC, and TAC are all zero (for directed fishing). Therefore, there are no short-term implications for the alternative relative to status quo.

8.2.1 Medium- and long-term implications

The medium- and long-term implications are evaluated by projecting the population ahead 30 years. The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2010-2015) while the long-term implications consider the implications of the entire 30-year projection period.

Table 8-1 lists summaries of the posterior distributions for the key parameters which determine the productivity of the population. For medium and long term projections the implications of the alternatives were analyzed based on projections from a model based Tier 4 control rule. The extent of uncertainty captured within the stock assessment, σ_w, is 0.271.

8.2.1.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized by the model-based projected values for the ABC (which includes all sources of male catch), "ABC_{tot}" the retained directed component of ABC_{tot}, "ABC_{dir}", the output of the SOA control rule, "SOA", the retained catch in the directed fishery (which is the lower of the retained directed component of the ABC and the SOA TAC), "C_{dir}", the ratio of the mature male biomass at the time of mating to that the mature male biomass at which MSY is achieved, "MMB/B_{MSY}", and the probability of overfishing occurring. Results are shown in Table 8-2 for analyses based on the extent of additional uncertainty recommended (0.4), and for four multiplier levels (1, 0.8, 0.6 and 0.4) and choices for P* (0.4, 0.3, 0.2 and 0.1). These multiplier levels correspond to buffer values of 0, 20%, 40% and 60% respectively.

The probability of overfishing (i.e. the probability that the total catch exceeds the true, but unknown, OFL) decreases as the size of the buffer is increased (the multiplier is decreased) and P* is reduced. The results of the medium-term projections are not very sensitive to whether the SOA control rule is implemented because both the Tier 4 control rule and SOA control rule suggest that the catch in the directed fishery should be zero with high probability. The mature male biomass at the time of mating is predicted to remain similar in all cases.

8.2.1.2 Long-term implications - Biological

Table 8-3 summarizes the results of the modeled long-term projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"), (b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B"), (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of TAC being computed by the output from the SOA control rule (column "Prob (SOA)"), , and (e) the mean and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period. Results are shown in Table 8-3 for projections which account for and ignore the SOA control rule.

Figure 8-2 shows the time-trajectories of catch and mature male biomass at mating relative to B_{35} for two illustrative choices for the buffer (0: ABC=OFL; 40%: the ABC is 60% of the OFL). As expected, the mature male biomass is larger (although only slightly) when the buffer is lower.

Figure 8-3 evaluates the implications of different buffer values between the ABC and the OFL in terms of metrics (c) and (e) in Table 8-3, except that results are shown for all four values of the extent of additional uncertainty instead of only the value recommended by the CPT. Results are not shown for metrics (a) and (b) because the probability of being overfished is high (essentially 1) for all cases. Applying the SOA control rule has a large impact on the outputs. Specifically, the probability of overfishing occurring is higher when the SOA control rule is not applied (Figure 8-4, upper panels) while the catch in 2039 is lower for this case. The probability of overfishing occurring is higher for the smallest buffers while catches are also highest for the smallest buffer.

Figure 8-5 and Figure 8-5 illustrate the differences among the 10 buffers and choices for P* in terms of the model-based median time-trajectory of mature male biomass at mating relative to B_{MSY} and the median time-trajectory of the catch of legal males in the directed fishery. The ratio of mature male biomass to B_{MSY} increases in latter years with changes in the buffer. The rate at which catch drops with increasing buffer sizes is, however, not the same as that at which biomass increases with the catch in 2038 steadily increasing for buffers between 0 and 20%.

8.2.1.3 Medium and long-term implications - Economic

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures in are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference and evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30- year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

Revenue forecasts are based on probabilistic price forecasts using the time-series vector autoregression model for Alaskan red king crab, adjusted by a factor of 0.86 to account for the mean difference between Alaskan blue king and red king crab mean wholesale price over the period 1991 to 2003 when the fishery was open (see Chapter 3 for details). The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume using the average product recovery rate for Alaska red king crab (0.64%). Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

The medium and long-term impacts of ACL alternatives are summarized in Table 8-2 and Table 8-3. Table 8-4 and Table 8-5 present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014. Projections over the medium-term period analyzed do not indicate that a significant directed fishery will occur and the ABC would not be binding at any buffer or P* level. In the 2010-2039 long-term period, directed catch is projected to occur late in the trajectory, resulting in a small median value of wholesale revenue from the fishery. Higher discount rates significantly diminish these value due to distant period in which directed catch is likely to occur. Differences in catch revenues are generally proportional to buffer levels, although under all scenarios, likely catch revenues are limited to the $15- to $30- thousand range.

8.3 Tables and Figures

Table 8-1 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes.

Parameter	Distribution
Virgin MMB	10.8 (9.8, 11.9)
Steepness, h	0.531 (0.512, 0.549)
F_{MSY} ($F_{35\%}$)	0.18
B_{MSY} ($B_{35\%}$)	3.6 (3.2, 3.9)
σ_R	7.943 (5.817, 10.133)*

* σ_R was set to 1.5 for the projections

Table 8-2 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for PIBKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on $\sigma_b = 0.4$.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} ('t)	MMB /B_{MSY}	Prob (overfishing)
2010	2 (1- 27)	0 (0- 23)	0 (0- 0)	0 (0- 1)	16 (11- 27)	0.394
2011	2 (1- 38)	0 (0- 31)	0 (0- 0)	0 (0- 2)	16 (11- 29)	0.354
2012	2 (1- 70)	0 (0- 51)	0 (0- 0)	0 (0- 1)	18 (11- 36)	0.351
2013	2 (1- 127)	0 (0- 91)	0 (0- 0)	0 (0- 2)	19 (12- 52)	0.306
2014	3 (1- 212)	0 (0- 160)	0 (0- 0)	0 (0- 2)	21 (12- 68)	0.279
2015	6 (1- 280)	0 (0- 221)	0 (0- 0)	0 (0- 2)	24 (12- 76)	0.251

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} ('t)	MMB /B_{MSY}	Prob (overfishing)
2010	1 (0- 22)	0 (0- 18)	0 (0- 0)	0 (0- 1)	16 (11- 27)	0.230
2011	1 (0- 30)	0 (0- 24)	0 (0- 0)	0 (0- 1)	16 (11- 29)	0.215
2012	2 (1- 56)	0 (0- 41)	0 (0- 0)	0 (0- 1)	18 (11- 36)	0.214
2013	2 (1- 102)	0 (0- 73)	0 (0- 0)	0 (0- 1)	19 (12- 52)	0.183
2014	3 (1- 169)	0 (0- 128)	0 (0- 0)	0 (0- 1)	21 (12- 68)	0.184
2015	5 (1- 224)	0 (0- 177)	0 (0- 0)	0 (0- 2)	24 (12- 79)	0.169

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} ('t)	MMB /B_{MSY}	Prob (overfishing)
2010	1 (0- 16)	0 (0- 14)	0 (0- 0)	0 (0- 0)	16 (11- 27)	0.101
2011	1 (0- 23)	0 (0- 18)	0 (0- 0)	0 (0- 0)	16 (11- 29)	0.096
2012	1 (0- 42)	0 (0- 30)	0 (0- 0)	0 (0- 0)	18 (11- 36)	0.090
2013	1 (0- 76)	0 (0- 55)	0 (0- 0)	0 (0- 0)	19 (12- 52)	0.077
2014	2 (0- 127)	0 (0- 96)	0 (0- 0)	0 (0- 0)	22 (12- 68)	0.080
2015	3 (0- 168)	0 (0- 133)	0 (0- 0)	0 (0- 1)	24 (12- 81)	0.071

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 11)	0 (0- 9)	0 (0- 0)	0 (0- 0)	16 (11- 27)	0.016
2011	1 (0- 15)	0 (0- 12)	0 (0- 0)	0 (0- 0)	16 (11- 29)	0.020
2012	1 (0- 28)	0 (0- 20)	0 (0- 0)	0 (0- 0)	18 (11- 36)	0.015
2013	1 (0- 51)	0 (0- 37)	0 (0- 0)	0 (0- 0)	19 (12- 52)	0.018
2014	1 (0- 85)	0 (0- 64)	0 (0- 0)	0 (0- 0)	22 (12- 68)	0.011
2015	3 (0- 116)	0 (0- 89)	0 (0- 0)	0 (0- 1)	24 (12- 81)	0.045

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	2 (1- 31)	0 (0- 26)	0 (0- 0)	0 (0- 26)	16 (11- 26)	0.448
2011	2 (1- 38)	0 (0- 31)	0 (0- 0)	0 (0- 31)	16 (11- 28)	0.436
2012	2 (1- 62)	0 (0- 45)	0 (0- 0)	0 (0- 46)	18 (11- 35)	0.460
2013	2 (1- 113)	0 (0- 75)	0 (0- 0)	0 (0- 76)	19 (12- 48)	0.436
2014	3 (1- 195)	0 (0- 144)	0 (0- 0)	0 (0- 144)	21 (12- 63)	0.472
2015	4 (1- 258)	0 (0- 209)	0 (0- 0)	1 (0- 208)	24 (12- 69)	0.466

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (1- 25)	0 (0- 21)	0 (0- 0)	0 (0- 20)	16 (11- 26)	0.176
2011	1 (1- 31)	0 (0- 25)	0 (0- 0)	0 (0- 25)	16 (11- 28)	0.147
2012	2 (1- 50)	0 (0- 37)	0 (0- 0)	0 (0- 37)	18 (11- 35)	0.170
2013	2 (1- 91)	0 (0- 60)	0 (0- 0)	0 (0- 60)	19 (12- 49)	0.160
2014	2 (1- 161)	0 (0- 119)	0 (0- 0)	0 (0- 118)	22 (12- 64)	0.183
2015	3 (1- 214)	0 (0- 177)	0 (0- 0)	0 (0- 175)	24 (12- 72)	0.171

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 18)	0 (0- 16)	0 (0- 0)	0 (0- 14)	16 (11- 26)	0.022
2011	1 (0- 24)	0 (0- 19)	0 (0- 0)	0 (0- 18)	16 (11- 28)	0.015
2012	1 (0- 38)	0 (0- 28)	0 (0- 0)	0 (0- 28)	18 (11- 35)	0.022
2013	1 (1- 69)	0 (0- 46)	0 (0- 0)	0 (0- 45)	19 (12- 50)	0.018
2014	2 (1- 124)	0 (0- 92)	0 (0- 0)	0 (0- 90)	22 (12- 65)	0.020
2015	2 (1- 165)	0 (0- 137)	0 (0- 0)	0 (0- 134)	24 (12- 75)	0.020

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 12)	0 (0- 11)	0 (0- 0)	0 (0- 9)	16 (11- 26)	0.001
2011	1 (0- 16)	0 (0- 13)	0 (0- 0)	0 (0- 12)	16 (11- 28)	0.001
2012	1 (0- 26)	0 (0- 19)	0 (0- 0)	0 (0- 18)	18 (11- 36)	0.001
2013	1 (0- 46)	0 (0- 31)	0 (0- 0)	0 (0- 29)	19 (12- 50)	0.001
2014	1 (0- 85)	0 (0- 63)	0 (0- 0)	0 (0- 61)	22 (12- 68)	0.000
2015	2 (0- 116)	0 (0- 96)	0 (0- 0)	0 (0- 92)	24 (12- 79)	0.001

(i) P*=0.4; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 24)	0 (0- 20)	0 (0- 0)	0 (0- 1)	16 (11- 27)	0.289
2011	2 (0- 34)	0 (0- 27)	0 (0- 0)	0 (0- 1)	16 (11- 29)	0.279
2012	2 (1- 62)	0 (0- 45)	0 (0- 0)	0 (0- 1)	18 (11- 36)	0.270
2013	2 (1- 112)	0 (0- 80)	0 (0- 0)	0 (0- 1)	19 (12- 52)	0.233
2014	3 (1- 187)	0 (0- 142)	0 (0- 0)	0 (0- 1)	21 (12- 68)	0.228
2015	5 (1- 248)	0 (0- 196)	0 (0- 0)	0 (0- 2)	24 (12- 77)	0.200

(j) P*=0.3; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 21)	0 (0- 18)	0 (0- 0)	0 (0- 1)	16 (11- 27)	0.218
2011	1 (0- 29)	0 (0- 24)	0 (0- 0)	0 (0- 1)	16 (11- 29)	0.190
2012	2 (1- 54)	0 (0- 39)	0 (0- 0)	0 (0- 1)	18 (11- 36)	0.199
2013	2 (1- 99)	0 (0- 71)	0 (0- 0)	0 (0- 1)	19 (12- 52)	0.168
2014	3 (1- 164)	0 (0- 124)	0 (0- 0)	0 (0- 1)	21 (12- 68)	0.168
2015	4 (1- 217)	0 (0- 172)	0 (0- 0)	0 (0- 1)	24 (12- 80)	0.149

(k) P*=0.2; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 18)	0 (0- 15)	0 (0- 0)	0 (0- 0)	16 (11- 27)	0.140
2011	1 (0- 25)	0 (0- 20)	0 (0- 0)	0 (0- 1)	16 (11- 29)	0.125
2012	1 (0- 47)	0 (0- 34)	0 (0- 0)	0 (0- 0)	18 (11- 36)	0.128
2013	2 (0- 85)	0 (0- 61)	0 (0- 0)	0 (0- 0)	19 (12- 52)	0.102
2014	2 (0- 141)	0 (0- 107)	0 (0- 0)	0 (0- 1)	22 (12- 68)	0.119
2015	4 (0- 187)	0 (0- 147)	0 (0- 0)	0 (0- 1)	24 (12- 80)	0.100

(l) P*=0.1; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 15)	0 (0- 12)	0 (0- 0)	0 (0- 0)	16 (11- 27)	0.063
2011	1 (0- 20)	0 (0- 16)	0 (0- 0)	0 (0- 0)	16 (11- 29)	0.061
2012	1 (0- 38)	0 (0- 27)	0 (0- 0)	0 (0- 0)	18 (11- 36)	0.059
2013	1 (0- 68)	0 (0- 49)	0 (0- 0)	0 (0- 0)	19 (12- 52)	0.056
2014	2 (0- 114)	0 (0- 86)	0 (0- 0)	0 (0- 0)	22 (12- 68)	0.049
2015	3 (0- 151)	0 (0- 119)	0 (0- 0)	0 (0- 0)	24 (12- 81)	0.044

(m) P*=0.4; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 24)	0 (0- 20)	0 (0- 0)	0 (0- 20)	16 (11- 26)	0.310
2011	2 (0- 33)	0 (0- 26)	0 (0- 0)	0 (0- 26)	16 (11- 28)	0.308
2012	2 (1- 60)	0 (0- 41)	0 (0- 0)	0 (0- 42)	18 (11- 35)	0.318
2013	2 (1- 106)	0 (0- 73)	0 (0- 0)	0 (0- 73)	19 (12- 49)	0.321
2014	3 (1- 165)	0 (0- 124)	0 (0- 0)	0 (0- 124)	21 (12- 63)	0.334
2015	4 (1- 222)	0 (0- 163)	0 (0- 0)	1 (0- 163)	24 (12- 69)	0.330

(n) P*=0.3; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 21)	0 (0- 18)	0 (0- 0)	0 (0- 17)	16 (11- 26)	0.229
2011	1 (0- 29)	0 (0- 23)	0 (0- 0)	0 (0- 22)	16 (11- 28)	0.209
2012	2 (1- 53)	0 (0- 36)	0 (0- 0)	0 (0- 37)	18 (11- 35)	0.235
2013	2 (1- 93)	0 (0- 64)	0 (0- 0)	0 (0- 64)	19 (12- 49)	0.230
2014	2 (1- 148)	0 (0- 111)	0 (0- 0)	0 (0- 110)	21 (12- 64)	0.236
2015	4 (1- 199)	0 (0- 149)	0 (0- 0)	1 (0- 148)	24 (12- 71)	0.233

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 18)	0 (0- 15)	0 (0- 0)	0 (0- 14)	16 (11- 26)	0.146
2011	1 (0- 25)	0 (0- 20)	0 (0- 0)	0 (0- 19)	16 (11- 28)	0.135
2012	1 (0- 46)	0 (0- 31)	0 (0- 0)	0 (0- 31)	18 (11- 35)	0.153
2013	2 (0- 81)	0 (0- 56)	0 (0- 0)	0 (0- 55)	19 (12- 49)	0.134
2014	2 (0- 130)	0 (0- 97)	0 (0- 0)	0 (0- 95)	22 (12- 65)	0.161
2015	3 (0- 175)	0 (0- 130)	0 (0- 0)	0 (0- 129)	24 (12- 74)	0.151

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} (t)	ABC_{dir} (t)	SOA (t)	C_{dir} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1 (0- 15)	0 (0- 12)	0 (0- 0)	0 (0- 11)	16 (11- 26)	0.064
2011	1 (0- 20)	0 (0- 16)	0 (0- 0)	0 (0- 15)	16 (11- 28)	0.065
2012	1 (0- 38)	0 (0- 26)	0 (0- 0)	0 (0- 25)	18 (11- 35)	0.071
2013	1 (0- 66)	0 (0- 46)	0 (0- 0)	0 (0- 45)	19 (12- 50)	0.074
2014	2 (0- 107)	0 (0- 79)	0 (0- 0)	0 (0- 78)	22 (12- 66)	0.063
2015	3 (0- 144)	0 (0- 107)	0 (0- 0)	0 (0- 109)	24 (12- 75)	0.065

Table 8-3 Summary of the long-term consequences of the alternatives for PIBKC. The column "retained catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2039. The results in the table are based on $\sigma_b = 0.4$.

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Retained catch (2039) (t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Retained catch (2039) (t)
Multiplier = 1		1.000	1.000	0.201	0.667	0 (0- 774)	1.000	1.000	0.419	142 (7- 763)
Multiplier = 0.9		1.000	1.000	0.179	0.652	0 (0- 765)	1.000	1.000	0.335	135 (12- 729)
Multiplier = 0.8		1.000	1.000	0.149	0.628	0 (0- 757)	1.000	1.000	0.250	128 (13- 701)
Multiplier = 0.7		1.000	1.000	0.113	0.581	0 (0- 729)	1.000	1.000	0.168	120 (11- 681)
Multiplier = 0.6		1.000	1.000	0.074	0.557	0 (0- 663)	1.000	1.000	0.099	112 (10- 620)
Multiplier = 0.5		1.000	1.000	0.041	0.548	0 (0- 585)	1.000	1.000	0.050	101 (8- 560)
Multiplier = 0.4		1.000	1.000	0.016	0.543	0 (0- 494)	1.000	1.000	0.018	87 (6- 471)
Multiplier = 0.3		1.000	1.000	0.004	0.536	0 (0- 378)	1.000	1.000	0.004	71 (4- 368)
Multiplier = 0.2		1.000	1.000	0.000	0.530	0 (0- 271)	1.000	1.000	0.000	50 (2- 265)
Multiplier = 0.1		1.000	1.000	0.000	0.525	0 (0- 144)	1.000	1.000	0.000	24 (0- 142)
P* = 0.5	1.0	1.000	1.000	0.201	0.667	0 (0- 774)	1.000	1.000	0.419	142 (7- 763)
P* = 0.45	0.941	1.000	1.000	0.189	0.659	0 (0- 764)	1.000	1.000	0.370	138 (10- 742)
P* = 0.4	0.885	1.000	1.000	0.174	0.650	0 (0- 765)	1.000	1.000	0.323	134 (12- 725)
P* = 0.35	0.830	1.000	1.000	0.158	0.639	0 (0- 767)	1.000	1.000	0.275	130 (12- 717)
P* = 0.3	0.776	1.000	1.000	0.140	0.618	0 (0- 739)	1.000	1.000	0.229	126 (13- 704)
P* = 0.25	0.722	1.000	1.000	0.121	0.592	0 (0- 731)	1.000	1.000	0.185	121 (12- 691)
P* = 0.2	0.666	1.000	1.000	0.100	0.569	0 (0- 702)	1.000	1.000	0.143	118 (11- 664)
P* = 0.15	0.606	1.000	1.000	0.076	0.558	0 (0- 668)	1.000	1.000	0.102	112 (10- 624)
P* = 0.1	0.538	1.000	1.000	0.053	0.551	0 (0- 611)	1.000	1.000	0.065	105 (9- 586)
P* = 0.05	0.452	1.000	1.000	0.027	0.546	0 (0- 544)	1.000	1.000	0.031	95 (7- 518)

Table 8-4 Summary of medium-term economic impacts of a subset of the ACL alternatives for PIBKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2010-2015, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ_b). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b=0.4. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2010-2015 ($ Thousand)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	0(0,49.8)	0(0,47.7)	0(0,45.7)	0	0
	Multiplier = 0.8	0(0,18.8)	0(0,18)	0(0,16.3)	0	0
	Multiplier = 0.6	0(0,0)	0(0,0)	0(0,0)	0	0
	Multiplier = 0.4	0(0,0)	0(0,0)	0(0,0)	0	0
0.4	Multiplier = 1	0(0,180)	0(0,170)	0(0,156.4)	0	0
	Multiplier = 0.8	0(0,102.6)	0(0,96.4)	0(0,88.7)	0	0
	Multiplier = 0.6	0(0,44.1)	0(0,41.4)	0(0,36.5)	0	0
	Multiplier = 0.4	0(0,0)	0(0,0)	0(0,0)	0	0
0.4	P* = 0.5	0(0,180)	0(0,170)	0(0,156.4)	0	0
	P* = 0.4	0(0,143.3)	0(0,134.8)	0(0,124.6)	0	0
	P* = 0.3	0(0,101.2)	0(0,95.8)	0(0,87.7)	0	0
	P* = 0.2	0(0,74.6)	0(0,70.1)	0(0,63.1)	0	0
	P* = 0.1	0(0,23.6)	0(0,23.6)	0(0,20.3)	0	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2010-2015 ($ Thousand)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.4**
0	Multiplier = 1	46.7(0,5646.8)	42.8(0,5221.8)	39.3(0,4594.8)	0	0
	Multiplier = 0.8	17.7(0,4623.1)	16.3(0,4253.3)	14.8(0,3744.2)	62	0
	Multiplier = 0.6	0(0,3508.5)	0(0,3223.8)	0(0,2807.2)	100	0
	Multiplier = 0.4	0(0,2327.9)	0(0,2094.6)	0(0,1790.2)	100	0
0.4	Multiplier = 1	108.4(0,5264.3)	95.8(0,4956.3)	81.8(0,4490.4)	-124	0
	Multiplier = 0.8	64.7(0,4339.9)	59.7(0,4081.9)	53.4(0,3607.1)	-39	38
	Multiplier = 0.6	26.7(0,3318.4)	25.3(0,3118.1)	22.2(0,2736.9)	41	74
	Multiplier = 0.4	0(0,2234.4)	0(0,2042.5)	0(0,1808.8)	100	100
0.4	P* = 0.5	108.4(0,5264.3)	95.8(0,4956.3)	81.8(0,4490.4)	-124	0
	P* = 0.4	81.7(0,4757.3)	74.4(0,4476.7)	63.2(0,3992.4)	-74	22
	P* = 0.3	58.5(0,4234.6)	54.2(0,3982.4)	46.9(0,3496.3)	-27	43
	P* = 0.2	35.9(0,3663.1)	32.6(0,3443.6)	28.4(0,3011.7)	24	66
	P* = 0.1	15.8(0,3000.1)	14.7(0,2818.8)	12.6(0,2452.2)	66	85

Table 8-5 Summary of long-term economic impacts of a subset of the ACL alternatives for PIBKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the 30-year period 2010-2039, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ_b). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4), and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b = 0.4. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2010-2039 ($ Thousand)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives Discount rate: r=0.27%	
σ_b	Alternative	r=0	r=2.7%	r=7.0%	Baseline A :Multiplier=**1**, σ_b=**0.0**	Baseline B: Multiplier=**1**, σ_b=**0.4**
0	Multiplier = 1	14620(0,120042)	7845(0,71465)	3085(0,32607)	0	0
	Multiplier = 0.8	13313(0,117924)	7302(0,70173)	2836(0,31609)	7	0
	Multiplier = 0.6	11303(0,104798)	6067(0,60287)	2303(0,26714)	23	0
	Multiplier = 0.4	7976(0,75338)	4264(0,43638)	1652(0,20053)	46	0
0.4	Multiplier = 1	11668(0,117553)	6350(0,69193)	2550(0,33092)	19	0
	Multiplier = 0.8	10738(0,116547)	5881(0,67299)	2307(0,32465)	25	7
	Multiplier = 0.6	8885(0,102907)	4757(0,59682)	1798(0,28494)	39	25
	Multiplier = 0.4	6550(0,77711)	3347(0,46269)	1267(0,21283)	57	47
0.4	P* = 0.5	11668(0,117553)	6350(0,69193)	2550(0,33092)	19	0
	P* = 0.4	11297(0,116549)	6108(0,69243)	2408(0,33592)	22	4
	P* = 0.3	10574(0,116439)	5822(0,67240)	2258(0,33140)	26	8
	P* = 0.2	9665(0,107938)	5251(0,63230)	1981(0,30487)	33	17
	P* = 0.1	8164(0,95964)	4414(0,55985)	1653(0,26343)	44	30

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2010-2039 ($ Thousand)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives Discount rate: r=0.27%	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0	Multiplier = 1	30963(1959,142774)	18454(1038,84289)	8647(430,42406)	0	
	Multiplier = 0.8	27221(1632,126804)	16110(828,75601)	7477(331,37236)	13	
	Multiplier = 0.6	22677(1215,107111)	13273(615,64309)	6015(252,30969)	28	
	Multiplier = 0.4	16581(776,79874)	9562(438,48819)	4284(184,22860)	48	
0.4	Multiplier = 1	30260(1932,140603)	17914(972,84768)	8479(430,43617)	3	0
	Multiplier = 0.8	26672(1495,127503)	15613(783,75646)	7345(336,39519)	15	13
	Multiplier = 0.6	22027(1090,111654)	12838(634,65036)	5942(247,34279)	30	28
	Multiplier = 0.4	16001(741,83906)	9278(422,50854)	4217(158,24885)	50	48
0.4	P* = 0.5	30260(1932,140603)	17914(972,84768)	8479(430,43617)	3	0
	P* = 0.4	28291(1670,132556)	16637(861,79269)	7840(372,41916)	10	7
	P* = 0.3	26152(1441,126368)	15280(758,74231)	7199(328,38695)	17	15
	P* = 0.2	23695(1217,119197)	13818(707,68103)	6432(276,36154)	25	23
	P* = 0.1	20223(1021,103531)	11771(593,61567)	5450(219,31282)	36	34
0.4	Multiplier = 1	3229(978,6428)	2258(728,4413)	1466(550,2689)	9	8
	Multiplier = 0.8	2895(838,5693)	1998(633,3868)	1273(460,2325)	20	18
	Multiplier = 0.6	2336(664,4644)	1602(495,3072)	989(346,1831)	36	35
	Multiplier = 0.4	3458(1086,6782)	2450(808,4704)	1626(624,2955)	2	0
0.4	P* = 0.5	3349(1031,6622)	2363(770,4563)	1546(589,2820)	5	4
	P* = 0.4	3285(1001,6513)	2307(746,4496)	1501(567,2741)	7	6
	P* = 0.3	3185(959,6335)	2222(713,4342)	1437(536,2644)	11	9
	P* = 0.2	3494(1110,6953)	2489(847,4676)	1627(629,2933)	0	0
	P* = 0.1	3281(1022,6546)	2307(771,4338)	1480(557,2683)	7	0

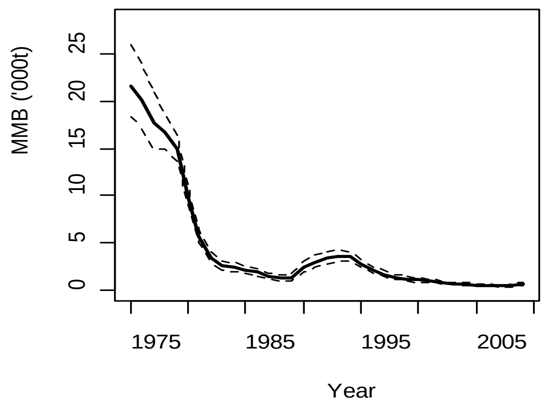


Figure 8-1 Time-trajectory of mature male biomass at the time of mating for PIBKC (thousand t).

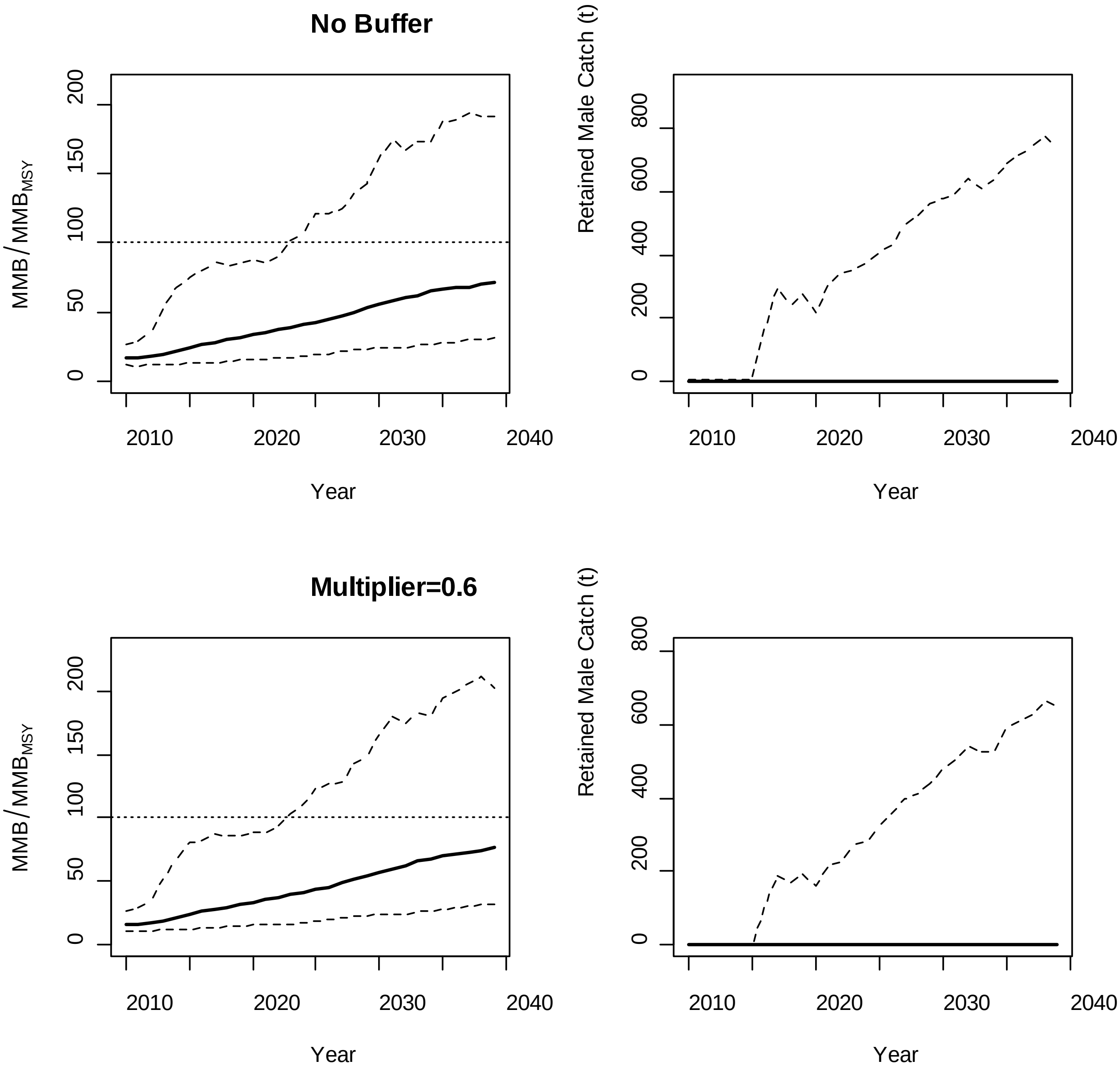


Figure 8-2 Time-trajectories of mature male biomass at mating relative to the proxy for B_{MSY} and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the figure are based on $\sigma_b = 0.4$ and on applying the SOA control rule.

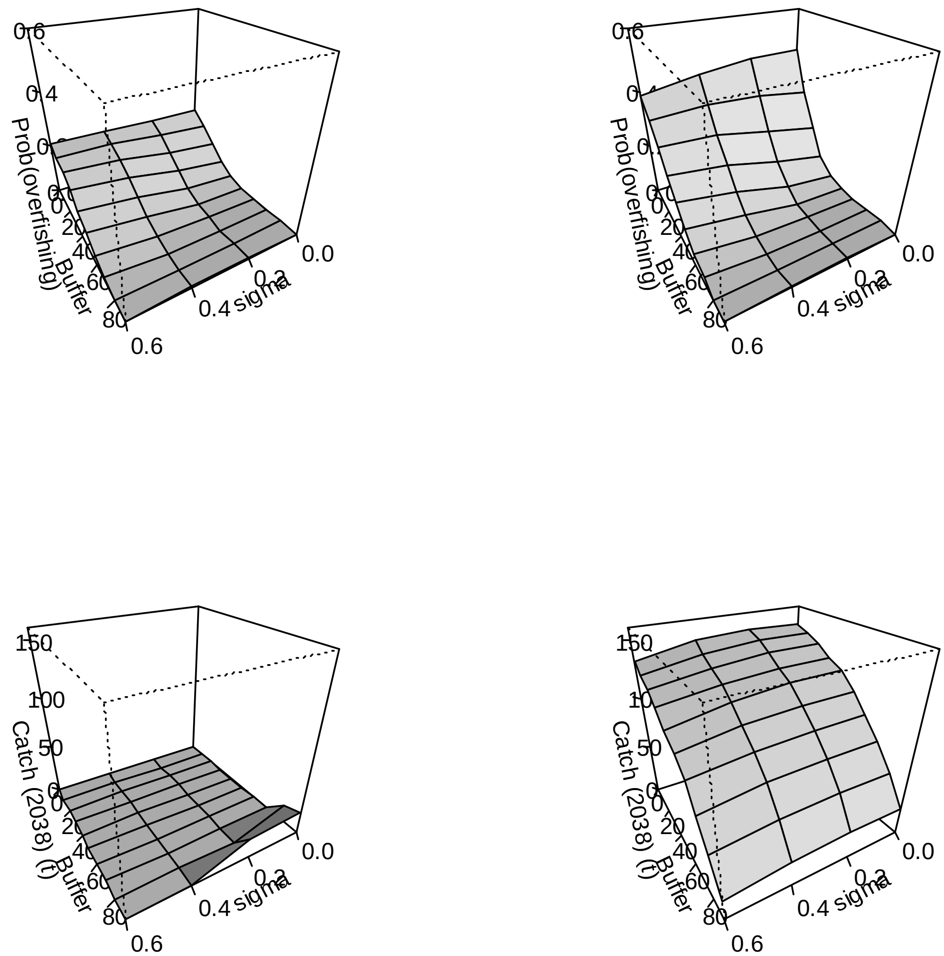


Figure 8-3 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for PIBKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

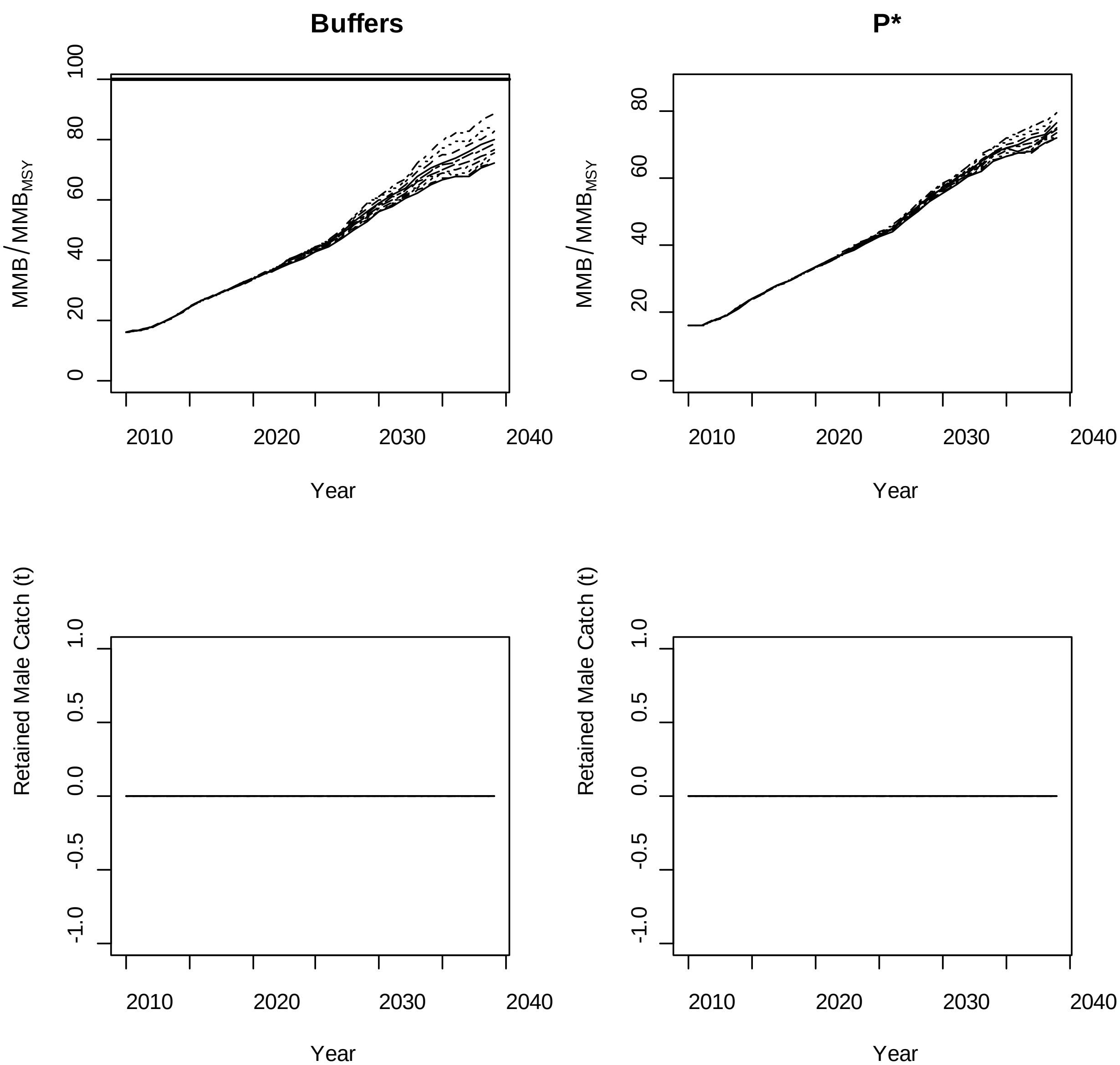


Figure 8-4 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on $\sigma_b = 0.4$ and imposing the SOA control rule.**

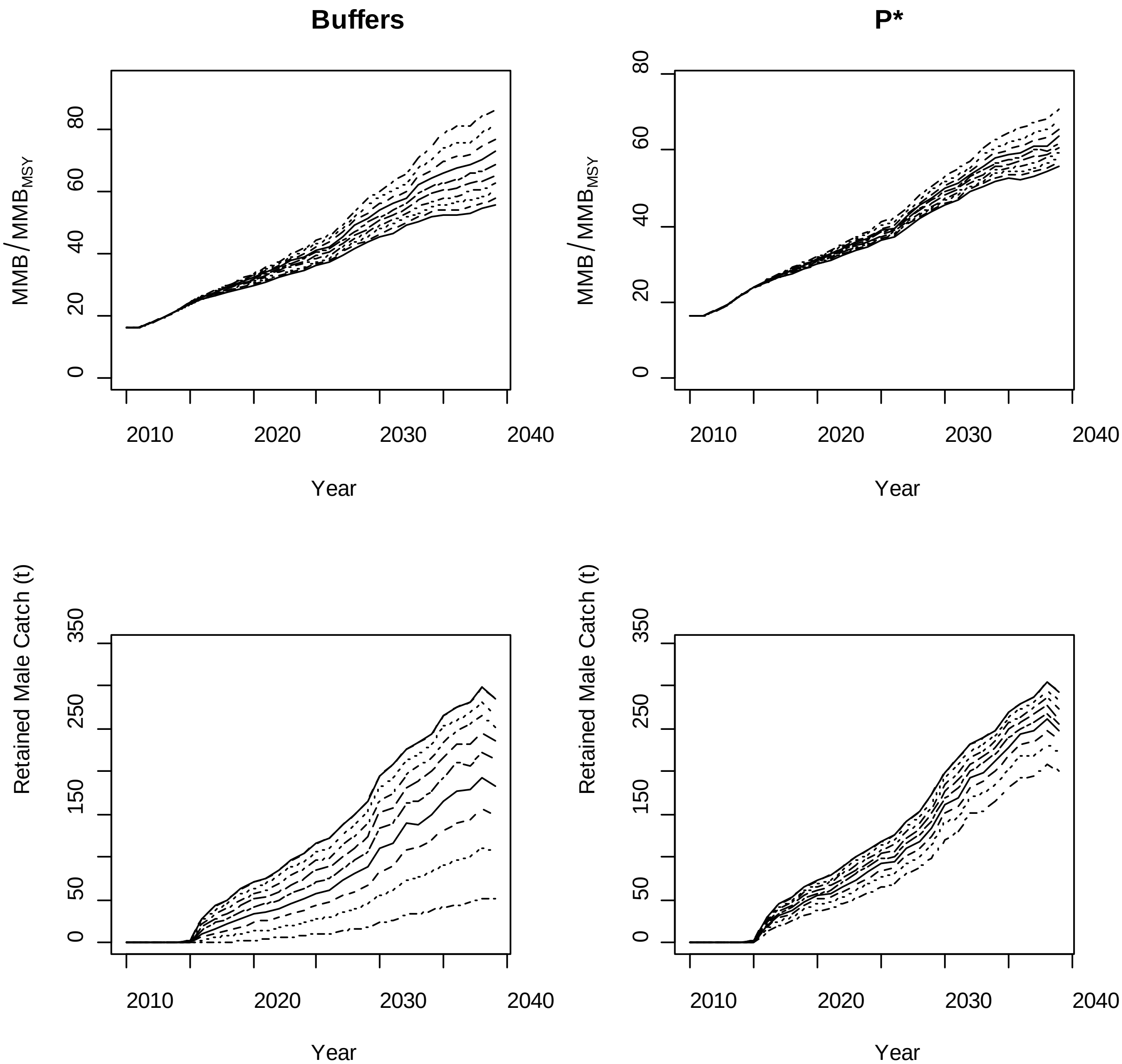


Figure 8-5 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on $\sigma_b = 0.4$ and not imposing the SOA control rule**

9 St. Matthew Blue King Crab

The St. Matthew Island Section for blue king crab is within the Northern District of the Bering Sea king crab registration area (Area Q2) and includes the waters north of the latitude of Cape Newenham (58°39' N. lat.) and south of the latitude of Cape Romanzof (61°49' N. lat.) (Bowers et al. 2008).

9.1 Assessment overview

The St. Matthew blue king crab (SMBKC) stock biomass is above its estimated B_{MSY} (7.9 million lbs of mature male biomass, at the time of mating) with model-estimated mature male biomass at mating having increased to 12.47 million lbs in 2009 (Zheng et al. 2009; Figure 9-1). The high abundance estimate for 2009 was primarily caused by the relatively high trawl survey abundance of prerecruit-2s in 2006 and 2008, very high trawl survey abundance of prerecruit-1s and prerecruit-2s in 2007 and 2009, and high trawl survey abundance of postrecruits in 2008, and high pot survey abundance in 2007. MMB has fluctuated greatly during three periods: (a) an increase from 7.6 to over 17.6 million lbs from 1978 to 1981 followed by a decline to 2.9 million lbs in 1985, (b) an increase from the low in 1985 to 13.3 million lbs in 1997 followed by a second decline to 2.8 million lbs in 1999, and c) a third increase from the low in 1999 to the present high of over 12.47 million lbs in 2009. The stock is estimated to have been above the B_{MSY} proxy for two years, and is now considered rebuilt from its previous overfished status (NPFMC, 2009). It is no longer under a rebuilding plan.

A four-stage catch survey analysis is employed to assess this stock (Zheng et al. 2009). The model incorporates annual trawl survey data from 1978 to the present, triennial pot survey data from 1995 to 2007, and commercial catch data from 1978 to 2008, and uses a maximum likelihood approach to estimate male crab biomass. The model links crab abundance in four crab stages based on a growth matrix, estimated mortalities, and molting probabilities. The four stages are prerecruit-2s (90-104 mm CL), prerecruit-1s (105-119 mm CL), recruits (newshell 120-133 mm CL), and postrecruits (oldshell ≥ 120 mm CL and newshell ≥ 134 mm CL). The current assessment fixes q and M (although M for 1999 is treated as an estimable parameter).

The OFL for SMBKC is currently based on the Tier 4 control rule (NMFS 2008). The proxy for B_{MSY} is the average mature male biomass at mating over a pre-specified period. The current time frame for this calculation is 1989 – present in order to exclude time periods before 1986 when the stock was harvested at high rates. The OFL is a total male catch OFL. The OFL includes catches in the directed fishery, discards in the directed fishery, bycatch in the trawl fishery and bycatch in the fixed gear fishery.

9.1.1 Uncertainty in stock assessment

The reliability of the assessment is extremely low because many of the key parameters of the population dynamics and observation models are pre-specified rather than being estimated (e.g. survey catchability and natural mortality for all years except 1999). The coefficient of variation (CV) for the estimate of mature male biomass for the most recent year is 0.16, compared to the survey CV of 0.238. Since the model uses much more information than the estimate of biomass from the 2009 survey to derive this CV, this result is expected. There are several other reasons why the measures of uncertainty reported as part of the stock assessment (a coefficient of variation of 0.16 for the estimate of mature male biomass for the most recent year) may potentially underestimate the true uncertainty:

- F_{msy} is assumed to be equal to M when applying the OFL control rule.
- The selection of 1989-2009 as the basis for the proxy B_{MSY} is clearly subject to considerable uncertainty given that this range of years does not take into account the years of stock collapse or years of stock productivity and high harvest prior to that period.

- Q is fixed to be 1 for legal crab.
- The selectivity for the bycatch in the directed pot fishery was pre-specified rather than being estimated.
- There is considerable uncertainty in the survey distribution for this stock as an accurate indication of the availability of the stock to the survey, and particularly the catchability of mature crab to the survey.

For SMBKC, additional uncertainty is thought to be medium, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.3 to quantify this level of additional uncertainty, which is the value recommended by the CPT and SSC. The analysis of the short-term implications includes results for a σ_b of 0, 0.2, 0.4, and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.3. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

9.2 Impacts of alternatives

As described in Chapter 2, there are two methods under consideration for computing a total-catch (male-only) ABC for SMBKC: (a) the OFL can be multiplied by a pre-specified “multiplier” (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternatives 3 and 4).

The analyses of impacts in this chapter are based on the assumption that there are no sector-specific ACLs, that the ACL applies to all removals of male SMBKC (a total male catch ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the trawl and fixed gear fisheries. A total male catch ACL can be computed from the output of the SOA control rule (which pertains to the retained catch in the directed fishery) by adding the estimates of bycatch and discard to the output from the SOA control rule. As noted in Chapter 3, two scenarios are considered related to the SOA control rule: (a) the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule, and (b) the ACL equals the ABC (i.e. the SOA control rule is ignored).

The short-, medium- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the buffer value (shown as the result of application of a multiplier to the OFL) and P* on the ABC which would have been advised for the 2010/11 fishery (assuming that ABCs had been specified for that fishery) while the medium- and long-term implications are evaluated by projecting the population ahead 30 years. The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2010-2015) while the long-term implications consider the implications of the entire 30-year projection period.

9.2.1 Short-term implications

The short-implications focus on the size of the ABC for the 2010/11 fishing year. The biological implications of the choice of an alternative are addressed in Section 9.2.2.1 and 9.2.2.2.

Table 9-1 lists the ABC values for the 2010/11 fishing year for each of the alternatives, along with the corresponding estimate of the retained catch in the directed fishery. The table header indicates the TAC calculated using the SOA control rule. The difference between ABC_{tot} and ABC_{dir} reflects the losses to discard in the directed fishery, and bycatch in the trawl and fixed gear fisheries (see Table 9-2 for the breakdown of the OFL to each source of removals). The gross revenue from the directed fishery associated with each of the alternatives is also shown in Table 9-1. The posterior distribution for the OFL is highly skewed for SMBKC, with the result that the ABC exceeds the OFL for some choices of P* and σ_b.

For SMBKC, the output of the SOA control rule is 1,597t, which is higher than the retained catch portion of all buffer values under consideration. Therefore any ABC value under consideration would constrain the SOA control rule. Under Alternative 4, ADF&G would be required to set the TAC below the ABC.

There is a linear relationship between the ABC and buffer (Table 9-1a, Figure 9-2a) with the ABC set equal to the OFL when there is no buffer, and being 10% of the ABC for a buffer of 90% (a multiplier of 0.1). The relationship between the buffer and P* is, however, not simple linear proportionality (Table 9-1b-e, Figure 0-1b). The buffer gets larger (and hence the ABC for 2010/11 decreases) for the same value for P* as the value for σ_b is increased. For example, the buffer for a P* of 0.2 (20% probability that the ABC will exceed the true OFL) is 3% if there is no uncertainty that is not captured by the stock assessment, but is 10%, 23% and 39% if σ_b is 0.2, 0.4 or 0.6 (Table 9-1b-e, Figure 9-2b). The relationship between P* and the buffer (as indicated by the result of multiplying the OFL by the multiplier) based on the OFL calculated for 2010/11 is given in the "P* (additional uncertainty)" column of Table 9-1a.

As of this analysis, final wholesale price data for Alaska crab are available only through 2008. Estimated revenue under alternative multiplier- and σ_b-levels presented in Table 9-1 use the 2009/10 forecast price from the red king crab price model, adjusted for blue king crab as described above. In the single-year short term results, the incremental change in revenues associated with a 0.1 increment in the multiplier is approximately $1.5 million (Table 9-1 (a)). For the P* alternative, at σ=0.6, each 0.1 incremental decrease in P* is associated with nearly constant decline in gross revenues $1.6 to 1.9 million. This corresponds to the linear relationship between the ABC and the multiplier, and nonlinear relationship between the multiplier and P* depicted in Figure 9-2 (noting that the relationship between the multiplier and P* is nearly linear for the σ=0.6 curve.

9.2.2 Medium- and long-term implications

Table 9-3 lists summaries of the posterior distributions for the key parameters which determine the productivity of the population. The extent of uncertainty captured within the stocks assessment, σ_w, is 0.16 based on the asymptotic variance-covariance matrix..

9.2.2.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized in Table 9-4 for analyses based on the extent of additional uncertainty recommended by the CPT (0.6), and for four multiplier levels (1, 0.8, 0.6 and 0.4) and choices for P* (0.4, 0.3, 0.2 and 0.1). These multiplier levels correspond to buffer values of 0, 20%, 40% and 60% respectively.

As expected from Table 9-1, the retained catch in the directed fishery is less than the output from the SOA control rule for all buffers and additional uncertainties (Table 9-4). The SOA control rule was designed with a high catch threshold for increasing fishery manageability. Harvest rates based on a fishing mortality equal to M are generally lower than the harvest rates from SOA control rule. One consequence of the output from the SOA control rule being substantially larger than the ABCs from the

ABC control rule is that the results for the projections that account for and ignore the SOA control rule are essentially identical (compared Table 9-4a-d with Table 9-4e-h and Table 9-4i-l with Table 9-4m-p).

The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) decreases as the size of the buffer in increased (the multiplier is decreased) or P* is reduced. However, this reduction is at a cost of substantially lower annual catches (particularly in the earlier years of the projection period). For example, the retained catch in the directed fishery in 2010 drops from 900t to 300t as the buffer is increased from 0 to 60% (multipliers from 1 to 0.4; Table 9-4a-d). One consequence of larger buffers is, however, larger stock sizes. The impact of different choices for P* is somewhat less than for different choices for the buffer because the range of buffers for P* in the range 0.05 to 1 is only 64%-0, a narrower range than the range of buffers under consideration. The range of buffers is wider for SMBKC than for, for example, BBRKC because the uncertainty captured within the assessment is higher and particularly because the extent of additional uncertainty recommended by the CPT is 0.6 rather than 0.2.

The mature male biomass at the time of mating is predicted to be declining during 2010-2015 and there is high probability of MMB being above B_{MSY} proxy during these years. This occurs in part because of the relatively high mature male biomass in 2009 and strong recent recruitment.

9.2.2.2 Long-term implications - Biological

Table 9-5 summarizes the results of the long-term projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"),(b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B") (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of TAC being computed by adding predicted bycatch and discard to the output from the SOA control rule (column "Prob (SOA)"), and (e) the mean and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period. Results are shown in Table 9-5 for projections which account for and ignore the SOA control rule.

Figure 9-4 shows the time-trajectories of catch and mature male biomass at mating relative to the proxy for B_{MSY} for two illustrative choices for the buffer (0; ABC=OFL; 40%; the ABC is 60% of the OFL). As expected, the mature male biomass is larger when the buffer is larger (the multiplier is smaller). As noted above, the mature male biomass drops over the early years of the projection period because the current mature male biomass is substantially larger than the proxy for B_{MSY} at present and setting the ABC to the OFL (without a buffer) would be expected to drive the stock back (down) to B_{MSY}.

Figure 9-5 and Figure 9-6 evaluate the implications of different buffer values between the ABC and the OFL in terms of metrics (a), (b), (c) and (e) in Table 9-5, except that results are shown for all four values of the extent of additional uncertainty instead of only the value recommended by the CPT. As expected, applying or ignoring the SOA control rule has virtually no impact on the results in Figure 9-5 and Figure 9-6. Higher values for P* and smaller buffers (higher multipliers) lead to higher probabilities of the stock becoming overfished. In contrast to the case for Bristol Bay red king crab, the probability of becoming overfished once during the 30-year projection period is not sensitive to the extent of additional uncertainty. However, the annual probability of being overfished is higher for highest extent of additional uncertainty. The probability of overfishing is high when there is no buffer (a multiplier of 1) for all levels of additional uncertainty, and is higher for greater extents of additional uncertainty for given values for the buffer. The median catch in 2039 is highest for when there is no buffer and for the lowest extent of additional uncertainty (Figure 9-6, lower panels).

Figure 9-7 and Figure 9-8 illustrate the differences among the 10 buffer values and choices for P* in terms of the median time-trajectory of mature male biomass at mating relative to B_{MSY} and the median time-trajectory of the catch of legal males in the directed fishery. The ratio of mature male biomass to the proxy for B_{MSY} increases essentially continuously with changes in the buffer and P* and this result is again independent of whether the SOA control rule is applied or not.

The catch is constrained to a substantial extent by the ABC for all buffer sizes and values for P* except when there is no buffer (P*=0.5) (Table 9-5). For this stock therefore, the ABC control rule almost completely overrides the SOA harvest control rule, essentially irrespective of the chosen buffer or value for P*.

9.2.2.3 Medium and long-term implications - Economic

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference on the evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30- year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

Revenue forecasts are based on probabilistic price forecasts using the time-series vector autoregression model for Alaskan red king crab, adjusted by a factor of 0.86 to account for the mean difference between Alaskan blue king and red king crab over the period 1991 to 2003 when the fishery was open (see Chapter 3 for details). The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume using the average product recovery rate for Alaska red king crab (64%). Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

The medium and long-term impacts of ACL alternatives are summarized in Table 9-6 and Table 9-7. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term. Table 9-6 (a) and (b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to 1) zero buffer (multiplier=1.0) and no additional uncertainty (σ=0), and 2) zero buffer, but holding the value of σ constant across compared alternatives. Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC (Table 9-6 (a)), and scenarios without the SOA control rule (Table 9-6 (b)).

9.3 Tables and Figures

Table 9-1 The values for catch-related quantities for SMBKC for 2010/11 for each of the alternatives. The column P* in Table 9-1a shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The SSC recommended additional uncertainty is shaded. The output from the SOA harvest control rule for this stock is 1,597t. Some of the multipliers for fixed values for P* exceed 1 owing to the skewness for the posterior for the OFL.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	P * (additional uncertainty					Revenue	
			None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	1,140	1,015	0.50	0.50	0.50	>0.50	>0.50	14	0
Multiplier = 0.9	1,026	914	0.13	0.19	0.26	0.32	0.41	12	14
Multiplier = 0.8	912	812	0.04	0.10	0.16	0.23	0.33	11	21
Multiplier = 0.7	798	711	0.01	0.04	0.09	0.14	0.27	9	36
Multiplier = 0.6	684	609	0.00	0.01	0.05	0.09	0.19	8	43
Multiplier = 0.5	570	508	0.00	0.00	0.01	0.04	0.12	6	57
Multiplier = 0.4	456	406	0.00	0.00	0.00	0.01	0.08	5	64
Multiplier = 0.3	342	305	0.00	0.00	0.00	0.00	0.03	3	79
Multiplier = 0.2	228	203	0.00	0.00	0.00	0.00	0.00	1	93
Multiplier = 0.1	114	102	0.00	0.00	0.00	0.00	0.00	0	100

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
$P^* = 0.5$	1,140[&]	1,015	1.00
$P^* = 0.4$	1235	1043	1.08
$P^* = 0.3$	1179	1008	1.03
$P^* = 0.2$	1105	846	0.97
$P^* = 0.1$	1003	811	0.88

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
$P^* = 0.5$	1,140&	1,015	1.00
$P^* = 0.4$	1208	929	1.06
$P^* = 0.3$	1136	940	1.00
$P^* = 0.2$	1032	884	0.90
$P^* = 0.1$	904	758	0.79

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier	Revenue	
				Millions $	% Change
$P^* = 0.5$	1,140&	1,015	1.00	13	0
$P^* = 0.4$	1179	999	1.03	12	8
$P^* = 0.3$	1076	872	0.94	11	15
$P^* = 0.2$	955	781	0.84	10	23
$P^* = 0.1$	816	608	0.72	8	38

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
$P^* = 0.5$	1,140&	1,015	1.00
$P^* = 0.4$	1132	930	0.99
$P^* = 0.3$	1013	829	0.89
$P^* = 0.2$	874	714	0.77
$P^* = 0.1$	721	608	0.63

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
$P^* = 0.5$	1,140&	1,015	1.00
$P^* = 0.4$	1015	880	0.89
$P^* = 0.3$	864	677	0.76
$P^* = 0.2$	694	535	0.61
$P^* = 0.1$	525	434	0.46

& - set to the point estimate

Table 9-2 Breakdown of the 2010/11 OFL for SMBKC among the sources of mortality included in the OFL

Component	Catch (t)
Directed fishery	1,015
Male discard in the directed fishery	92
Bycatch in the trawl fishery	1
Bycatch in the Fixed gear fishery	31
Total	**1,140**

Table 9-3 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes.

Parameter	Distribution
Virgin MMB	26.5 (18.8, 37.4)
Steepness, h	0.245 (0.235, 0.259)
F_{MSY} (M)	0.082
B_{MSY}	8.4 (6.0, 11.8)
σ_R	0.792 (0.467, 1.2.37)

Table 9-4 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for SMBKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on σ_b=0.3.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2010	1.3 (.7- 3.0)	1.1 (.5- 2.5)	1.7 (.8- 3.7)	1.1 (.5- 2.6)	225 (168-293)	0.450
2011	1.3 (.7- 2.7)	1.1 (.6- 2.3)	1.7 (.8- 3.5)	1.1 (.5- 2.4)	222 (161-301)	0.429
2012	1.3 (.7- 2.3)	1.1 (.6- 2.1)	1.6 (.8- 3.0)	1.1 (.5- 2.1)	204 (138-303)	0.445
2013	1.1 (.7- 2.1)	1.0 (.6- 1.8)	1.5 (.8- 2.7)	1.0 (.5- 1.8)	184 (112-289)	0.446
2014	1.0 (.6- 2.0)	.9 (.5- 1.7)	1.3 (.6- 2.4)	.9 (.5- 1.8)	162 (94-269)	0.456
2015	.9 (.5- 1.7)	.8 (.4- 1.5)	1.1 (.5- 2.3)	.8 (.4- 1.6)	140 (79-270)	0.446

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2010	1.0 (.5- 2.4)	.9 (.4- 2.0)	1.7 (.8- 3.7)	.8 (.4- 2.0)	233 (176-301)	0.212
2011	1.1 (.6- 2.3)	.9 (.5- 1.9)	1.7 (.8- 3.7)	.9 (.4- 2.0)	235 (175-313)	0.201
2012	1.1 (.6- 2.0)	.9 (.5- 1.8)	1.7 (.9- 3.2)	.9 (.4- 1.8)	221 (156-318)	0.219
2013	1.0 (.6- 1.9)	.8 (.5- 1.5)	1.6 (.8- 3.0)	.8 (.4- 1.6)	202 (133-310)	0.202
2014	.9 (.5- 1.8)	.8 (.5- 1.5)	1.4 (.7- 2.7)	.8 (.4- 1.5)	181 (111-292)	0.222
2015	.8 (.5- 1.6)	.7 (.4- 1.4)	1.2 (.6- 2.5)	.7 (.4- 1.4)	160 (92-292)	0.221

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB /B_{MSY}	Prob (overfishing)
2010	.8 (.4- 1.8)	.6 (.3- 1.5)	1.7 (.8- 3.7)	.6 (.2- 1.4)	240 (183-309)	0.048
2011	.8 (.4- 1.8)	.7 (.4- 1.5)	1.8 (.8- 3.8)	.6 (.3- 1.5)	249 (188-329)	0.054
2012	.8 (.4- 1.6)	.7 (.4- 1.4)	1.8 (.9- 3.4)	.7 (.3- 1.4)	239 (173-334)	0.047
2013	.8 (.4- 1.5)	.7 (.4- 1.3)	1.7 (.9- 3.2)	.6 (.3- 1.3)	221 (153-331)	0.058
2014	.7 (.4- 1.5)	.7 (.4- 1.3)	1.6 (.8- 3.0)	.6 (.3- 1.2)	201 (133-319)	0.049
2015	.7 (.4- 1.3)	.6 (.3- 1.2)	1.4 (.7- 2.7)	.5 (.3- 1.1)	182 (111-317)	0.054

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	.5 (.3- 1.2)	.4 (.2- 1.0)	1.7 (.8- 3.7)	.4 (.1- .9)	247 (190-318)	0.004
2011	.6 (.3- 1.2)	.5 (.2- 1.1)	1.8 (.9- 3.9)	.4 (.1- 1.0)	263 (201-344)	0.004
2012	.6 (.3- 1.2)	.5 (.3- 1.0)	1.9 (.9- 3.6)	.4 (.1- .9)	259 (191-356)	0.004
2013	.6 (.3- 1.1)	.5 (.3- 1.0)	1.8 (1.0- 3.5)	.4 (.2- .9)	244 (175-354)	0.005
2014	.5 (.3- 1.1)	.5 (.3- .9)	1.7 (.9- 3.4)	.4 (.2- .9)	227 (156-351)	0.003
2015	.5 (.3- 1.0)	.4 (.2- .9)	1.6 (.8- 3.2)	.4 (.1- .8)	208 (137-345)	0.000

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.3 (.7- 3.0)	1.1 (.5- 2.5)	1.7 (.8- 3.7)	1.1 (.5- 2.6)	225 (168-293)	0.450
2011	1.3 (.7- 2.7)	1.1 (.6- 2.3)	1.7 (.8- 3.5)	1.1 (.5- 2.4)	222 (161-301)	0.429
2012	1.3 (.7- 2.3)	1.1 (.6- 2.1)	1.6 (.8- 3.0)	1.1 (.5- 2.1)	204 (138-303)	0.445
2013	1.1 (.7- 2.1)	1.0 (.6- 1.8)	1.5 (.8- 2.7)	1.0 (.5- 1.8)	184 (112-289)	0.446
2014	1.0 (.6- 2.0)	.9 (.5- 1.7)	1.3 (.6- 2.4)	.9 (.5- 1.8)	162 (94-269)	0.456
2015	.9 (.5- 1.7)	.8 (.4- 1.5)	1.1 (.5- 2.3)	.8 (.4- 1.6)	140 (79-270)	0.446

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.0 (.5- 2.4)	.9 (.4- 2.0)	1.7 (.8- 3.7)	.8 (.4- 2.0)	233 (176-301)	0.212
2011	1.1 (.6- 2.3)	.9 (.5- 1.9)	1.7 (.8- 3.7)	.9 (.4- 2.0)	235 (175-313)	0.201
2012	1.1 (.6- 2.0)	.9 (.5- 1.8)	1.7 (.9- 3.2)	.9 (.4- 1.8)	221 (156-318)	0.219
2013	1.0 (.6- 1.9)	.8 (.5- 1.5)	1.6 (.8- 3.0)	.8 (.4- 1.6)	202 (133-310)	0.202
2014	.9 (.5- 1.8)	.8 (.5- 1.5)	1.4 (.7- 2.7)	.8 (.4- 1.5)	181 (111-292)	0.222
2015	.8 (.5- 1.6)	.7 (.4- 1.4)	1.2 (.6- 2.5)	.7 (.4- 1.4)	160 (92-292)	0.221

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	.8 (.4- 1.8)	.6 (.3- 1.5)	1.7 (.8- 3.7)	.6 (.2- 1.4)	240 (183-309)	0.048
2011	.8 (.4- 1.8)	.7 (.4- 1.5)	1.8 (.8- 3.8)	.6 (.3- 1.5)	249 (188-329)	0.054
2012	.8 (.4- 1.6)	.7 (.4- 1.4)	1.8 (.9- 3.4)	.7 (.3- 1.4)	239 (173-334)	0.047
2013	.8 (.4- 1.5)	.7 (.4- 1.3)	1.7 (.9- 3.2)	.6 (.3- 1.3)	221 (153-331)	0.058
2014	.7 (.4- 1.5)	.7 (.4- 1.3)	1.6 (.8- 3.0)	.6 (.3- 1.2)	201 (133-319)	0.049
2015	.7 (.4- 1.3)	.6 (.3- 1.2)	1.4 (.7- 2.7)	.5 (.3- 1.1)	182 (111-317)	0.054

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	.5 (.3- 1.2)	.4 (.2- 1.0)	1.7 (.8- 3.7)	.4 (.1- .9)	247 (190-318)	0.004
2011	.6 (.3- 1.2)	.5 (.2- 1.1)	1.8 (.9- 3.9)	.4 (.1- 1.0)	263 (201-344)	0.004
2012	.6 (.3- 1.2)	.5 (.3- 1.0)	1.9 (.9- 3.6)	.4 (.1- .9)	259 (191-356)	0.004
2013	.6 (.3- 1.1)	.5 (.3- 1.0)	1.8 (1.0- 3.5)	.4 (.2- .9)	244 (175-354)	0.005
2014	.5 (.3- 1.1)	.5 (.3- .9)	1.7 (.9- 3.4)	.4 (.2- .9)	227 (156-351)	0.003
2015	.5 (.3- 1.0)	.4 (.2- .9)	1.6 (.8- 3.2)	.4 (.1- .8)	208 (137-345)	0.000

(i) P*=0.4; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.3 (.7- 3.0)	1.1 (.5- 2.5)	1.7 (.8- 3.7)	1.1 (.5- 2.6)	225 (168-293)	0.450
2011	1.3 (.7- 2.7)	1.1 (.6- 2.3)	1.7 (.8- 3.5)	1.1 (.5- 2.4)	222 (161-301)	0.429
2012	1.3 (.7- 2.3)	1.1 (.6- 2.1)	1.6 (.8- 3.0)	1.1 (.5- 2.1)	204 (138-303)	0.445
2013	1.1 (.7- 2.1)	1.0 (.6- 1.8)	1.5 (.8- 2.7)	1.0 (.5- 1.8)	184 (112-289)	0.446
2014	1.0 (.6- 2.0)	.9 (.5- 1.7)	1.3 (.6- 2.4)	.9 (.5- 1.8)	162 (94-269)	0.456
2015	.9 (.5- 1.7)	.8 (.4- 1.5)	1.1 (.5- 2.3)	.8 (.4- 1.6)	140 (79-270)	0.446

(j) P*=0.3 Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.2 (.6- 2.7)	1.0 (.5- 2.3)	1.7 (.8- 3.7)	1.0 (.4- 2.4)	228 (172-296)	0.343
2011	1.2 (.6- 2.5)	1.0 (.5- 2.1)	1.7 (.8- 3.6)	1.0 (.5- 2.2)	227 (168-306)	0.335
2012	1.2 (.6- 2.2)	1.0 (.5- 1.9)	1.6 (.8- 3.1)	1.0 (.5- 1.9)	211 (146-309)	0.348
2013	1.1 (.6- 2.0)	.9 (.5- 1.7)	1.5 (.8- 2.8)	.9 (.5- 1.7)	191 (120-297)	0.349
2014	1.0 (.6- 1.9)	.8 (.5- 1.6)	1.3 (.6- 2.5)	.8 (.5- 1.7)	170 (101-278)	0.357
2015	.9 (.5- 1.7)	.7 (.4- 1.5)	1.2 (.5- 2.3)	.7 (.4- 1.5)	148 (85-279)	0.357

(k) P*=0.2; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.1 (.5- 2.5)	.9 (.5- 2.1)	1.7 (.8- 3.7)	.9 (.4- 2.1)	231 (175-300)	0.246
2011	1.1 (.6- 2.4)	.9 (.5- 2.0)	1.7 (.8- 3.7)	.9 (.4- 2.0)	233 (173-312)	0.233
2012	1.1 (.6- 2.1)	.9 (.5- 1.8)	1.7 (.8- 3.2)	.9 (.4- 1.8)	217 (152-315)	0.259
2013	1.0 (.6- 1.9)	.9 (.5- 1.6)	1.5 (.8- 2.9)	.9 (.4- 1.6)	198 (129-307)	0.248
2014	.9 (.5- 1.8)	.8 (.5- 1.6)	1.4 (.7- 2.6)	.8 (.4- 1.6)	177 (108-287)	0.257
2015	.8 (.5- 1.6)	.7 (.4- 1.4)	1.2 (.5- 2.4)	.7 (.4- 1.4)	156 (90-289)	0.269

(l) P*=0.1; Impose SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.0 (.5- 2.2)	.8 (.4- 1.9)	1.7 (.8- 3.7)	.8 (.3- 1.9)	235 (178-303)	0.160
2011	1.0 (.5- 2.2)	.8 (.4- 1.8)	1.7 (.8- 3.7)	.8 (.4- 1.8)	238 (179-318)	0.155
2012	1.0 (.5- 1.9)	.9 (.5- 1.7)	1.7 (.9- 3.3)	.8 (.4- 1.7)	225 (160-322)	0.177
2013	.9 (.5- 1.8)	.8 (.5- 1.5)	1.6 (.8- 3.0)	.8 (.4- 1.5)	206 (138-315)	0.149
2014	.9 (.5- 1.7)	.8 (.4- 1.4)	1.4 (.7- 2.7)	.7 (.4- 1.4)	186 (116-298)	0.182
2015	.8 (.4- 1.5)	.7 (.4- 1.3)	1.3 (.6- 2.5)	.6 (.3- 1.3)	165 (96-296)	0.165

(m) P*=0.4; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.3 (.7- 3.0)	1.1 (.5- 2.5)	1.7 (.8- 3.7)	1.1 (.5- 2.6)	225 (168-293)	0.450
2011	1.3 (.7- 2.7)	1.1 (.6- 2.3)	1.7 (.8- 3.5)	1.1 (.5- 2.4)	222 (161-301)	0.429
2012	1.3 (.7- 2.3)	1.1 (.6- 2.1)	1.6 (.8- 3.0)	1.1 (.5- 2.1)	204 (138-303)	0.445
2013	1.1 (.7- 2.1)	1.0 (.6- 1.8)	1.5 (.8- 2.7)	1.0 (.5- 1.8)	184 (112-289)	0.446
2014	1.0 (.6- 2.0)	.9 (.5- 1.7)	1.3 (.6- 2.4)	.9 (.5- 1.8)	162 (94-269)	0.456
2015	.9 (.5- 1.7)	.8 (.4- 1.5)	1.1 (.5- 2.3)	.8 (.4- 1.6)	140 (79-270)	0.446

(n) P*=0.3; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.2 (.6- 2.7)	1.0 (.5- 2.3)	1.7 (.8- 3.7)	1.0 (.4- 2.4)	228 (172-296)	0.343
2011	1.2 (.6- 2.5)	1.0 (.5- 2.1)	1.7 (.8- 3.6)	1.0 (.5- 2.2)	227 (168-306)	0.335
2012	1.2 (.6- 2.2)	1.0 (.5- 1.9)	1.6 (.8- 3.1)	1.0 (.5- 1.9)	211 (146-309)	0.348
2013	1.1 (.6- 2.0)	.9 (.5- 1.7)	1.5 (.8- 2.8)	.9 (.5- 1.7)	191 (120-297)	0.349
2014	1.0 (.6- 1.9)	.8 (.5- 1.6)	1.3 (.6- 2.5)	.8 (.5- 1.7)	170 (101-278)	0.357
2015	.9 (.5- 1.7)	.7 (.4- 1.5)	1.2 (.5- 2.3)	.7 (.4- 1.5)	148 (85-279)	0.357

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.1 (.5- 2.5)	.9 (.5- 2.1)	1.7 (.8- 3.7)	.9 (.4- 2.1)	231 (175-300)	0.246
2011	1.1 (.6- 2.4)	.9 (.5- 2.0)	1.7 (.8- 3.7)	.9 (.4- 2.0)	233 (173-312)	0.233
2012	1.1 (.6- 2.1)	.9 (.5- 1.8)	1.7 (.8- 3.2)	.9 (.4- 1.8)	217 (152-315)	0.259
2013	1.0 (.6- 1.9)	.9 (.5- 1.6)	1.5 (.8- 2.9)	.9 (.4- 1.6)	198 (129-307)	0.248
2014	.9 (.5- 1.8)	.8 (.5- 1.6)	1.4 (.7- 2.6)	.8 (.4- 1.6)	177 (108-287)	0.257
2015	.8 (.5- 1.6)	.7 (.4- 1.4)	1.2 (.5- 2.4)	.7 (.4- 1.4)	156 (90-289)	0.269

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000t)	ABC_{Dir} ('000t)	SOA ('000t)	C_{dir} ('000t)	MMB $/B_{MSY}$	Prob (overfishing)
2010	1.0 (.5- 2.2)	.8 (.4- 1.9)	1.7 (.8- 3.7)	.8 (.3- 1.9)	235 (178-303)	0.160
2011	1.0 (.5- 2.2)	.8 (.4- 1.8)	1.7 (.8- 3.7)	.8 (.4- 1.8)	238 (179-318)	0.155
2012	1.0 (.5- 1.9)	.9 (.5- 1.7)	1.7 (.9- 3.3)	.8 (.4- 1.7)	225 (160-322)	0.177
2013	.9 (.5- 1.8)	.8 (.5- 1.5)	1.6 (.8- 3.0)	.8 (.4- 1.5)	206 (138-315)	0.149
2014	.9 (.5- 1.7)	.8 (.4- 1.4)	1.4 (.7- 2.7)	.7 (.4- 1.4)	186 (116-298)	0.182
2015	.8 (.4- 1.5)	.7 (.4- 1.3)	1.3 (.6- 2.5)	.6 (.3- 1.3)	165 (96-296)	0.165

Table 9-5 **Summary of the long-term consequences of the alternatives for SMBKC. The column "retained catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2039. The results in the table are based on σ_b=0.3.**

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Retained catch (2039) (t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Retained catch (2039) (t)
Multiplier = 1		0.375	0.062	0.447	0.053	321 (63-1359)	0.388	0.064	0.448	321 (65-1359)
Multiplier = 0.9		0.310	0.047	0.329	0.023	320 (64-1325)	0.317	0.048	0.330	320 (64-1325)
Multiplier = 0.8		0.243	0.034	0.212	0.011	317 (62-1262)	0.245	0.035	0.212	317 (62-1262)
Multiplier = 0.7		0.180	0.024	0.115	0.007	305 (58-1194)	0.185	0.025	0.115	305 (58-1191)
Multiplier = 0.6		0.125	0.015	0.051	0.005	281 (54-1098)	0.125	0.015	0.051	281 (54-1098)
Multiplier = 0.5		0.081	0.009	0.015	0.004	252 (47- 953)	0.083	0.009	0.015	252 (46- 953)
Multiplier = 0.4		0.039	0.005	0.002	0.003	213 (35- 793)	0.040	0.005	0.002	213 (36- 793)
Multiplier = 0.3		0.023	0.003	0.000	0.002	156 (14- 601)	0.023	0.003	0.000	156 (14- 601)
Multiplier = 0.2		0.016	0.002	0.000	0.001	85 (0- 387)	0.016	0.002	0.000	85 (0- 387)
Multiplier = 0.1		0.010	0.001	0.000	0.001	1 (0- 140)	0.010	0.001	0.000	1 (0- 140)
P* = 0.5	1.0	0.375	0.062	0.447	0.053	321 (63-1359)	0.388	0.064	0.448	321 (65-1359)
P* = 0.45	0.958	0.351	0.055	0.398	0.037	320 (63-1349)	0.357	0.057	0.398	320 (65-1349)
P* = 0.4	0.917	0.323	0.049	0.349	0.026	320 (64-1337)	0.329	0.051	0.349	320 (64-1337)
P* = 0.35	0.877	0.295	0.044	0.300	0.019	318 (64-1317)	0.301	0.045	0.300	318 (64-1317)
P* = 0.3	0.837	0.256	0.038	0.253	0.014	316 (63-1298)	0.261	0.039	0.253	316 (63-1298)
P* = 0.25	0.795	0.243	0.034	0.206	0.010	317 (62-1257)	0.243	0.034	0.207	317 (62-1257)
P* = 0.2	0.751	0.212	0.028	0.160	0.009	314 (61-1254)	0.214	0.029	0.160	314 (60-1254)
P* = 0.15	0.703	0.182	0.024	0.117	0.007	306 (58-1199)	0.187	0.025	0.117	306 (58-1196)
P* = 0.1	0.647	0.146	0.019	0.075	0.006	290 (57-1142)	0.151	0.019	0.075	290 (56-1142)
P* = 0.05	0.572	0.113	0.013	0.038	0.005	274 (54-1064)	0.113	0.013	0.038	274 (54-1064)

Table 9-6 Summary of medium-term economic impacts of a subset of the ACL alternatives for SMBKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2010-2015, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b=0.3. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without the SOA control rule.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2010-2015 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	87(36,165)	82(34,156)	75(32,143)	0	0
	Multiplier = 0.8	71(30,137)	67(28,129)	62(26,118)	18	0
	Multiplier = 0.6	54(22,103)	51(21,97)	47(19,90)	38	0
	Multiplier = 0.4	35(12,66)	33(11,62)	30(10,57)	60	0
0.3	Multiplier = 1	83(33,168)	78(32,157)	71(29,144)	5	0
	Multiplier = 0.8	68(27,140)	64(25,132)	58(23,120)	22	18
	Multiplier = 0.6	51(20,110)	48(18,103)	44(17,95)	41	38
	Multiplier = 0.4	32(10,74)	30(9,69)	28(9,63)	63	62
0.3	P* = 0.5	83(33,168)	78(32,157)	71(29,144)	5	0
	P* = 0.4	77(31,156)	72(29,147)	66(27,135)	12	8
	P* = 0.3	71(28,145)	67(27,137)	61(24,126)	18	14
	P* = 0.2	64(25,133)	60(24,125)	55(22,114)	27	23
	P* = 0.1	56(21,117)	52(20,111)	48(18,102)	37	33

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2010-2015 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b **=0.0**	Baseline B: Multiplier=**1**, σ_b **=0.3**
0	Multiplier = 1	87(36,165)	82(34,156)	75(32,143)	0	0
	Multiplier = 0.8	71(30,137)	67(28,129)	62(26,118)	18	0
	Multiplier = 0.6	54(22,103)	51(21,97)	47(19,90)	38	0
	Multiplier = 0.4	35(12,66)	33(11,62)	30(10,57)	60	0
0.3	Multiplier = 1	83(33,168)	78(32,157)	71(29,144)	5	0
	Multiplier = 0.8	68(27,140)	64(25,132)	58(23,120)	22	18
	Multiplier = 0.6	51(20,110)	48(18,103)	44(17,95)	41	38
	Multiplier = 0.4	32(10,74)	30(9,69)	28(9,63)	63	62
0.3	P* = 0.5	83(33,168)	78(32,157)	71(29,144)	5	0
	P* = 0.4	77(31,156)	72(29,147)	66(27,135)	12	8
	P* = 0.3	71(28,145)	67(27,137)	61(24,126)	18	14
	P* = 0.2	64(25,133)	60(24,125)	55(22,114)	27	23
	P* = 0.1	56(21,117)	52(20,111)	48(18,102)	37	33

Table 9-7 **Summary of long-term economic impacts of a subset of the ACL alternatives for SMBKC. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2010-2039, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b=0.3. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule as a constraint, respectively.**

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2010-2039 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	248(80,599)	186(64,417)	133(49,282)	0	0
	Multiplier = 0.8	217(69,522)	163(56,365)	114(41,243)	12	0
	Multiplier = 0.6	179(56,429)	132(43,297)	91(32,192)	29	0
	Multiplier = 0.4	124(36,297)	92(28,203)	61(20,133)	51	0
0.3	Multiplier = 1	239(72,591)	181(60,419)	130(46,279)	3	0
	Multiplier = 0.8	210(59,536)	158(49,372)	112(39,245)	15	13
	Multiplier = 0.6	169(47,443)	127(38,305)	87(29,199)	32	30
	Multiplier = 0.4	117(27,330)	85(20,222)	58(15,137)	54	53
0.3	P* = 0.5	239(72,591)	181(60,419)	130(46,279)	3	0
	P* = 0.4	228(68,573)	172(56,401)	123(43,265)	8	5
	P* = 0.3	216(61,548)	163(51,380)	115(40,252)	12	10
	P* = 0.2	201(57,516)	152(47,361)	107(36,234)	18	16
	P* = 0.1	181(50,468)	135(41,323)	93(31,210)	27	25

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2010-2039 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.2**
0	Multiplier = 1	248(80,599)	186(64,417)	133(49,282)	0	0
	Multiplier = 0.8	217(69,522)	163(56,365)	114(41,243)	12	0
	Multiplier = 0.6	179(56,429)	132(43,297)	91(32,192)	29	0
	Multiplier = 0.4	124(36,297)	92(28,203)	61(20,133)	51	0
0.3	Multiplier = 1	239(72,591)	181(60,419)	130(46,279)	3	0
	Multiplier = 0.8	210(60,536)	158(49,372)	112(39,245)	15	13
	Multiplier = 0.6	169(47,443)	127(38,305)	87(29,199)	32	30
	Multiplier = 0.4	117(27,330)	85(20,222)	58(15,137)	54	53
0.3	P* = 0.5	239(72,591)	181(60,419)	130(46,279)	3	0
	P* = 0.4	228(68,573)	172(56,401)	123(43,265)	8	5
	P* = 0.3	216(62,548)	163(51,380)	115(40,252)	12	10
	P* = 0.2	202(57,516)	152(47,361)	107(36,234)	18	16
	P* = 0.1	181(50,468)	135(41,323)	93(31,210)	27	25

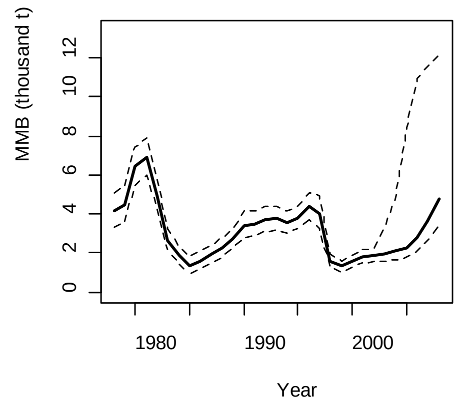


Figure 9-1 Time-trajectory of mature male biomass at the time of mating for SMBKC (thousand t).

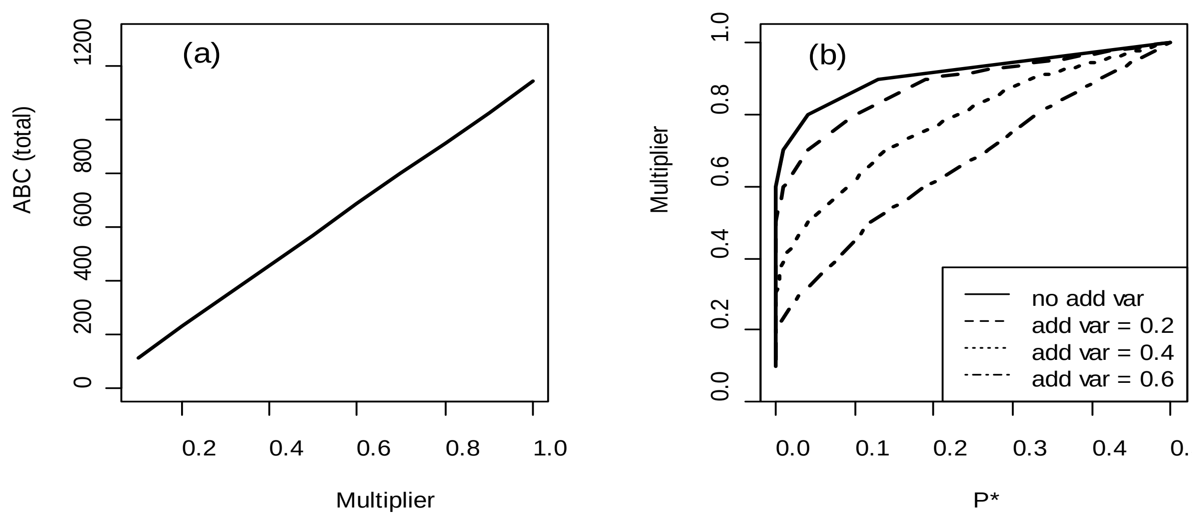


Figure 9-2 Relationship between the multiplier and the ABC (a), and the relationships between P* and the multiplier for four values for the extent of additional uncertainty (b).

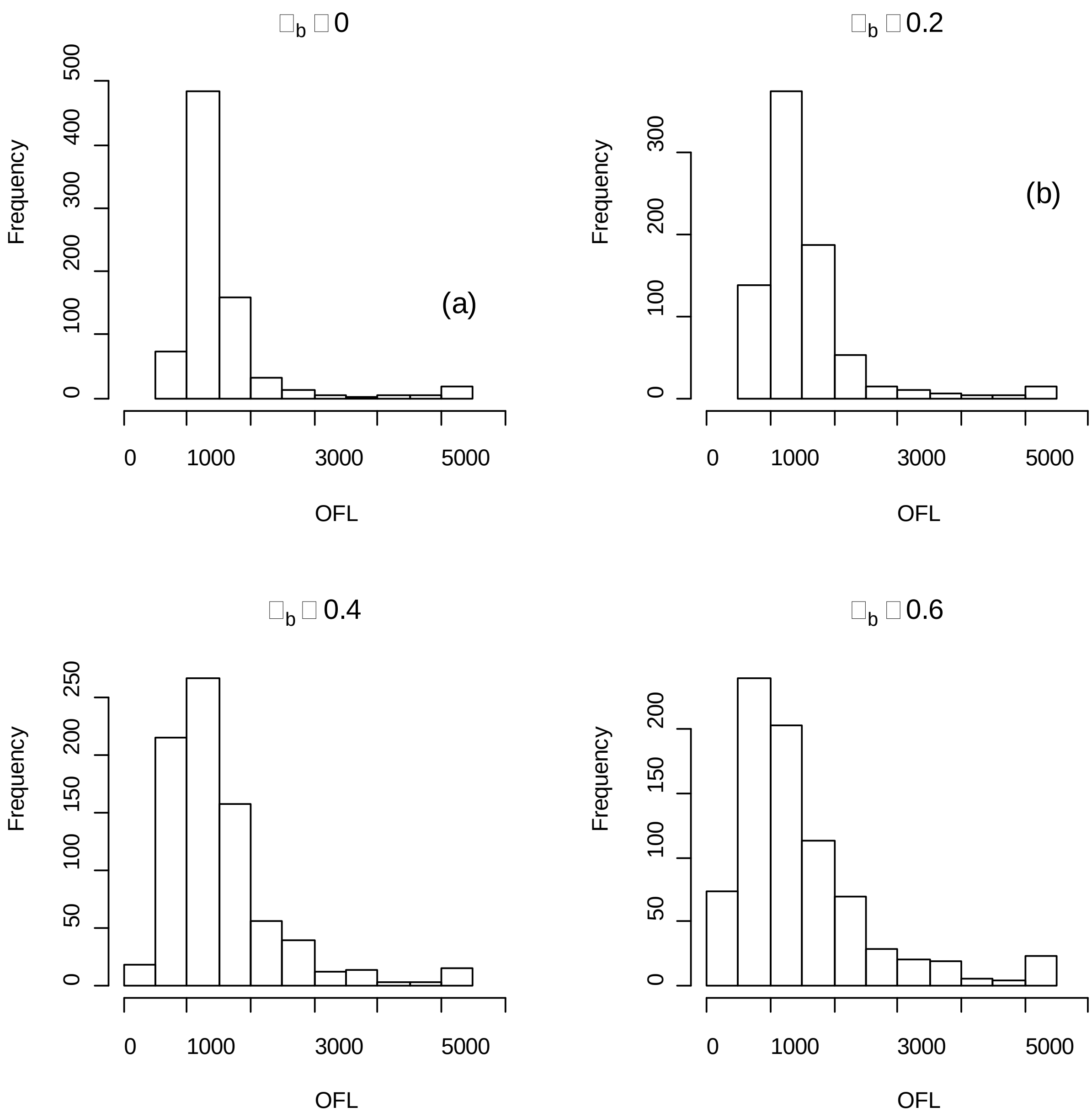


Figure 9-3 **Distribution of OFL values for SMBKC as a function of the assumed extent of additional uncertainty (σ_b).**

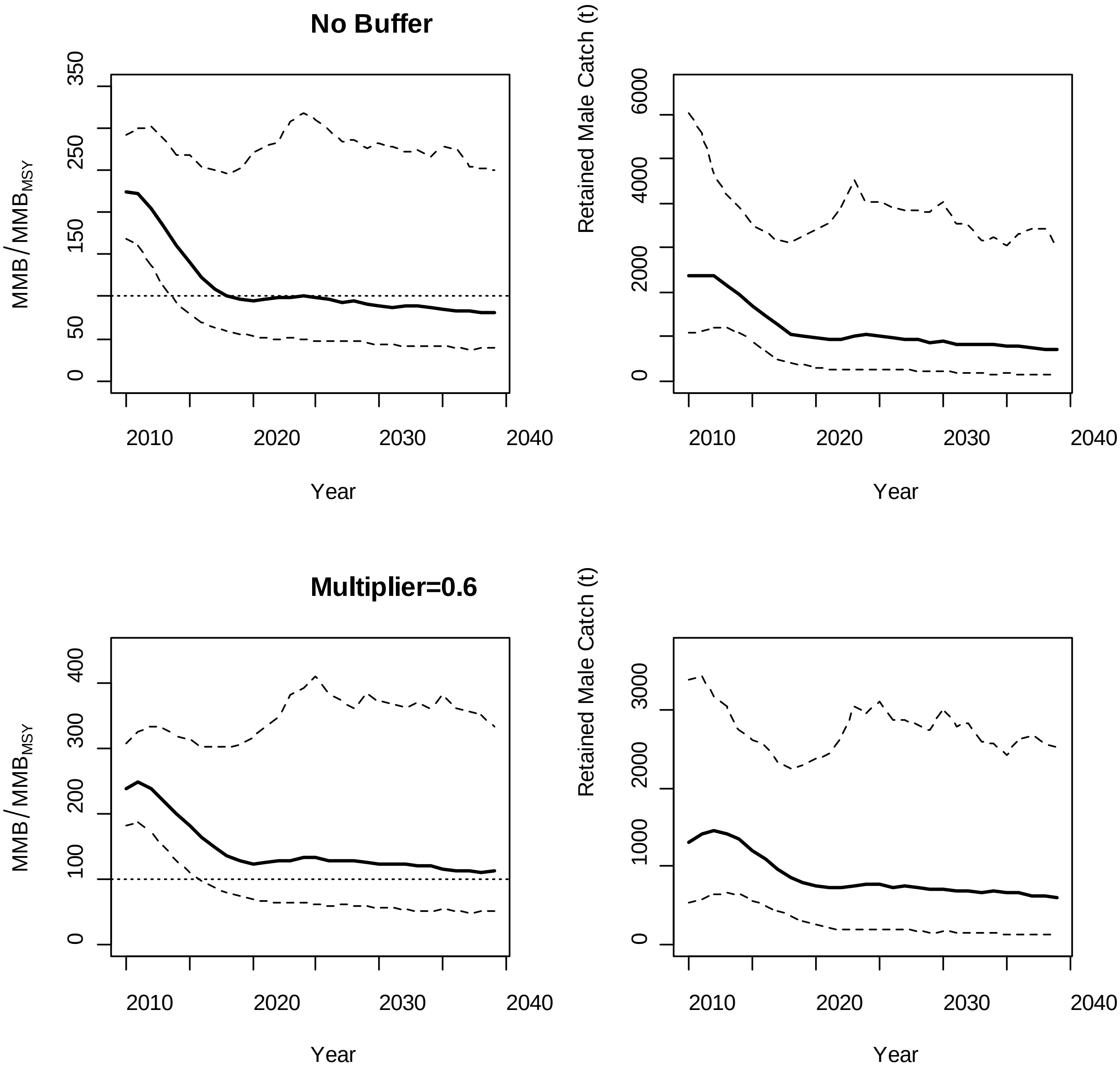


Figure 9-4 **Time-trajectories of mature male biomass at mating relative to the proxy for B_{MSY} and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the figure are based on σ_b=0.3 and on applying the SOA control rule.**

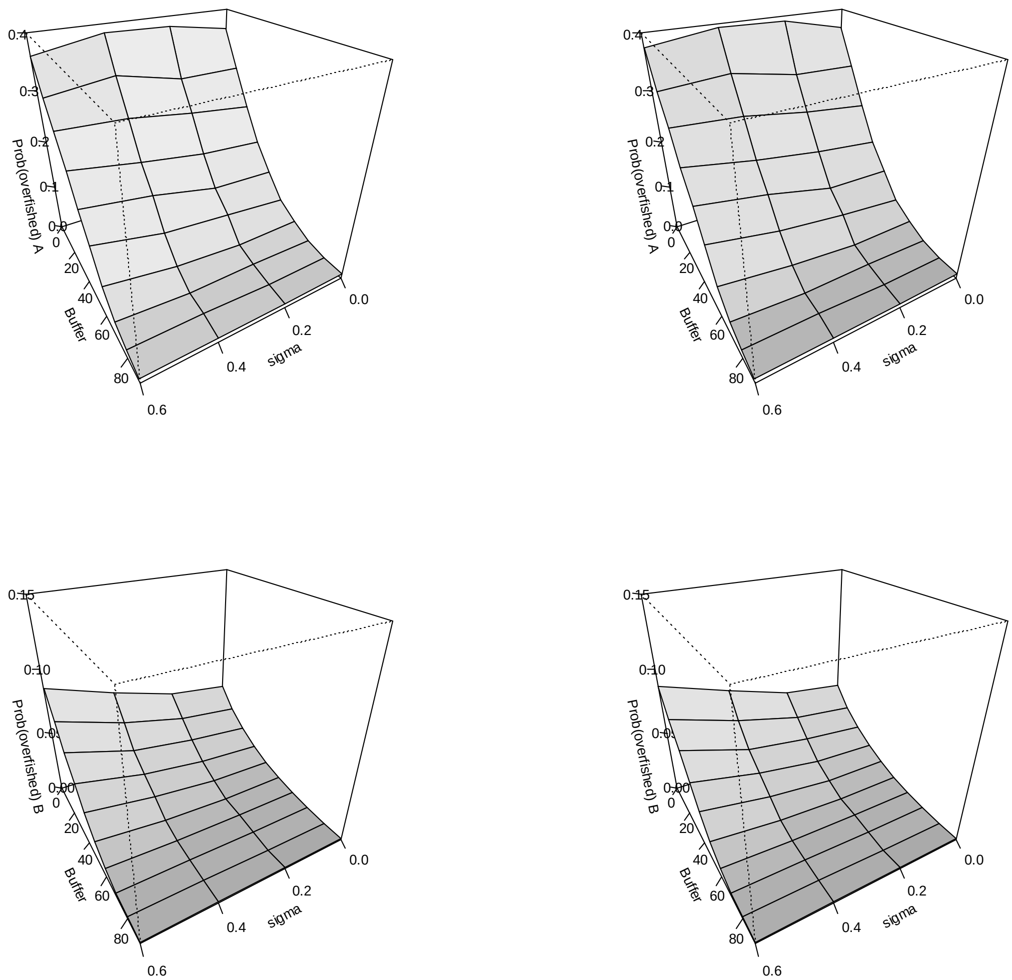


Figure 9-5 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for SMBKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

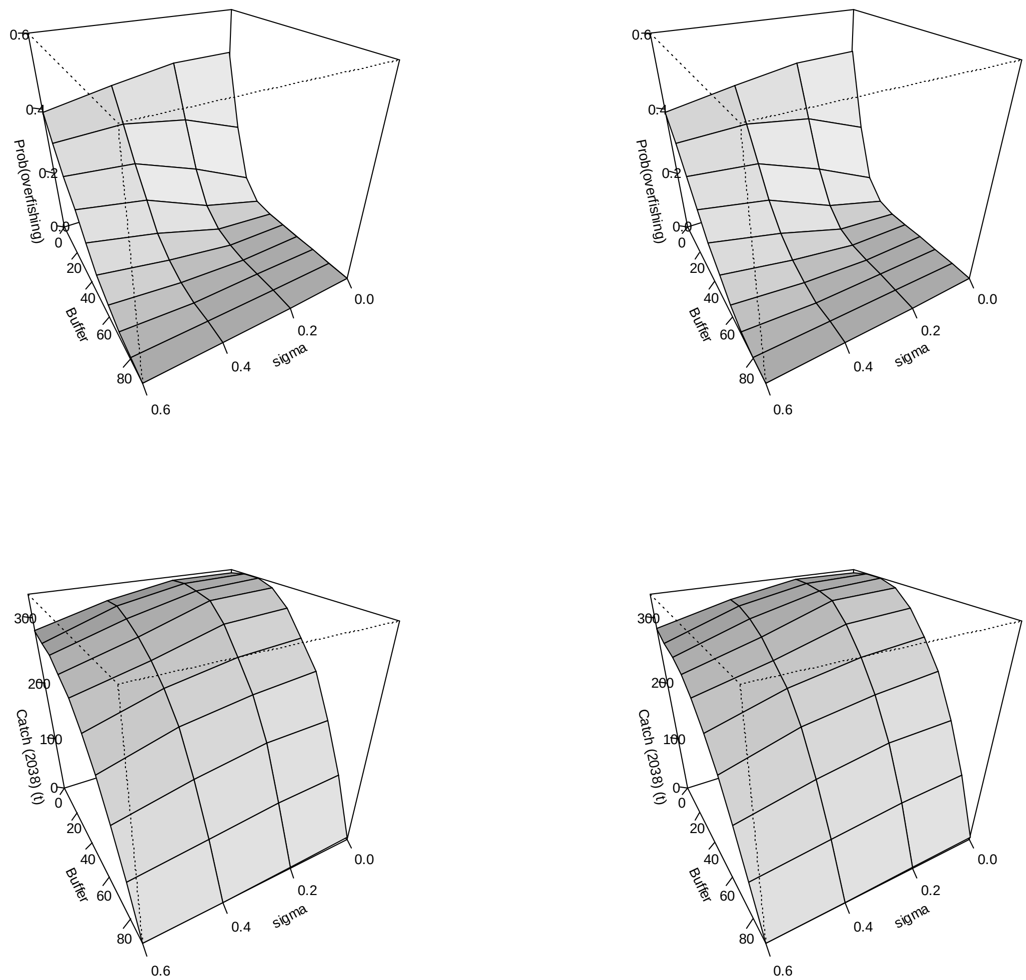


Figure 9-6 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for SMBKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

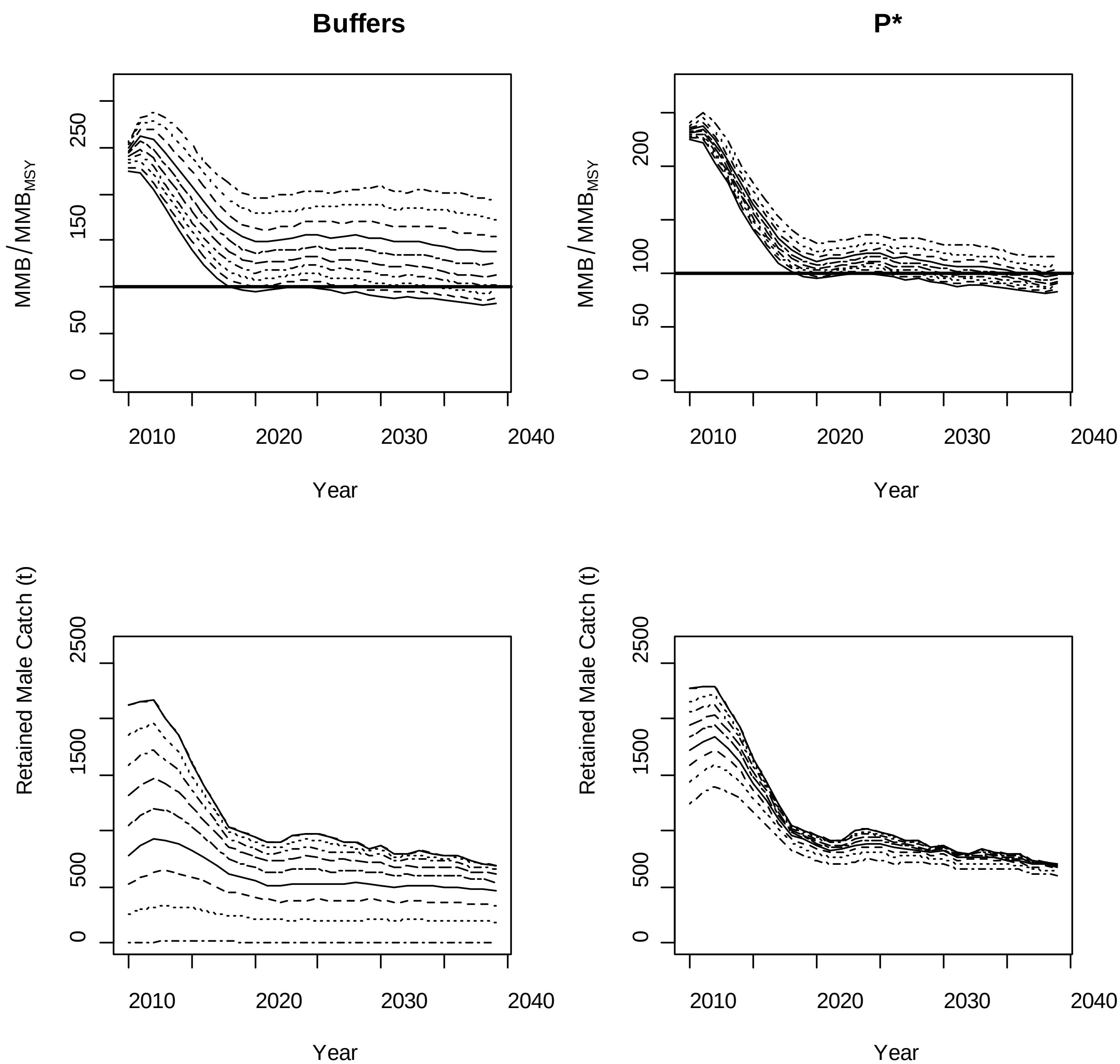


Figure 9-7 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.3 and imposing the SOA control rule.**

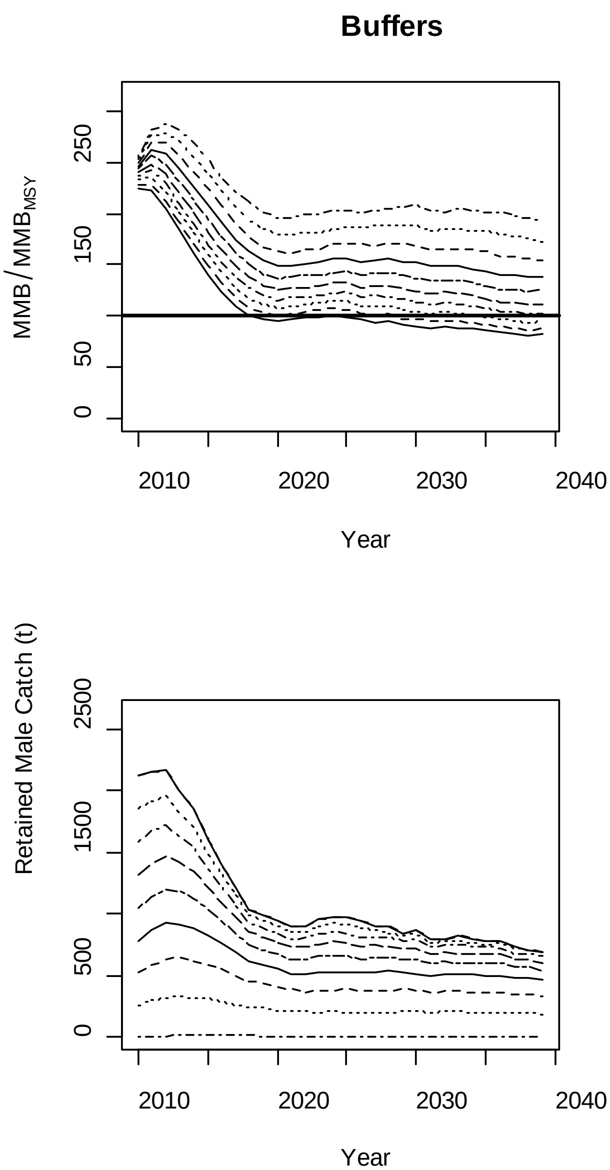


Figure 9-8 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.3 and not imposing the SOA control rule.**

10 Norton Sound Red King Crab

The Norton Sound red king crab (NSRKC) management area consists of two units: Norton Sound Section (Q3) and Kotzebue Section (Q4) (Soong et al., *in prep*). The Norton Sound Section (Q3) consists of all waters in Registration Area Q north of the latitude of Cape Romanzof, east of the International Dateline, and south of 66°N latitude. The Kotzebue Section (Q4) lies immediately north of the Norton Sound Section and includes Kotzebue Sound. Commercial fisheries have not occurred regularly in the Kotzebue Section.

10.1 Assessment overview

The NSRKC stock biomass is above its estimated $B_{MSYproxy}$ (3.07 million lbs of mature male biomass, at the time of mating) with model-estimated mature male biomass at mating estimated at 5.38 million lbs in 2009 (Zheng et al. 2009; Figure 10-1). Recent above-average year classes have largely recruited into the fished population with no evidence of new strong recruitment for the past three years.

The most recent assessment of NSRKC (Zheng et al. 2009) is based on a length-based stock assessment model using fishery and survey data. Fishery-dependent data are available for the three fisheries (summer, winter and subsistence). Fishery-independent data are available from four surveys: summer trawl, summer pot, winter pot, and a preseason pot survey. Surveys are conducted periodically with no survey being conducted on an annual basis. No observer program-based bycatch or discard data are available for the fisheries. A length-based stock model was originally developed to estimate annual stock abundance for the period 1976-2007 (Zheng et al. 1998). Summer commercial fishery data are available from 1977. The current (2009) stock assessment was updated using data from the 2008 fall trawl survey, the 2008 winter pot survey, and the 2008 summer commercial fishery. The 2008/09 retained fishery catch data used in the current assessment analysis are incomplete. No directed fishery discard losses, or stock losses resulting from non-directed fishery bycatch were included in this 2009 assessment.

The OFL for NSRKC is currently based on the Tier 4 control rule, i.e. the proxy for F_{MSY} is taken to be M=0.18yr^{-1} while the proxy for B_{MSY} is taken to be the average biomass during 1983-2009 (NPFMC, 2008). The OFL is a retained-catch OFL.

10.1.1 Uncertainty in stock assessment

The uncertainty associated with the estimation of the NSRKC stock assessment is relatively high. There are several other reasons why the measures of uncertainty reported as part of the stock assessment (a coefficient of variation of 0.11 for the estimate of mature male biomass for the most recent year) may underestimate the true uncertainty:

- Several of the key parameters of the model (survey catchability for mature males and natural mortality) are pre-specified rather than being estimated.
- F_{msy} is assumed to be equal to M when applying the OFL control rule.
- The selection of 1983-2009 as the basis for B_{MSY} is clearly subject to considerable uncertainty because harvest rates changed substantially during this period.
- The periodic / triennial nature of the survey (as opposed to an annual survey) is an additional source of uncertainty.
- No bycatch was estimated for the directed fishery due to lack of observer data.

For NSRKC, additional uncertainty is thought to be high, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.4 to quantify this level of additional uncertainty, which is the value recommended by the SSC. The analysis of the short-term implications includes results for a σ_b of 0, 0.2, 0.3, and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.4. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

10.2 Impacts of alternatives

As described in Chapter 2, there are two alternatives under consideration for computing an ABC for NSRKC: (a) the OFL can be multiplied by a pre-specified “multiplier” (Alternative 2), and (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternative 3 and Alternative 4). As noted in Chapter 3, two scenarios are considered related to the SOA control rule: (a) the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule, and (b) the ACL equals the ABC (i.e. the SOA control rule is ignored).

The short-, medium- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the buffer value (shown as the result of application of a multiplier to the OFL) and P* on the ABC which would have been advised for the 2009 fishery (assuming that ABCs had been specified for that fishery) while the medium- and long-term implications are evaluated by projecting the population ahead 30 years. The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2009-2014) while the long-term implications consider the implications of the entire 30-year projection period.

10.2.1 Short-term implications

The short-term implications focus on the size of the ABC for the 2009 fishing year. Given a one-year projection, it is not feasible to assess the biological implications of the choice of an alternative. These implications are addressed in Section 10.2.2.1 and 10.2.2.2.

Table 10-1 lists the ABC values for the 2009 fishing year for each of the alternatives, along with the corresponding estimate of the catch in the summer fishery. The table header indicates the TAC calculated using the SOA control rule. The difference between ABC_{tot} and ABC_{sum} reflects the catches in addition to those in the directed (summer) fishery (see Table 10-2 for the breakdown of the OFL to each source of removals). The gross revenue from the directed fishery associated with each of the alternatives is also shown.

As expected, a larger buffer (lower multiplier) leads to lower ABC levels and a lower probability that the ABC is less than the true (but unknown) OFL. For NSRKC, the TAC under the SOA control rule is 133t, which is lower than the catch in the summer fishery for a buffer between 0 and 40% (multipliers of 0.6 – 1) so in these cases the ABC would not constrain the fishery if TACs continue to be based on the SOA control rule. In contrast, the summer fishery component of the ABC is less than the output of the SOA control rule for buffer values of 50% or greater (multipliers of 0.5 or less). If a buffer of 50% or greater was selected, the ABC would constrain the SOA control rule. Therefore, Alternative 4 and the buffer values less that 50% would have impacts indistinguishable from status quo.

There is a linear relationship between the ABC and the buffer (Table 10-1a, Figure 10-2a) with the ABC set equal to the OFL when there is no buffer, and being 10% of the ABC for a buffer of 90% (a multiplier of 0.1). The relationship between the buffer and P* is, however, not simple linear proportionality (Table 10-1b-e, Figure 10-2b). Moreover, the impact of the (assumed) extent of additional uncertainty is substantial given that the variability of the OFL estimated from the assessment is relatively low (Figure 10-3a). Specifically, the buffers get larger (and the ABC for 2009 gets smaller) for the same value for P* as the value for σ_b is increased. For example, the buffer for a P* of 0.2 (20% probability that the ABC will exceed the true OFL) is 15% if there is no uncertainty that is not captured by the stock assessment, but is 28%, 44% and 60% if σ_b is 0.2, 0.4 or 0.6 (Table 10-1b-e, Figure 10-2b). The relationship between P* and the buffer (as indicated by the result of multiplying the OFL by the multiplier) based on the OFL calculated for 2009 is given in the "P* (additional uncertainty)" column of Table 10-1 (a).

As of this analysis, final wholesale price data for Alaska crab are available only through 2008. Estimated revenue under alternative multiplier- and σ_b-levels presented in Table 10-1 use the 2009/10 forecast price from the red king crab price model (see Chapter 3). In the single-year short term results, the incremental change in revenues associated with a 0.1 increment in the multiplier is approximately $360 thousand (Table 10-1 (a)), or approximately 10% of baseline revenue. For the P* alternative, at σ=0.4, each 0.1 incremental decrease in P* is associated with an increasing marginal decline in gross revenues, with the change from 0.5 to 0.4 producing a $430 thousand (14%) decrease in gross revenues relative to the baseline alternative, and the nearly linear marginal revenue decline with additional increments increment in P* from 0.4 to 0.1. This corresponds to the linear relationship between the ABC and the multiplier, and nonlinear relationship between the multiplier and P* depicted in **Figure 10-2**, noting that the relationship between the multiplier and P* is nearly linear for the σ=0.3 curve.

10.2.2 Medium- and long-term implications

Table 10-3 lists summaries of the posterior distributions for the key parameters which determine the productivity of the population. The extent of uncertainty captured within the stock assessment, σ_w, is 0.111.

10.2.2.1 Medium-term implications – Biological

The medium-term implications of the alternatives are summarized by the projected values for the ABC (which includes catches by the summer, winter and subsistence fisheries), "ABC_{tot}", the summer fishery component of ABC_{tot}, "ABC_{sum}", the output of the SOA control rule (which pertains to catches by the summer fishery), "SOA", the catch by summer fishery, "C_{sum}", the ratio of the mature male biomass at the time of mating to that the mature male biomass at which MSY is achieved, "MMB/B_{MSY}", and the probability of overfishing occurring. Results are shown in

Table 10-3 for analyses based on the level additional uncertainty of 0.4, and for four multiplier levels (1, 0.8, 0.6 and 0.4) and choices for P* (0.4, 0.3, 0.2 and 0.1). The multiplier levels correspond to buffer values of 0, 20%, 40%, and 60% respectively.

As expected from Table 10-1, the catch in the summer fishery is essentially equal to the output from the SOA control rule when there is no buffer between the OFL and the ABC and for buffers up to 60% (Table 10-4a-d) and values for P* as low as 0.1 (Table 10-4i-l). The median catch under SOA control rule does not match the point estimate in Table 10-1 owing to uncertainty. The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) depends on the size of the buffer and P* if the SOA control rule is not applied. However, P* and buffer have only a small impact on the probability of overfishing when the SOA control rule is imposed because the ABC is generally larger than output from the SOA control rule. If the SOA control rule is not applied, larger buffers and smaller values for P* lead to lower annual catches. For example, the total ABC in 2010 drops from 274t to 116t as the buffer is increased from 0 to 60% Table 10-4a-d) while this ABC drops 274t to 131t as P* is reduced from 1 to 0.1

The mature male biomass at the time of mating is predicted to be relatively stable and above B_{MSY} in all cases for the next 6 years (Table 10-4).

10.2.2.2 Long-term implications - Biological

Table 10-5 summarizes the results of the long-term projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"), (b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B"), (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of TAC being computed by the output from the SOA control rule (column "Prob (SOA)"), (e) the mean and 90% intervals for the catch by the summer fishery in the last year of the projection period. Results are shown in Table 6-5 for projections which account for and ignore the SOA control rule.

Figure 10-4 shows the time-trajectories of catch and mature male biomass at mating relative to the proxy for B_{MSY} for two illustrative choices for the buffer (0; ABC=OFL; 40%; the ABC is 60% of the OFL). As expected, the mature male biomass is larger when the buffer is larger (multiplier is lower). The mature male biomass drops over time because the current mature male biomass is substantially larger than B_{MSY} at present and setting the ABC to the OFL (without a buffer) would be expected to drive the stock back (down) to B_{MSY}. The recruitment during the recent years was also relatively high and was higher than the predicted future recruitment.

Figure 10-5 and Figure 10-6 evaluate the implications of different buffer values between the ABC and the OFL in terms of metrics (a), (b), (c) and (e) in Table 10-5, except that results are shown for all four values of the extent of additional uncertainty instead of only the value recommended by the CPT. Applying the SOA control rule has a major impact on all of the outputs. Specifically, the probability of overfishing and being overfishing are virtually zero for all buffers and values for the extent of additional uncertainty when the SOA control rule is applied (although these probabilities are highest for an additional CV of 0.6). In contrast, if the SOA control rule is ignored, smaller buffers lead to higher probabilities of being overfished at least once during the projection period and of overfishing occurring, while a higher level of additional uncertainty increases the annual probability of the stock being overfished (Figure 10-5 and Figure 10-6 right panels). The expected catch in the summer fishery in 2038 is highest for the lowest level of additional uncertainty and the smallest buffer when the SOA control rule is ignored while the expected catch in the summer fishery in 2038 is largely independent of the buffer and the additional uncertainty if the SOA control rule is applied (Figure 10-6, lower panels).

Figure 10-7 and Figure 10-8 illustrate the differences among the 10 buffers in terms of the median time-trajectory of mature male biomass at mating relative to B_{MSY} proxy and the median time-trajectory of the catch in the summer fishery. The ratio of mature male biomass to B_{MSY} proxy increases essentially continuously with changes in the buffer when the SOA control rule is ignored (Figure 10-6) while this is not as evident when the SOA control rule is applied (Figure 10-5). The opposite effects are evident for the catch in the summer fishery but the magnitude of the effect is lower.

10.2.2.3 Medium- and long-term implications - Economic

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference on the evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30- year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

Revenue forecasts are based on probabilistic price forecasts for Alaskan red king crab using the time-series vector autoregression model detailed in Chapter 3. The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume using the average product recovery rate for Alaska red king crab (0.64%). Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

The medium and long-term impacts of ACL alternatives are summarized in Table 6-6 and **Table** 6-7. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term. Table 6-6 (a) and (b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to 1) multiplier=1.0 and no additional uncertainty (σ=0), and 2) multiplier=1.0, but holding the value of σ constant across compared alternatives.

Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC (Table 6-6 (a)) and scenarios without the SOA control rule (Table 6-6 (b)). Under the SOA control rule, the ABC would not be binding at higher multiplier levels, with only the multiplier=0.4 option resulting in a lower directed catch level than that produced by the SOA control rule. The median estimate of all foregone revenue over the 2009-2014 period ranges from 7% to 32% potential reduction in gross revenues from the fishery. At the recommended level of additional uncertainty for Tier 4 stocks (σ= 0.4), the estimate of total potential foregone revenues for this multiplier level is approximately $600 thousand, or 5% of baseline revenue, discounted at 2.7%. No P* scenarios produced more limited catch levels than the SOA control rule.

Results of economic comparisons between ACL alternatives resulting from catch projections without SOA constraints are shown in Table 6-6 (b). The SOA control rule remains in effect as the protocol for TAC-setting, however, the potential foregone revenues that could result from the ACL alternatives would increase substantially relative to a baseline scenario of multiplier=1, with the ABC as the binding constraint on TAC rather than the SOA control rule. Note that this “baseline” does not represent the status quo alternative, but is intended to provide a representation of the effects of ACL alternatives under potential future decision-making scenarios where the SOA control rule is no longer binding. It should be noted that this comparison does not indicate that costs of ACL’s would be higher in the event that the SOA rule was not applied, rather that the SOA rule effectively represents a buffer in itself, and results in foregone catch and revenues relative to the least conservative ACL alternatives under consideration. Exclusive of the SOA outcomes, the percentage change in estimated revenues ranges from a 16% reduction at the 0.8 multiplier level at σ=0.0, to 54% reduction at the 0.4 multiplier level at σ=0.4. Holding σ=0.6, percentage reductions in revenue range from 17 to 54 percent, corresponding to multipliers of 0.8 to 0.4.

Economic results of ACL alternatives over the long term (2009-2038) are represented in **Table** 6-7. As in the mid-term results ACL options analyzed do not produce lower catch levels than the SOA control rule for multiplier levels large than 0.4. Exclusive of the SOA control rule, the range of potential foregone revenues relative to a zero buffer (multiplier = 1) range from nearly $7 million (multiplier = .8 and σ= 0) to $33 million (multiplier = 0.4 and σ= 0.6). At the recommended level of additional uncertainty for Tier 4 stocks (σ= 0.4), the estimate of potential foregone revenues for the 30-year period ranges from zero to 45% reduction from baseline revenue.

It should be noted that the relative economic effects of the ACLs are not qualitatively different between the mid- and long-term, nor do alternative discount rates appreciably change the relative ranking of alternatives in terms of economic outcomes. This is largely due to the effect of the constancy of the buffer in the model projections, in both the buffer and P* scenarios. With fixed buffers, which are not responsive to changes in the stock status, there is little change in the timing of harvest over the period of analysis. That is, none of the alternatives under consideration implement different buffers over time according to stock conditions, and thus the timing of relative economic benefits from the fishery across the time horizon are not appreciably different under the alternatives analyzed.

10.3 Tables and Figures

Table 10-1 Values for catch-related quantities for NSRKC for 2009 for each of the alternatives. The column P* in Table 10-1a shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The SSC recommended additional uncertainty is shaded. The TAC under the SOA control rule is 133 t. Revenues reported are median and 90% confidence intervals for estimated gross revenue, using price forecast model results.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	P * (additional uncertainty					Revenue	
			None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	270	253	0.56	0.55	0.56	0.57	0.61	3.59	0
Multiplier = 0.9	243	228	0.21	0.37	0.43	0.48	0.54	3.23	10
Multiplier = 0.8	216	203	0.03	0.20	0.29	0.37	0.47	2.87	20.1
Multiplier = 0.7	189	177	0.00	0.07	0.17	0.25	0.37	2.51	30.1
Multiplier = 0.6	162	152	0.00	0.01	0.07	0.15	0.30	2.15	40.1
Multiplier = 0.5	135	127	0.00	0.00	0.02	0.06	0.18	1.79	50.1
Multiplier = 0.4	108	101	0.00	0.00	0.00	0.02	0.10	1.43	60.2
Multiplier = 0.3	81	76	0.00	0.00	0.00	0.00	0.04	1.07	70.2
Multiplier = 0.2	54	51	0.00	0.00	0.00	0.00	0.01	0.71	80.2
Multiplier = 0.1	27	25	0.00	0.00	0.00	0.00	0.00	0.36	90

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot} (t)	ABC_{sum} (t)	Multiplier
$P^* = 0.5$	270[&]	253	1
$P^* = 0.4$	258	241	0.95
$P^* = 0.3$	252	236	0.93
$P^* = 0.2$	243	228	0.90
$P^* = 0.1$	230	214	0.85

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot} (t)	ABC_{sum} (t)	Multiplier
$P^* = 0.5$	270[&]	253	1
$P^* = 0.4$	248	233	0.92
$P^* = 0.3$	233	218	0.86
$P^* = 0.2$	217	203	0.80
$P^* = 0.1$	196	183	0.72

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot} (t)	ABC_{sum} (t)	Multiplier
$P^* = 0.5$	270&	253	1
$P^* = 0.4$	236	221	0.87
$P^* = 0.3$	218	204	0.81
$P^* = 0.2$	198	185	0.73
$P^* = 0.1$	171	161	0.63

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot} (t)	ABC_{sum} (t)	Multiplier	Revenue	
				Millions $	% Change
$P^* = 0.5$	270[&]	253	1	3.37	0
$P^* = 0.4$	227	212	0.84	3.03	0
$P^* = 0.3$	201	188	0.74	2.71	0
$P^* = 0.2$	178	167	0.66	2.37	33
$P^* = 0.1$	151	142	0.56	1.97	33

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot} (t)	ABC_{sum} (t)	Multiplier	Revenue
$P^* = 0.5$	270&	253	1	2.996
$P^* = 0.4$	195	183	0.72	2.565
$P^* = 0.3$	163	153	0.60	2.174
$P^* = 0.2$	140	131	0.52	1.788
$P^* = 0.1$	107	100	0.40	1.365

& - set to the point estimate

Table 10-2 Breakdown of the 2009 OFL for NSRKC among the sources of mortality included in the OFL.

Component	Catch (t)
Summer fishery	253
Winter fishery	6
Subsistence fishery	11
Total	270

Table 10-3 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes.

Parameter	Distribution
Virgin MMB	3517 (3216 3826)
Steepness, h	0.416 (0.411, 0.422)
F_{MSY} (M)	0.18
B_{MSY}	1363 (1249, 1479)
σ_R	1.217 (0.916, 1.764)

Table 10-4 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P* = 0.4, 0.3, 0.2, 0.1) for NSRKC. The point estimates are medians and the intervals 90% intervals. The results in the table are based on σ_b=0.4.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	247 (122- 496)	247 (122- 496)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	315 (163- 613)	315 (163- 613)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	340 (181- 643)	340 (181- 643)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	333 (184- 605)	333 (184- 605)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	321 (178- 560)	321 (178- 560)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	301 (172- 545)	301 (172- 545)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	198 (98- 397)	198 (98- 397)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	252 (130- 490)	252 (130- 490)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	272 (145- 515)	272 (145- 515)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	267 (147- 484)	267 (147- 484)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	257 (143- 448)	257 (143- 448)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	241 (138- 436)	241 (138- 436)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	148 (73- 297)	148 (73- 297)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	189 (98- 368)	189 (98- 368)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	204 (109- 386)	204 (109- 386)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	200 (111- 363)	200 (111- 363)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	192 (107- 336)	192 (107- 336)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	181 (103- 327)	181 (103- 327)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	99 (49- 198)	99 (49- 198)	121 (0- 244)	92 (0- 186)	205 (175- 237)	0.010
2010	126 (65- 249)	126 (65- 249)	151 (38- 305)	120 (36- 236)	235 (198- 277)	0.010
2011	138 (72- 264)	138 (72- 264)	144 (37- 279)	132 (36- 254)	234 (195- 282)	0.014
2012	135 (74- 251)	135 (74- 251)	128 (34- 253)	122 (33- 236)	221 (177- 296)	0.007
2013	130 (71- 229)	130 (71- 229)	115 (0- 233)	110 (0- 213)	210 (161- 308)	0.006
2014	121 (69- 222)	121 (69- 222)	53 (0- 223)	51 (0- 206)	198 (146- 314)	0.005

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	247 (122- 496)	247 (122- 496)	121 (0- 244)	231 (114- 466)	205 (175- 237)	0.427
2010	298 (156- 564)	298 (156- 564)	144 (37- 283)	283 (148- 536)	223 (187- 265)	0.421
2011	307 (166- 535)	307 (166- 535)	132 (35- 238)	294 (159- 514)	210 (167- 259)	0.421
2012	284 (164- 465)	284 (164- 465)	56 (0- 198)	273 (156- 447)	190 (138- 262)	0.435
2013	251 (150- 415)	251 (150- 415)	46 (0- 186)	242 (143- 395)	170 (114- 268)	0.430
2014	219 (134- 402)	219 (134- 402)	41 (0- 172)	210 (129- 383)	153 (93- 263)	0.434

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	198 (98- 397)	198 (98- 397)	121 (0- 244)	185 (91- 373)	205 (175- 237)	0.237
2010	242 (126- 465)	242 (126- 465)	146 (37- 289)	231 (120- 444)	227 (190- 269)	0.248
2011	255 (136- 459)	255 (136- 459)	136 (36- 249)	244 (129- 441)	217 (177- 265)	0.228
2012	242 (135- 410)	242 (135- 410)	117 (0- 211)	231 (129- 393)	198 (149- 272)	0.241
2013	218 (125- 363)	218 (125- 363)	50 (0- 199)	210 (120- 346)	182 (128- 278)	0.229
2014	194 (116- 357)	194 (116- 357)	44 (0- 187)	187 (112- 340)	165 (109- 278)	0.240

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	148 (73- 297)	148 (73- 297)	121 (0- 244)	139 (68- 279)	205 (175- 237)	0.072
2010	185 (96- 362)	185 (96- 362)	148 (37- 296)	176 (91- 344)	230 (193- 273)	0.077
2011	199 (104- 369)	199 (104- 369)	140 (36- 264)	190 (99- 356)	224 (185- 272)	0.086
2012	192 (105- 338)	192 (105- 338)	122 (0- 230)	184 (100- 325)	208 (163- 282)	0.077
2013	178 (98- 309)	178 (98- 309)	53 (0- 215)	172 (94- 297)	193 (143- 291)	0.080
2014	162 (92- 292)	162 (92- 292)	48 (0- 205)	157 (89- 279)	177 (124- 296)	0.081

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB $/B_{MSY}$	Prob (overfishing)
2009	99 (49- 198)	99 (49- 198)	121 (0- 244)	92 (46- 186)	205 (175- 237)	0.010
2010	126 (65- 249)	126 (65- 249)	150 (38- 305)	119 (61- 236)	235 (197- 276)	0.010
2011	138 (70- 264)	138 (70- 264)	144 (37- 279)	132 (67- 254)	232 (194- 280)	0.014
2012	135 (71- 251)	135 (71- 251)	128 (0- 253)	129 (68- 240)	219 (176- 294)	0.014
2013	128 (68- 229)	128 (68- 229)	114 (0- 233)	123 (65- 221)	206 (159- 300)	0.011
2014	118 (65- 222)	118 (65- 222)	52 (0- 222)	114 (63- 214)	192 (142- 308)	0.007

(i) P*=0.4; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB /B_{MSY}	Prob (overfishing)
2009	222 (110- 446)	222 (110- 446)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	283 (147- 552)	283 (147- 552)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	306 (163- 579)	306 (163- 579)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	300 (166- 544)	300 (166- 544)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	289 (161- 504)	289 (161- 504)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	271 (155- 490)	271 (155- 490)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(j) P*=0.3; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB /B_{MSY}	Prob (overfishing)
2009	199 (98- 399)	199 (98- 399)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	253 (131- 493)	253 (131- 493)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	274 (145- 517)	274 (145- 517)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	268 (148- 486)	268 (148- 486)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	258 (143- 450)	258 (143- 450)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	242 (138- 438)	242 (138- 438)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(k) P*=0.2; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB /B_{MSY}	Prob (overfishing)
2009	174 (86- 349)	174 (86- 349)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	222 (115- 432)	222 (115- 432)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	240 (128- 454)	240 (128- 454)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	235 (130- 426)	235 (130- 426)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	226 (126- 394)	226 (126- 394)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	212 (121- 384)	212 (121- 384)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(l) P*=0.1; Impose SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} (‘t)	MMB /B_{MSY}	Prob (overfishing)
2009	145 (72- 291)	145 (72- 291)	121 (0- 244)	113 (0- 228)	205 (175- 237)	0.029
2010	185 (96- 360)	185 (96- 360)	150 (38- 302)	142 (36- 288)	234 (197- 275)	0.034
2011	200 (106- 378)	200 (106- 378)	143 (37- 273)	137 (36- 264)	231 (192- 278)	0.018
2012	196 (108- 355)	196 (108- 355)	127 (34- 245)	122 (33- 235)	219 (174- 292)	0.009
2013	188 (105- 328)	188 (105- 328)	114 (0- 229)	109 (0- 219)	208 (158- 304)	0.011
2014	177 (101- 320)	177 (101- 320)	53 (0- 219)	51 (0- 210)	196 (143- 309)	0.006

(m) P*=0.4; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} ('t)	MMB /B_{MSY}	Prob (overfishing)
2009	222 (110- 446)	222 (110- 446)	121 (0- 244)	208 (103- 419)	205 (175- 237)	0.328
2010	271 (141- 515)	271 (141- 515)	145 (37- 286)	257 (134- 491)	225 (188- 267)	0.328
2011	281 (151- 498)	281 (151- 498)	134 (36- 243)	269 (144- 480)	213 (172- 262)	0.314
2012	265 (149- 439)	265 (149- 439)	114 (0- 207)	253 (143- 422)	194 (144- 267)	0.330
2013	236 (138- 393)	236 (138- 393)	48 (0- 192)	227 (132- 374)	176 (121- 274)	0.329
2014	207 (126- 382)	207 (126- 382)	42 (0- 180)	199 (121- 362)	159 (101- 270)	0.336

(n) P*=0.3; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} ('t)	MMB /B_{MSY}	Prob (overfishing)
2009	199 (98- 399)	199 (98- 399)	121 (0- 244)	186 (92- 374)	205 (175- 237)	0.244
2010	243 (127- 467)	243 (127- 467)	146 (37- 288)	232 (120- 446)	227 (190- 269)	0.254
2011	256 (136- 460)	256 (136- 460)	136 (36- 248)	245 (130- 442)	217 (177- 265)	0.229
2012	243 (135- 411)	243 (135- 411)	117 (0- 211)	232 (129- 395)	198 (149- 272)	0.244
2013	219 (125- 364)	219 (125- 364)	50 (0- 199)	211 (120- 347)	182 (128- 278)	0.231
2014	195 (117- 358)	195 (117- 358)	44 (0- 187)	188 (112- 341)	165 (108- 277)	0.246

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} ('t)	MMB /B_{MSY}	Prob (overfishing)
2009	174 (86- 349)	174 (86- 349)	121 (0- 244)	163 (80- 328)	205 (175- 237)	0.149
2010	215 (112- 418)	215 (112- 418)	147 (37- 291)	205 (106- 397)	229 (191- 271)	0.144
2011	229 (121- 418)	229 (121- 418)	138 (36- 255)	219 (115- 402)	220 (181- 268)	0.150
2012	219 (121- 379)	219 (121- 379)	119 (0- 219)	209 (115- 364)	203 (156- 276)	0.158
2013	200 (112- 343)	200 (112- 343)	51 (0- 206)	193 (108- 326)	187 (136- 283)	0.141
2014	180 (105- 326)	180 (105- 326)	46 (0- 195)	174 (101- 314)	170 (115- 286)	0.161

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} (t)	ABC_{sum} (t)	SOA (t)	C_{sum} ('t)	MMB /B_{MSY}	Prob (overfishing)
2009	145 (72- 291)	145 (72- 291)	121 (0- 244)	136 (67- 273)	205 (175- 237)	0.065
2010	181 (94- 355)	181 (94- 355)	148 (37- 297)	172 (89- 337)	231 (194- 273)	0.065
2011	195 (102- 363)	195 (102- 363)	140 (36- 265)	187 (97- 350)	225 (186- 273)	0.077
2012	188 (102- 333)	188 (102- 333)	123 (0- 231)	180 (98- 320)	209 (164- 283)	0.071
2013	175 (96- 305)	175 (96- 305)	54 (0- 216)	169 (92- 293)	194 (144- 291)	0.074
2014	159 (91- 288)	159 (91- 288)	48 (0- 205)	154 (87- 275)	178 (125- 296)	0.074

Table 10-5 Summary of the long-term consequences of the alternatives for NSRKC. The column “Summer catch” lists the posterior mean and 90% intervals for the catch of legal males in the summer fishery in 2038. The results in the table are based on σ_b=0.4.

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Summer catch (t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Summer catch (t)
Multiplier = 1		0.001	0.000	0.014	1.000	42 (0- 212)	0.128	0.014	0.432	110 (39- 303)
Multiplier = 0.9		0.001	0.000	0.014	1.000	42 (0- 212)	0.084	0.009	0.335	108 (39- 300)
Multiplier = 0.8		0.001	0.000	0.014	1.000	42 (0- 212)	0.055	0.005	0.236	107 (38- 292)
Multiplier = 0.7		0.001	0.000	0.014	1.000	42 (0- 212)	0.033	0.003	0.147	102 (38- 271)
Multiplier = 0.6		0.001	0.000	0.014	0.998	42 (0- 212)	0.020	0.002	0.078	97 (36- 251)
Multiplier = 0.5		0.001	0.000	0.014	0.977	42 (0- 209)	0.010	0.001	0.034	90 (34- 232)
Multiplier = 0.4		0.001	0.000	0.008	0.809	43 (0- 205)	0.005	0.000	0.010	80 (30- 202)
Multiplier = 0.3		0.001	0.000	0.001	0.595	43 (0- 167)	0.003	0.000	0.001	66 (25- 167)
Multiplier = 0.2		0.000	0.000	0.000	0.497	44 (0- 126)	0.000	0.000	0.000	48 (18- 125)
Multiplier = 0.1		0.000	0.000	0.000	0.190	27 (0- 72)	0.000	0.000	0.000	27 (10- 72)
P* = 0.5	1.0	0.001	0.000	0.014	1.000	42 (0- 212)	0.128	0.014	0.432	110 (39- 303)
P* = 0.45	0.949	0.001	0.000	0.014	1.000	42 (0- 212)	0.106	0.012	0.383	109 (39- 302)
P* = 0.4	0.900	0.001	0.000	0.014	1.000	42 (0- 212)	0.084	0.009	0.335	108 (39- 300)
P* = 0.35	0.852	0.001	0.000	0.014	1.000	42 (0- 212)	0.072	0.007	0.286	107 (38- 299)
P* = 0.3	0.804	0.001	0.000	0.014	1.000	42 (0- 212)	0.055	0.006	0.240	107 (38- 293)
P* = 0.25	0.756	0.001	0.000	0.014	1.000	42 (0- 212)	0.046	0.004	0.196	105 (38- 284)
P* = 0.2	0.705	0.001	0.000	0.014	1.000	42 (0- 212)	0.035	0.003	0.151	103 (38- 272)
P* = 0.15	0.650	0.001	0.000	0.014	1.000	42 (0- 212)	0.028	0.002	0.110	99 (37- 262)
P* = 0.1	0.587	0.001	0.000	0.014	0.998	42 (0- 212)	0.020	0.002	0.070	96 (36- 248)
P* = 0.05	0.505	0.001	0.000	0.014	0.981	42 (0- 211)	0.011	0.001	0.035	90 (34- 234)

Table 10-6 Summary of medium-term economic impacts of a subset of the ACL alternatives for NSRKC. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the six year period 2009-2014, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty σ. Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty (σ_b=0.4). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	11(5,20)	11(5,18)	10(5,17)	0	0
	Multiplier = 0.8	11(5,20)	11(5,18)	10(5,17)	0	0
	Multiplier = 0.6	11(5,20)	11(5,18)	10(5,17)	0	0
	Multiplier = 0.4	11(5,18)	10(5,17)	9(4,16)	7.1	0
0.4	Multiplier = 1	10(1,24)	9(1,22)	8(1,21)	15.58	0
	Multiplier = 0.8	10(1,24)	9(1,22)	8(1,21)	15.58	0
	Multiplier = 0.6	10(1,24)	9(1,22)	8(1,21)	15.58	0
	Multiplier = 0.4	9(1,22)	9(1,21)	8(1,19)	19.91	5.13
0.4	P* = 0.5	10(1,24)	9(1,22)	8(1,21)	15.58	0
	P* = 0.4	10(1,24)	9(1,22)	8(1,21)	15.58	0
	P* = 0.3	10(1,24)	9(1,22)	8(1,21)	15.58	0
	P* = 0.2	10(1,24)	9(1,22)	8(1,21)	15.58	0
	P* = 0.1	10(1,24)	9(1,22)	8(1,21)	15.58	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2014 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	27(13,42)	25(12,39)	23(11,36)	0	0
	Multiplier = 0.8	22(11,35)	21(10,33)	19(9,30)	16	0
	Multiplier = 0.6	18(8,28)	17(8,26)	15(7,24)	32	0
	Multiplier = 0.4	12(6,19)	12(5,18)	10(5,16)	52	0
0.4	Multiplier = 1	25(10,46)	24(9,44)	22(9,41)	4	0
	Multiplier = 0.8	21(8,41)	20(8,38)	18(7,35)	20	17
	Multiplier = 0.6	16(6,33)	15(6,30)	14(5,28)	40	38
	Multiplier = 0.4	11(4,23)	11(4,22)	10(4,19)	56	54
0.4	P* = 0.5	25(10,46)	24(9,44)	22(9,41)	4	0
	P* = 0.4	23(9,44)	22(9,41)	20(8,38)	12	8
	P* = 0.3	21(8,41)	20(8,38)	18(7,35)	20	17
	P* = 0.2	19(7,37)	18(7,35)	16(6,32)	28	25
	P* = 0.1	16(6,32)	15(6,30)	14(5,27)	40	38

Table 10-7 Summary of long-term economic impacts of the ACL alternatives for NSRKC. Economic impacts are estimated as discounted present value of forecasted gross first wholesale revenues over the 30-year period 2009-2038 (2008 dollars), and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty, σ. Alternatives include fixed buffers (multipliers of 1.0 to 0.4) and P* levels (0.5 to 0.1), for additional uncertainty σ_b = 0.4. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	36(10,79)	26(9,55)	18(7,35)	0	0
	Multiplier = 0.8	36(10,79)	26(9,55)	18(7,35)	0	0
	Multiplier = 0.6	36(10,79)	26(9,55)	18(7,35)	0	0
	Multiplier = 0.4	34(9,77)	25(8,53)	17(7,34)	3.75	0
0.4	Multiplier = 1	31(3,95)	22(3,67)	15(2,44)	13.63	0
	Multiplier = 0.8	31(3,95)	22(3,67)	15(2,44)	13.63	0
	Multiplier = 0.6	31(3,95)	22(3,67)	15(2,44)	13.63	0
	Multiplier = 0.4	30(3,91)	22(3,65)	15(2,42)	16.41	3.22
0.4	P* = 0.5	31(3,95)	22(3,67)	15(2,44)	13.63	0
	P* = 0.4	31(3,95)	22(3,67)	15(2,44)	13.63	0
	P* = 0.3	31(3,95)	22(3,67)	15(2,44)	13.63	0
	P* = 0.2	31(3,95)	22(3,67)	15(2,44)	13.63	0
	P* = 0.1	31(3,95)	22(3,67)	15(2,44)	13.63	0

(b) Results are exclusive of SOA control rule effect.

σ_b	Alternative	Present Value of Total Revenue, 2009-2038 ($ Million) r=0	r=2.7%	r=7.0%	Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives, Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.4**
0	Multiplier = 1	85(27,164)	63(22,117)	44(17,76)	0	0
	Multiplier = 0.8	76(24,147)	56(19,103)	38(14,66)	11.15	0
	Multiplier = 0.6	64(20,123)	46(15,86)	31(12,54)	26.03	0
	Multiplier = 0.4	48(15,91)	34(11,63)	23(8,39)	45	0
0.4	Multiplier = 1	79(25,160)	58(20,116)	41(15,79)	6.67	0
	Multiplier = 0.8	70(22,144)	52(17,104)	35(13,71)	17.73	11.85
	Multiplier = 0.6	59(18,124)	43(14,91)	29(10,59)	31.58	26.69
	Multiplier = 0.4	44(13,98)	32(10,71)	21(7,45)	48.6	44.93
0.4	P* = 0.5	79(25,160)	58(20,116)	41(15,79)	6.67	0
	P* = 0.4	75(23,153)	55(18,110)	38(14,75)	11.81	5.51
	P* = 0.3	70(22,145)	52(17,104)	36(13,71)	17.44	11.54
	P* = 0.2	65(20,135)	48(15,98)	32(11,65)	23.98	18.55
	P* = 0.1	58(17,123)	42(13,90)	28(10,58)	32.66	27.85

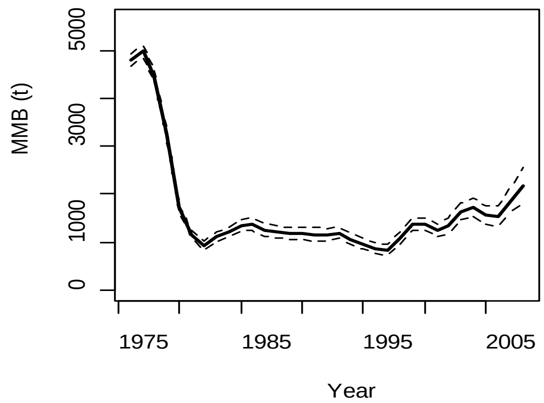


Figure 10-1 Time-trajectory of mature male biomass at the time of mating for NSRKC (t).

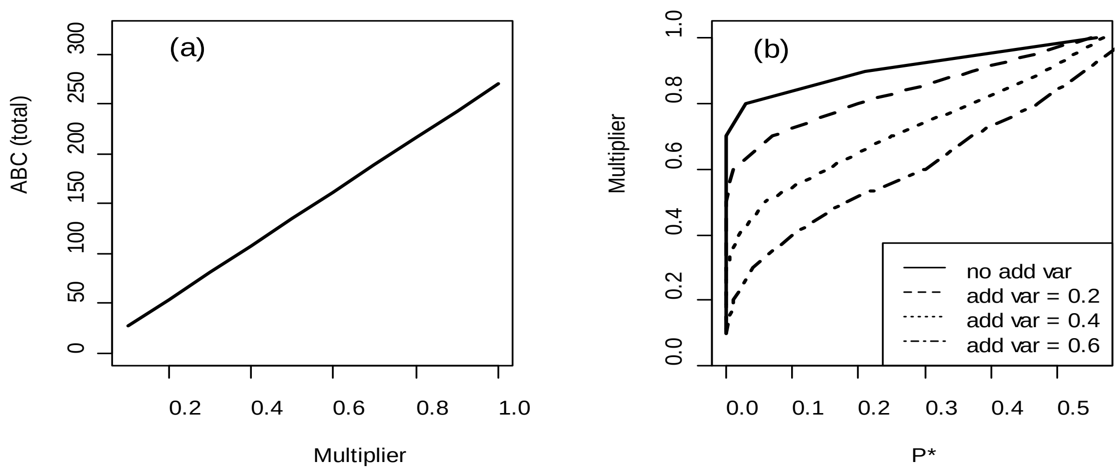


Figure 10-2 Relationship between the buffer and the ABC (a), and the relationships between P* and the buffer for four values for the extent of additional uncertainty (b).

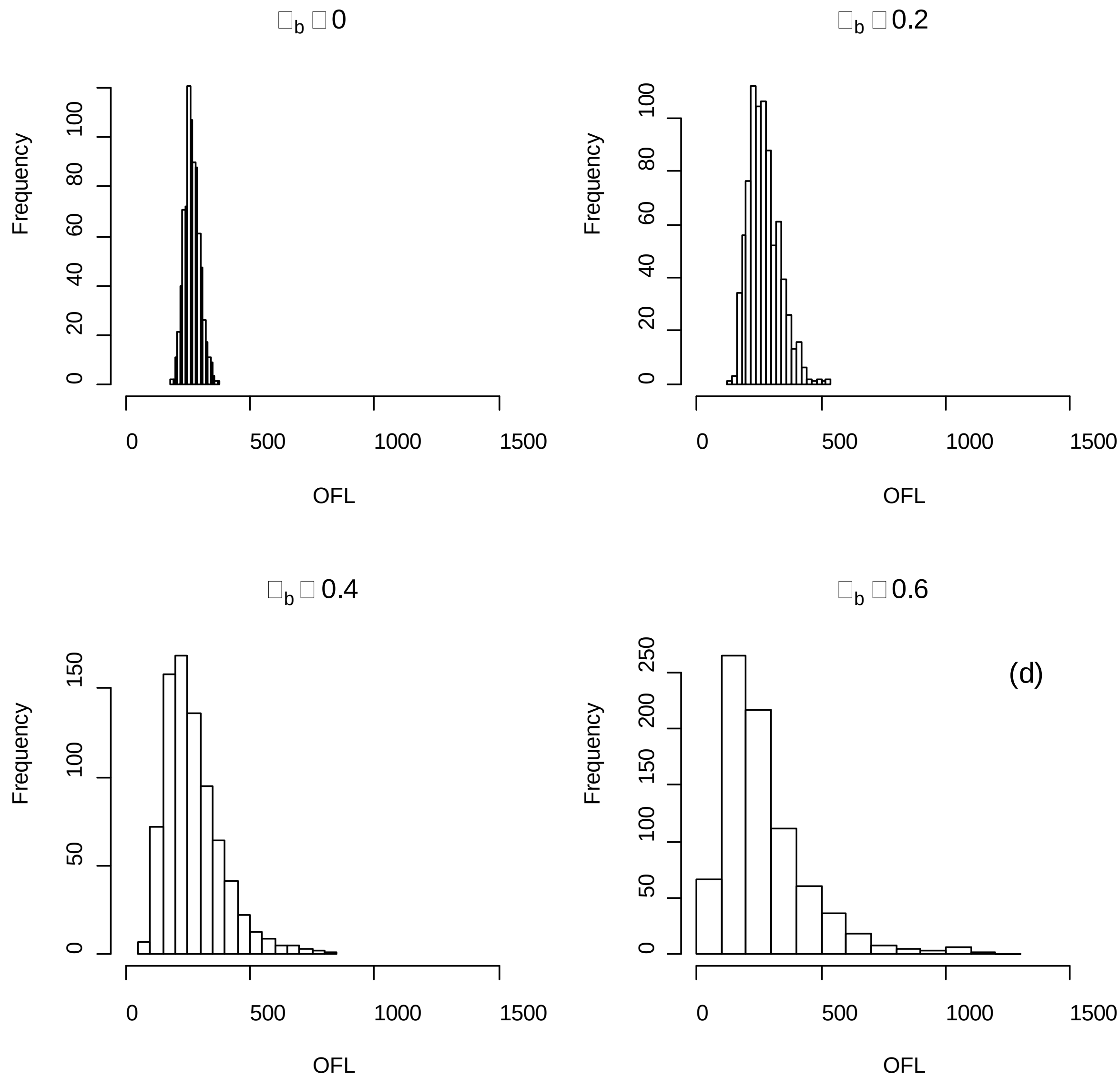


Figure 10-3 **Distribution of OFL values for NSRKC as a function of the assumed extent of additional uncertainty (σ_b).**

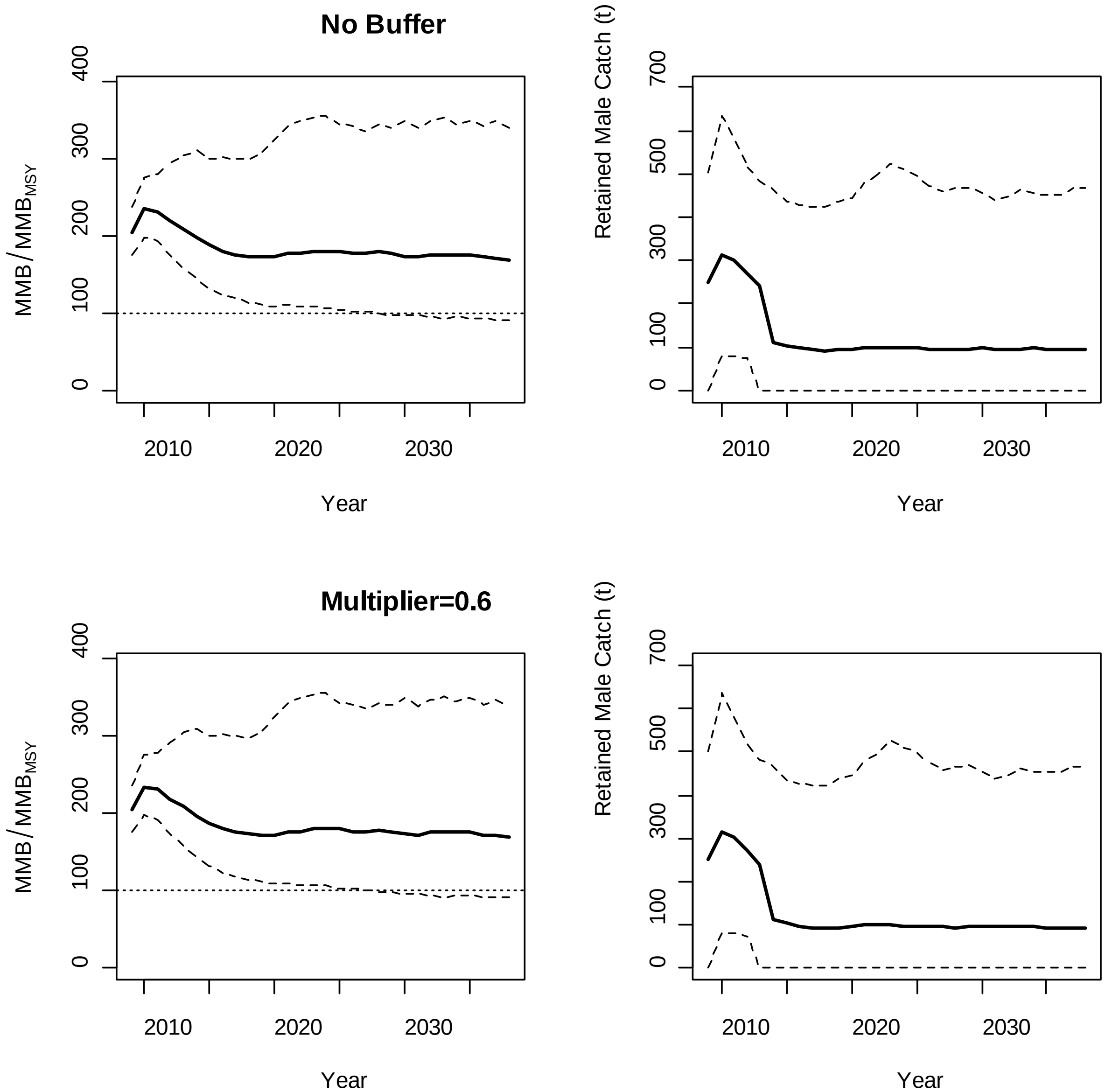


Figure 10-4 Time-trajectories of mature male biomass at mating relative to the proxy for B_{MSY} and catch, for projections based on two choices for the multiplier between the OFL and the ABC. The results in the figure are based on σ_b=0.4 and on applying the SOA control rule.

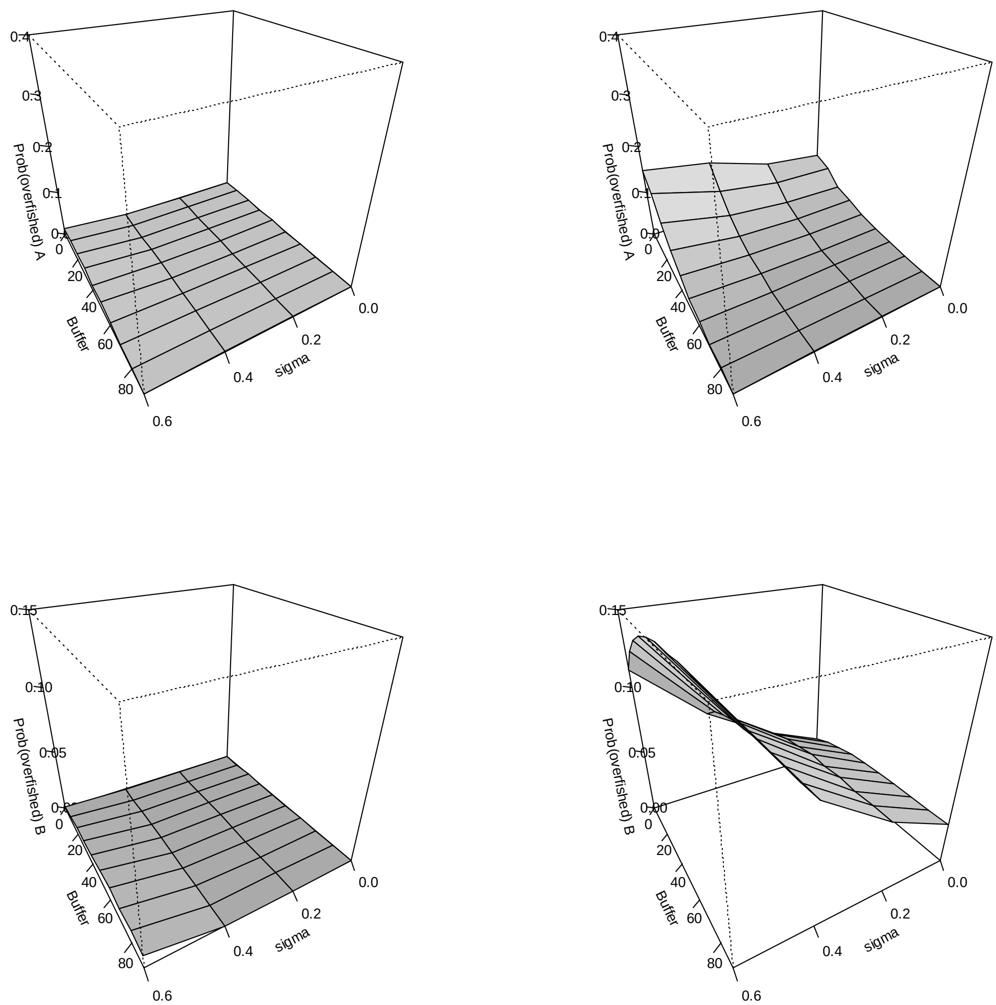


Figure 10-5 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for NSRKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

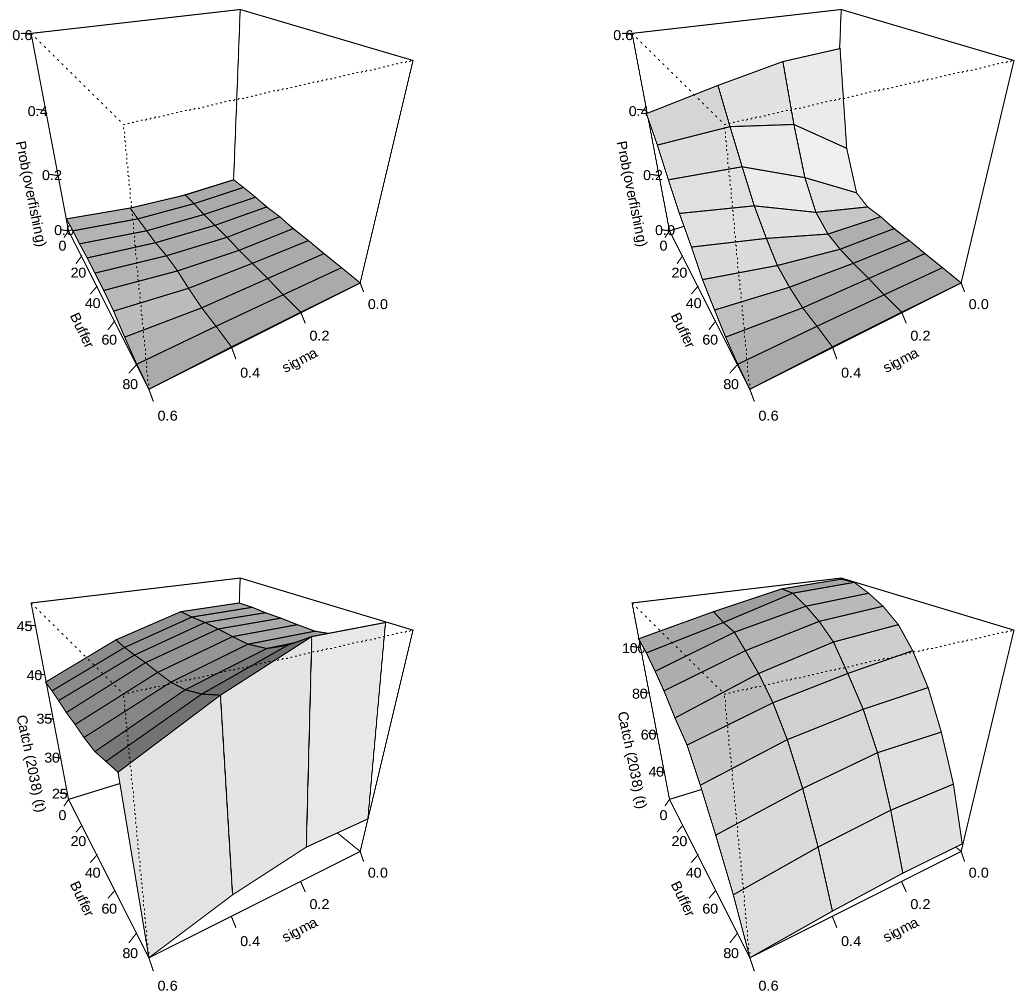


Figure 10-6 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for NSRKC. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

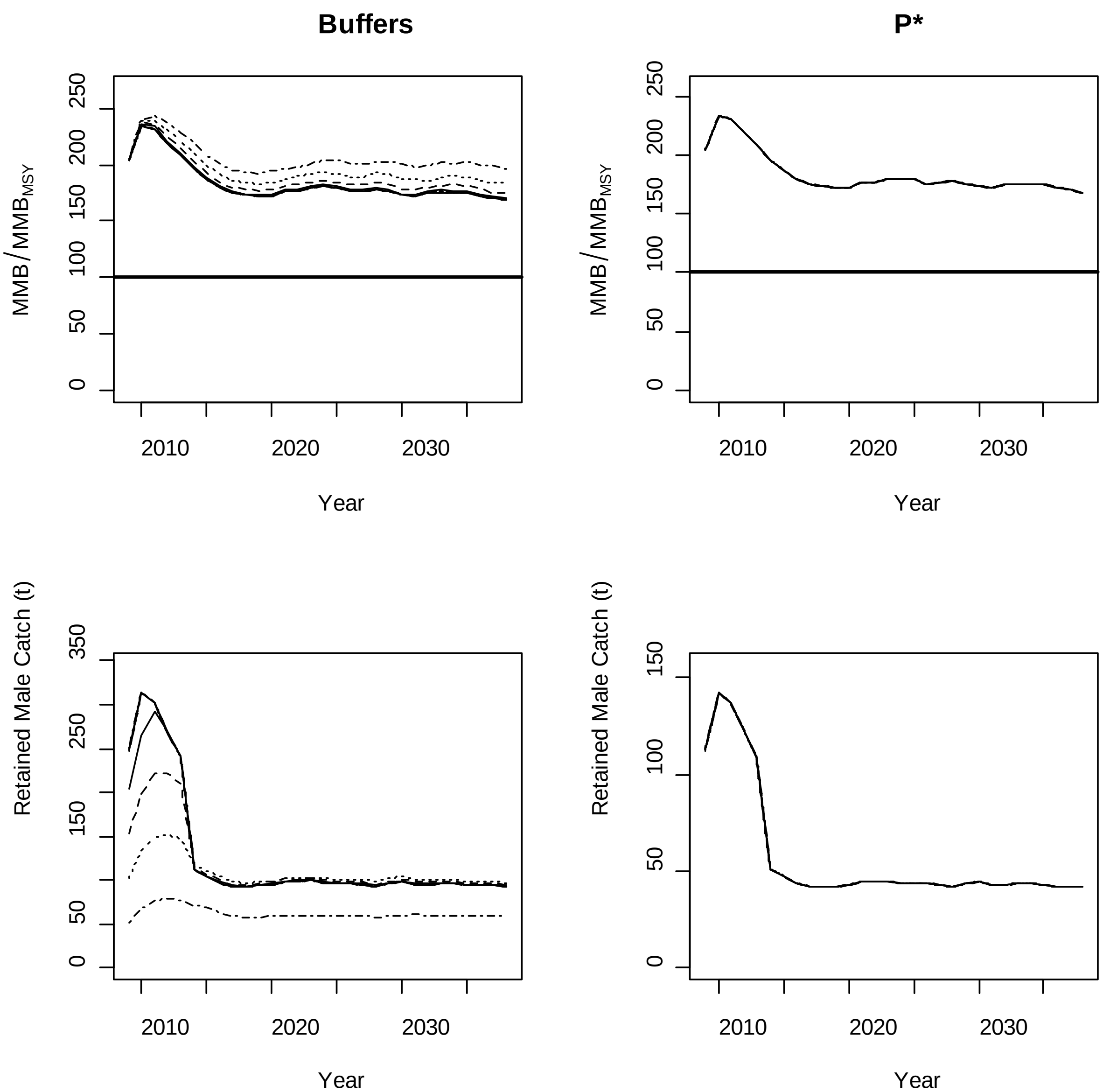


Figure 10-7 Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for BMSY and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.4 and imposing the SOA control rule.

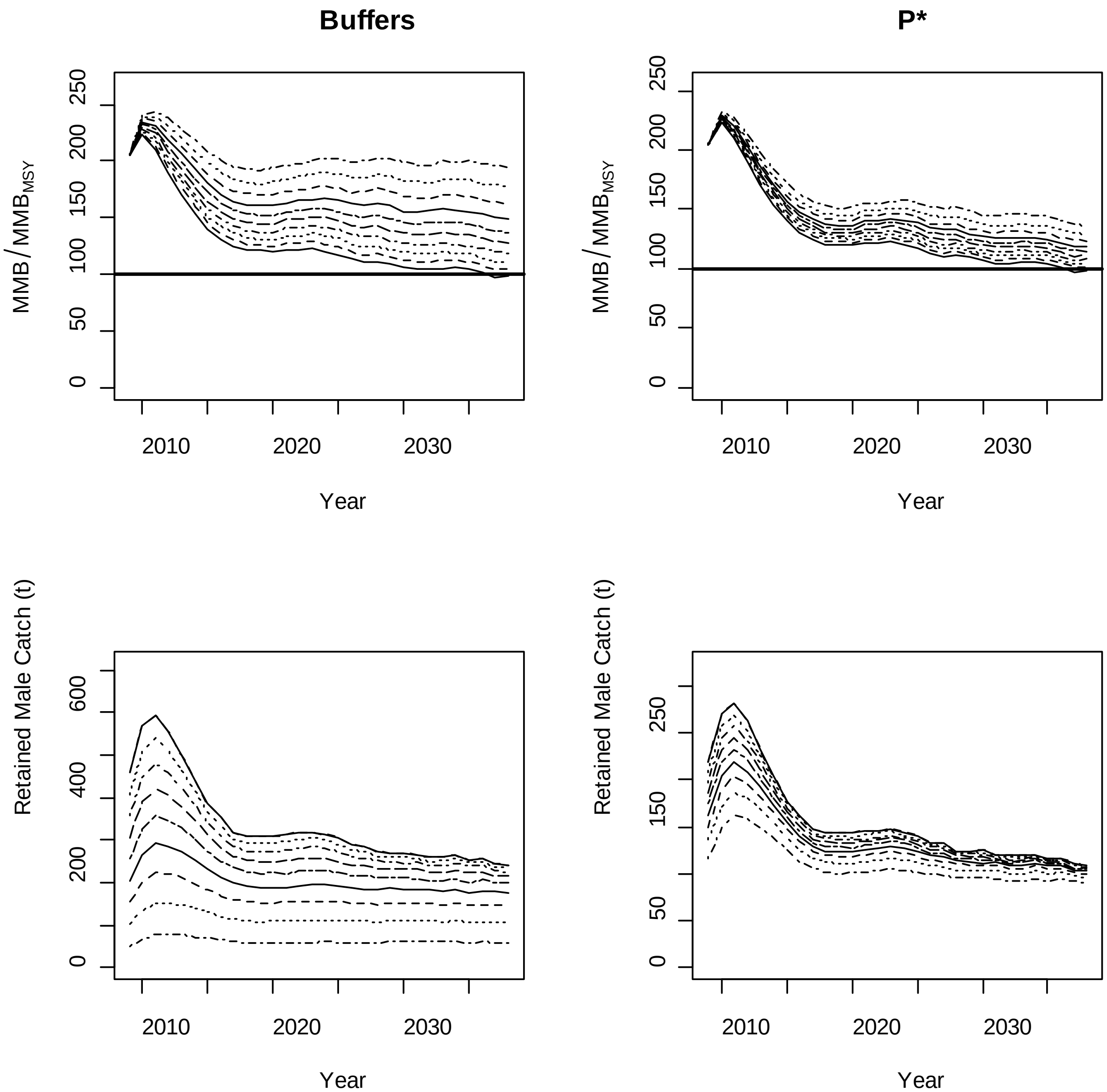


Figure 10-8 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are based on σ_b=0.4 and not imposing the SOA control rule.**

11 Aleutian Island Golden King Crab

General distribution of golden king crabs *Lithodes aequispinus* is summarized by NMFS (2004):

> Golden king crab, also called brown king crab, range from Japan to British Columbia. In the BSAI, golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island passes (page 3-34).
>
> Golden, or brown, king crab occur from the Japan Sea to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett et al. 1985). They are typically found on the continental slope at depths of 300-1,000 m on extremely rough bottom. They are frequently found on coral bottom (page 3-43).

The largest populations of golden king crab are found in the Aleutian Islands. The State of Alaska has divided the Aleutian Islands into the areas east of 174°W (Dutch Harbor region) and west of 174°W (Adak region) for management purposes (ADF&G 2002).

11.1 Fishery and assessment overview

The Aleutian Islands golden king crab (AIGKC) fishery has been prosecuted since the 1981/82 season without any closure. Retained catch peaked during the 1985/86–1989/90 seasons (average catch of 11.9 million lbs [5,398t]), but average harvests dropped sharply from the 1989/90 to the 1990/91 season and the average harvest for the period 1990/91–1995/96 was 6.9 million lbs (3,130t) for the entire Aleutian Islands region. Management based on a formally established GHL was first introduced with a 5.9 million lbs (2,676t) GHL for the entire Aleutian Islands region in the 1996/97 season based on previous five-year average catch, subsequently reduced to 5.7 million lbs (2,586t) beginning with the 1998/99 season. Since the Crab Rationalization Program in 2005/06, the TAC has remained at 5.7 million lbs (2,586t) through 2007/08 for the entire Aleutian Islands region. In 2008, however, the TAC was increased by 5% to 5.985 million lbs (2,715t) following a decision by the Alaska Board of Fisheries, and the AIGKC stock is managed towards this fixed TAC in SOA regulations.

Under the current FMP, the OFL and TAC for AIGKC are determined under Tier 5 (average retained catch) because of the absence of a reliable survey and the lack of model estimates of biomass. Under Tier 5, only a single OFL is established for the total AIGKC stock (although the stock in the areas east and west of 174° W longitude are managed towards separate TACs by the State). The 2009/10 OFL for AIGKC was established as 9.18 million lbs (4,164t) of retained catch (October 2009 SSC minutes). That OFL was computed as the average of the annual retained catch during 1985/86–1995/96 (9,178,438 lbs [4,163t]), rounded to the nearest 0.01-million pounds.

11.1.1 Dutch Harbor region fishery

The Dutch Harbor region harvest peaked in 1986/87 (5.9 million lbs [2,676t]), and stabilized since 1996/97 because of the implementation of a fixed TAC of 3 million lbs (1,361t). The stock was managed using this constant annual TAC until 2007/08. Since 2008/09, the TAC (retained catch) has been 3.15 million lbs [1,429t] (a 5% increase to the previous TAC) by SOA regulation.

Triennial pot surveys had been undertaken in a restricted area around 171°W during 1997, 2000, 2003, and 2006 (this area is within the Dutch Harbor management region, Pengilly (2009), Siddeek et al. (2009)). However, those surveys have had a limited ability to determine the entire stock biomass. Most recently, following an SSC recommendation, the average retained catch OFL was determined to be 9.18 million lbs (4,164t) for the entire Aleutian Islands fishery districts based on the period 1985/86 to 1995/96.[69]

11.1.2 Adak region fishery

The Adak region harvest peaked in 1986/87 (8.8 million lbs [3,992t]) and became steady since 1996/97 because of the implementation of a fixed GHL (or TAC) of 2.7 million lbs (1,225t). This TAC was maintained until 2007/08. Since 2008/09, the TAC (retained catch) has been increased to 2.835 million lbs (1,286t) by SOA regulation.

11.1.3 Stock assessment model

A male-only length-based assessment model was developed for golden king crab in the Dutch Harbor and Adak regions to evaluate ACL alternatives and options under a Tier 4 control rule. This model utilizes commercial catch, catch size composition, commercial CPUE, CPUE size composition, pot survey CPUE, and pot survey CPUE size distribution data to estimate a number of parameters, including natural mortality (M), fishing mortality (F), and annual recruitment. The model for the stock in the Adak region did not consider the pot survey components because the pot surveys were conducted only in the Dutch Harbor region. The model is able to predict mature male biomass (*MMB*) at mating (15 Feb), but has not been recommended by the CPT or the SSC as the basis for management advice.

11.1.4 Uncertainty in stock assessment

Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Aleutian Islands golden king crab is relatively high. Aleutian Islands golden king crab is data-poor, although the model estimates of the coefficients of variation for the estimates of mature male biomass in 2009 are only 0.021 and 0.027 respectively for the Dutch Harbor and Adak regions. However, several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment on which the analyses of this chapter are based:[70]

- A number of the key parameters of the models are pre-specified rather than being estimated.
- F_{msy} is assumed to be equal to M when applying the OFL control rule.
- The assessments on which the analyses are based have not been reviewed nor adopted by the CPT and the SSC.
- Unlike many other BSAI crab stocks, Aleutian Islands golden king crab are not sampled in the standard NMFS trawl survey.
- There is no basis to specify a prior distribution for the catchability coefficient for the survey.
- B_{msy} is assumed to be a mean *MMB* (at mating) over the years 1990-2009 (Dutch Harbor) and 1989-2009 (Adak region). Recruitment was, however, likely to be much higher before this (due to high harvest levels in the late 1980s, Siddeek et al. 2009) and the selection of 1990/1989-2009 as the basis for B_{MSY} is clearly subject to not inconsiderable uncertainty.

For AIGKC, additional uncertainty is thought to be medium, given the relative amount of information available. This analysis uses the additional standard deviation on the log scale of 0.3 to quantify this medium level of additional uncertainty, which is the value recommended by the SSC. This analysis of the short-term implications for Tier 4 includes results for a σ_b of 0, 0.2, 0.4 and 0.6, to show the impacts of these different values. Note that, under Alternative 4, additional uncertainty would be addressed in more

[69] The CPT had recommended in 2009 that the OFL be based on the average catch during 1990/91 through 1995/96, whereas the OFL is based on the SSC-selected period (1985/86 to 1995/96).
[70] As noted above, there is no adopted stock assessment for Aleutian Islands golden king crab at present.

detail by the CPT and SSC and the resulting uncertainty quantified for the ABC control rule may be different than 0.3. Additionally, under Alternative 4, the State would address additional uncertainty that is not quantifiable in the ABC control rule in the TAC setting process.

11.2 Impacts of alternatives

The AIGKC stock is anticipated to be re-classified as a Tier 4 stock, pending adoption of stock-assessment models that have been developed for the Dutch Harbor and Adak components of the stock (NPFMC 2009, p. 23). During the period that the assessment model for the AIGKC stock remains in development, however, it has been recommended by the Council (2007) and by the CPT and SSC in 2008 and 2009 that the AIGKC stock be managed as a Tier 5 stock. Thus, the impacts of the alternatives were analyzed for AIGKC as both a Tier 4 stock and as a Tier 5 stock.

11.3 Tier 4 analysis

As Tier 4 stock, the ABC could be set as (a) the OFL can be multiplied by a pre-specified “multiplier” (Alternative 2), or as (b) a distribution can be computed for the OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternative 3 and Alternative 4).

The analyses of impacts in this chapter are based on the assumption that the ACL applies to all removals of male golden king crab (a total-catch male ACL), and that the TAC (which pertains to catches of legal male crab in the directed fishery) is lower than the ABC to allow for discards and catches in the non-directed fisheries.[71] A total (male) catch ACL can be computed from the output of the SOA control rule (which pertains to the retained catch in the directed fishery) by adding the estimated bycatch and discard to the output from the SOA control rule. As noted in Chapter 3, two scenarios are considered related to the SOA control rule: (a) the ACL equals the lower of the ABC and the total catch corresponding to the TAC computed using the SOA control rule, and (b) the ACL equals the ABC (i.e. the SOA control rule is ignored).

The short-, medium- and long-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the buffer value (shown as the result of application of a multiplier by the OFL) and P* on the ABC which would have been advised for the 2009/10 fishery (assuming that ABCs had been specified for that fishery) while the medium- and long-term implications are evaluated by projecting the population ahead 30 years. The medium-term implications are evaluated using the results of projections for the first six years of the projection period (2009-2014) while the long-term implications consider the implications of the entire 30-year projection period.

For each time frame, a summary estimate of economic impacts of ACL alternatives is provided in terms of the expected total gross revenue at first wholesale produced from the projected annual catch in the directed fishery. Revenue figures in Sections 11.3.1and 11.3.2.3 are reported in constant (2008) dollar terms and future revenues are presented as both nominal (undiscounted) values and in present value terms using OMB-recommended discount rates, r=2.7% and 7.0%. Effects of alternative discount rates are presented in order to provide a comparison of the effect of the time preference on the evaluation of the relative costs of ACL alternatives in terms of foregone revenues accruing at different points in the 30-year forecast period. Higher discount rates place greater emphasis on near-term results relative to more distant costs and benefits.

[71] This chapter does not explicitly consider such catches as they are negligible for the size groups considered in the model (Siddeek et al. 2009).

Revenue forecasts are based on probabilistic price forecasts for Alaskan golden king crab using the time-series vector autoregression model detailed in Chapter 3. The price forecast model is used to estimate a 90% confidence interval for annual prices over the 30 year period 2009-2038. Estimated catch values produced by the stock assessment model are converted to finished product volume using the average product recovery rate for Alaska golden king crab (0.64%). Estimated revenue projections are presented in terms of the median and 90% confidence interval for forecasted revenue. Revenue computations incorporate uncertainty in both price and directed catch estimates. The price model does not explicitly include the effect of Alaska king crab sales volume, and price forecasts are therefore not responsive to catch levels predicted in the stock forecasts.

11.3.1 Short-term implications

The short-implications focus on the size of the ABC for the 2009/10 fishing year. Given a one-year projection, it is not feasible to assess the biological implications of the choice of an alternative. These implications are addressed in Section 11.3.2 and 11.3.2.2.

Table 11-1 and Table 11-2 list the ABC values for the 2009/10 fishing year for each of the alternatives, along with the corresponding estimate of the landed catch in the directed fishery for the Dutch and Adak regions, respectively. The table headers indicates the TACs calculated using the SOA control rule. The differences between ABC_{tot} and ABC_{dir} reflect the losses to discard in the directed fishery (see Table 11-3 for the breakdown of the ABC between the retained catch and the discards). The gross revenue from the directed fishery associated with each of the alternatives is also shown.

As expected, a larger buffer (smaller multiplier) leads to lower ABC levels and a lower probability that the ABC is larger than the true (but unknown) OFL. For golden king crab in the Dutch Harbor and Adak regions, the output of the SOA control rule are 3.15 million lbs (1,429t) and 2.835 million lbs (1,286t), respectively, which are substantially lower than the retained catch component of ABC when there is a zero buffer (11,875t and 8,255t, respectively); so in this case the ABC would not constrain the fishery and TACs would continue to be based on the SOA control rule. In contrast, the retained components of the ABC for the buffer value of 90% (a multiplier of 0.1) are less than the outputs of the SOA control rule for the two regions. If a buffer of 90% was selected, the ABC would constrain the SOA control rule. In other words, the impact to the stock under Alternative 4 is indistinguishable from the impact under Alternative 2 with buffer values from 0 – 80%, Alternative 3 with $P^* < 0.1$ and additional uncertainty of 0.3, or Alternative 1, status quo.

There is a linear relationship between the ABC and buffer [Table 11-1(a), Table 11-2(a), Figure 11-2(a)] with the ABC set equal to the OFL when there is no buffer and being 10% of the ABC for a buffer of 90% (a multiplier of 0.1). The relationship between the buffer and P* is, however, not simple linear proportionality (Table 11-1b Table 11-2b, Figure 11-2b). Moreover, the impact of the (assumed) extent of additional uncertainty is substantial given that the uncertainty of the OFL estimated from the assessment is very low (Figure 11-3 and Figure 11-4). The buffer gets larger (and hence the ABC for 2009/10 gets smaller) for the same value for P* as the value for σ_b is increased. For example, the buffers for a P* of 0.4 (40% probability that the ABC will exceed the true OFL) are 3% and 9% for Dutch Harbor and Adak regions, respectively if there is no uncertainty that is not captured by the stock assessment, but increase to 62% and 63% respectively for the Dutch Harbor and Adak regions if σ_b=0.3. [Table 11-1(b-e), Table 11-2(b-e), Figure 11-2(b)]. The relationship between P* and the buffer (as indicated by the result of multiplying the OFL by the multiplier) based on the OFL calculated for the 2009/10 fishery are given in the “P* (additional uncertainty)” columns of Table 11-1(a) and Table 11-2(a) for the two regions. The linear effect of increasing fixed buffers by an increment of a 0.1 on directed catch equates to approximately $16 million in decreased gross revenue from the Dutch Harbor fishery and an $11 million decrease in the Adak component of the fishery. The near-linear effect between the buffer and P* at σ_b =0.3 results in approximately the same incremental cost for a 0.1 increment in P*.

11.3.2 Medium- and long-term implications

Table 11-4a and Table 11-4b list summaries of the posterior distributions for the key parameters which determine the productivity of the population. The extent of uncertainty captured within the stock assessment, σ_w, is 0.021 (Dutch Harbor) and is 0.027 (Adak) based on the assessment.

11.3.2.1 Medium-term implications - Biological

The medium-term implications of the alternatives are summarized in Table 11-5 and Table 11-6 by the projected values for the ABC (which includes retained and discarded male catches), "ABC_{tot},", the retained directed component of ABC_{tot}, "ABC_{ret}", the output of the SOA control rule (which pertains to retained catches in the directed fishery), "SOA", the retained catch in the directed fishery, "C_{dir}", the ratio of the mature male biomass at the time of mating to that the mature male biomass at which MSY is achieved, "MMB/B_{MSY}", and the probability of overfishing occurring. Results are shown in Table 11-5 and Table 11-6 for analyses based on the additional uncertainty of 0.3, and for four multiplier levels (1, 0.8, 0.6 and 0.4) and four values for P* (0.4, 0.3, 0.2 and 0.1). The multiplier levels correspond to buffer values of 0, 20%, 40% and 60% respectively. Results are for cases in which the SOA control rule is imposed and in which it is ignored. As expected from Table 11-1 and Table 11-2, the retained catch in the directed fishery is equal to the output from the SOA control rule for all of the buffers for the Dutch harbor and Adak regions [Table 11-5(a-d); (i-l) and Table 11-6(a-d); (i-l)] when the SOA control rule is imposed. The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) is zero for all the buffers when the SOA control rule is imposed because the TACs (1,286t for Adak; 1,429t for Dutch Harbor) are markedly lower than the output from the OFL control rule.

The probability of overfishing (i.e. the probability that the total catch exceeds the OFL) decreases as the size of the buffer in increased (the multiplier is decreased) or P* is reduced when the SOA control rule is not imposed. However, this reduction is at the cost of substantially lower annual catches (particularly during the earlier years of the projection period). For example, the retained catch of Dutch Harbor golden king crab in the directed fishery in 2010 drops from 8,700t to 3,900t as the buffer is increased from 0 to 60% [multipliers from 1 to 0.4; Table 11-5(e-h)]. One consequence of larger buffers is, however, larger stock sizes. The impact of different choices for P* is somewhat less than for different choices for the buffer because the range of buffers for P* in the range 0.05 to 1 is only 42%-0, a much narrower range than the range of buffers under consideration. The impact to the stock under Alternative 4 is indistinguishable from the impact under Alternative 2 with buffer values from 0 – 60%, Alternative 3 with P* < 0.1 and additional uncertainty of 0.3, or Alternative 1, status quo.

11.3.2.2 Long-term implications - Biological

Table 11-7 and Table 11-8 summarize the results of the long-term projections in terms of (a) the probability of the mature male biomass at mating dropping below the overfished level at least once over the 30-year period (column "Prob (overfished) A"), (b) the annual probability of the mature male biomass at mating dropping below the overfished level (column "Prob (overfished) B") (c) the annual probability of the catch exceeding the true OFL (column "Prob (overfishing)"), (d) the probability of TAC being computed by adding predicted male discard to the output from the SOA control rule (column "Prob (SOA)"), and (e) the mean and 90% intervals for the catch of legal males by the directed fishery in the last year of the projection period. Results are shown in Table 11-7 and Table 11-8 for projections which account for and ignore the SOA control rule.

Figure 11-5 and Figure 11-6 show the time-trajectories of catch and mature male biomass at mating relative to the proxy for B_{MSY} for two illustrative choices for the buffer (0; ABC=OFL; 40%; the ABC is 60%of the OFL) for the two stocks of golden king crab (Dutch Harbor and Adak regions) when the SOA control rule is not imposed (the results are essentially independent of the choice of the buffer if the SOA control rule is imposed). As expected, the mature male biomass is larger when the buffer is larger (the multiplier is smaller). The golden king crab stock off Adak (Figure 11-6) starts below the proxy for B_{MSY} but recovers to B_{MSY} relatively quickly. Figure 11-7 and Figure 11-10 evaluate the implications of different buffer values between the ABC and the OFL in terms of metrics (a), (b), (c) and (e) in Table 11-5 and Table 11-6, except that results are shown for all four values of the extent of additional uncertainty instead of only the recommended value. As expected, imposing the SOA control rule leads to negligible probabilities of overfishing occurring and the stock being in an overfished state and to catches which are independent of the size of the buffer (Figure 11-7 and Figure 11-10, left panels). In contrast, the probability of being overfished once during the 30-year period is highest when there is no buffer between the OFL and the ABC for Dutch Harbor golden king crab (Figure 11-7, upper right panel) while the probability of being overfished on an annual basis and that of overfishing occurring on an annual basis is highest for smallest buffer and greatest level of additional uncertainty (Figure 11-7, lower right panel; Figure 11-8, upper right panel). The catch of Dutch Harbor golden king crab at the end of the projection period is highest for the smallest level of additional uncertainty and for the smallest buffer (Figure 11-8, lower right panel). The results for Adak golden king crab are qualitatively similar to those for Dutch Harbor golden king crab when the SOA control rule is not implemented, but the probability of being overfished is lower (Figure 11-9 and Figure 11-10).

Figure 11-11 to Figure 11-14 illustrate the differences among the 10 buffers in terms of the median time-trajectory of mature male biomass at mating relative to the proxy for B_{MSY} and the median time-trajectory of the catch of legal males in the directed fishery. The results are essentially independent of the buffer or value for P* if the SOA control rule is imposed, with predicted continuous increases in biomass over time (Figure 11-11 and Figure 11-13). The ratio of mature male biomass to B_{MSY} increases essentially continuously over time with changes in the buffer and P* when the SOA control rule is not imposed (Figure 11-12 and Figure 11-14). The range of catches is broader than that in biomass, particularly during the earlier years of the projection period.

11.3.2.3 Medium- and long-term implications - Economic

The medium term economic impacts of ACL alternatives are summarized in Table 11-9 and Table 11-10 for the Dutch Harbor and Adak golden king crab fisheries, respectively. As noted above, increasing the size of the buffer (i.e., decreasing multiplier from 1.0 to 0.1) produces a lower probability of overfishing at the cost of substantially lower annual catches, particularly during earlier years. This translates into lower gross earnings in the fishery in the medium term. Table 11-9(a) and (b) present the median and 90% confidence intervals for present value of total annual revenues produced from the annual directed catch projected for the ACL alternatives over the period 2009-2014, and the comparative economic effects of alternatives in foregone revenue relative to 1) a zero buffer (multiplier=1.0) and no additional uncertainty (σ=0), and 2) a zero buffer, but holding the value of σ constant across compared alternatives. Results are shown for scenarios that apply the SOA control rule as an upper bound on TAC Table 11-8(a), and scenarios without the SOA control rule [Table 11-9(b)].

Under the SOA control rule, the ABC would not be binding at any buffer or P* level. Results of economic comparisons between ACL alternatives resulting from catch projections without SOA constraints are shown in Table 6-6b. Exclusive of the SOA constraints, potential foregone mid-term revenues in the Dutch Harbor fishery range from 15% reduction from a zero buffer revenue at the 0.8 multiplier level at σ=0.0, to a 52% reduction in revenue at the 0.4 multiplier level at σ=0.3. Corresponding figures for the Adak fishery are 16% to 55% potential foregone revenue. Holding additional uncertainty at the recommended level for this stock, σ_b=0.3, potential foregone revenues in the Dutch Harbor fishery range from $80 million (15% reduction from baseline forecasted revenue) to $ 256 million (52% of baseline revenue), and from $111 to $366 million in the Adak fishery, corresponding to multipliers of 0.8 to 0.4. Marginal revenue reduction increases with the buffer size over this range. Note that the SOA control rule remains in effect as the protocol for TAC-setting, however, the potential foregone revenues that could result from the ACL alternatives would increase substantially relative to a zero buffer, with the ABC as the binding constraint on TAC rather than the SOA control rule. Note that a zero buffer does not represent the status quo alternative, but is intended to provide a representation of the effects of ACL alternatives under potential future decision-making scenarios where the SOA control rule is no longer binding. It should be noted that this comparison does not indicate that costs of ACLs would be higher in the event that the SOA rule was not applied, rather that the SOA rule effectively represents a buffer in itself, and results in foregone catch and revenues relative to the least conservative ACL alternatives under consideration.

Economic results of ACL alternatives over the long term (2009-2038) are represented in Table 11-11 and Table 11-12 for Dutch Harbor and Adak fisheries. As in the mid-term results ACL options analyzed do not produce lower catch levels than the SOA control rule for any buffer level. Exclusive of the SOA control rule, the range of long-term (30 year) potential foregone revenues in the Dutch Harbor fishery relative to a zero buffer range from $372 million (multiplier = .8 and σ= 0) to $1615 million (multiplier = 0.4 and σ= 0.3), a range of 11% to 44% percent reduction from a zero buffer. At the recommended level of additional uncertainty for this stock (σ= 0.3), the estimate of potential foregone revenues ranges from 11% to 44% of potential expected revenue with a zero buffer.

It is important to note the large range of uncertainty in the revenue figures, particularly over the long range. The figures described above represent median values in a broad distribution of potential outcomes, and should not be interpreted as predicted values for purposes other than to support a comparative evaluation of the ACL alternatives, and the proportional description of potential changes from a zero buffer are likely more illustrative in this regard. It should also be noted that the relative economic effects of the ACLs are not qualitatively different between the mid- and long-term, nor do alternative discount rates appreciably change the relative ranking of alternatives in terms of economic outcomes. This is largely due to the effect of the constancy of the buffer in the model projections, in both the buffer and P* scenarios. With fixed buffers, which are not responsive to changes in the stock status, there is little change in the timing of harvest over the period of analysis. That is, none of the alternatives under consideration implement different buffers over time according to stock conditions, and thus the timing of relative economic benefits from the fishery across the time horizon are not appreciably different under the alternatives analyzed.

11.4 Tier 5 analysis

This section analyses ACLs for the AIGKC stock managed as a Tier 5 stock, as it would be if the stock assessment model in development is not implemented in the stock assessment process.

11.4.1 Tier 5 Assessment overview

For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST without an estimate of biomass, and “the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock" (NMFS 2008). Without use of the stock assessment model under development, no B_{MSY} estimate or proxy and no overfished determination (i.e., MSST) is possible for this stock.

Under Tier 5 management, only a single OFL is established for the total AIGKC stock (although the stock in the areas east and west of 174° W longitude are managed towards separate TACs by the SOA).

11.4.2 Uncertainty in Tier 5 stock assessment

Under Tier 5 management, lack of an assessment model in the stock assessment process results in a lack of estimates of mature biomass or population and recruitment trends for the AIGKC stock.

Uncertainty of the Tier 5 retained-catch OFL exists due to questions on whether the retained catch data and time period chosen to compute the retained-catch OFL actually provides data that are "representative of the production potential of the stock." The degree uncertainty may be gauged qualitatively to some extent by the difference between the time periods and OFLs that have been recommended for the AIGKC stock by the CPT and those that have been recommended by the SSC. In 2009, for example, the CPT recommended 1990/91–1995/96 as the years for computing average retained catch for the AIGKC OFL resulting in an OFL of 6.93 million pounds [3,143t] (NPFMC 2009), whereas the SSC recommended 1985/86–1995/96 as the time period, resulting in an OFL of 9.18 million pounds [4,164t](June 2009 SSC minutes). Hence uncertainty exists in the choice of the appropriate time period for the AIGKC stock. Uncertainty on the time period for the AIGKC stock also exists due to the short length of time on which the OFL is based relative to the life span of the species. In addition, the time since the last year of the time period used to compute the 2009/10 OFL(1985/86–1995/96) increases uncertainty on the OFL because of uncertainty that the time period is applicable to present conditions of the AIGKC stock and environment. Finally, the minimum value of the annual retained catch from the fishery since 1983/84 relative to the OFL also provides a qualitative measure of relative uncertainty on the OFLs. The minimum annual retained catch from the AIGKC stock was 4.95 million pounds [2,245t] (Pengilly 2009), or 54% of the 9.18 million pounds [4,164t] 2009/10 OFL.

11.4.3 Impacts of Tier 5 alternatives

As described in Chapter 3, there are two methods under consideration for computing a Tier 5 retained-catch ABC for AIGKC: (a) the retained-catch OFL can be multiplied by a pre-specified multiplier (=1-buffer; Alternative 2 and Alternative 4), or (b) a distribution can be computed for the retained-catch OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternative 3).

The analyses of impacts in this section are based on the assumptions that: 1) the AIGKC stock is treated as a Tier 5 stock with a retained-catch OFL; 2) like the OFL, the ACL and ABC are defined in terms of retained (male) catch only; and 3) that the ACL equals the lower of the ABC and the retained catch corresponding to the TAC that is established for the AIGKC fishery in SOA regulation (5.985 million lbs [2,715t]).

The short- and medium-term implications of the alternatives for calculating the ABC under the Tier 5 scenario are evaluated in this section. The short-term implications are assessed by impact of the alternatives for the buffer and P* on the ABC which would have been advised for the 2009/10 fishery (assuming that ABCs had been specified for that fishery), whereas the medium-term implications would be evaluated by projecting the impacts of alternative during the 2009/10–2018/19 fishery seasons under the assumptions that the retained catch equals the lower of the ABC and a 5.985 million lbs [2,715t] TAC.

The implications of a buffer (either the fixed buffer or the P*-based buffer) are not estimated in terms of effects to stock biomass beyond computing the removals from the unknown stock biomass due to the retained catch because the Tier 5 scenario for AIGKC assumes that an assessment model and reliable biomass estimates are lacking for the stock. Hence biological implications (e.g., effects on mature biomass and stock productivity) are not be analyzed for the Tier 5 scenario. Likewise, the long-term implications are not analyzed due to lack of an assessment model in the Tier 5 scenario,

In this analysis it is assumed that OFL will be specified to the nearest 0.01-million pounds, as has been the case in past specifications (e.g., 9.18-million lbs [4,164t] for 2009/10), and, accordingly, it is assumed that the ABC will be specified to the nearest 0.01million lbs. In this analysis the rounding to the nearest 0.01million pounds occurs after computations are completed to specify an ABC (i.e., data and statistics are not rounded to 0.01 million lbs prior to computing the ABC). The ABCs so calculated were then converted to tonnes and are reported here to the nearest whole tonnes so as to impart analytic heft.

Data and relevant sample statistics for the AIGKC stock are in Table 11-13.

11.4.4 Short-term Tier 5 implications

The short-implications focus on the size of the Tier 5 retained-catch ABC for the 2009/10 fishing year relative to the TAC established for the fishery in regulation (5.985 million lbs).

Buffers > 30% (i.e., multipliers <70%) would result in ABCs less the 2009/10 TAC in SOA regulation (5.985 million lbs [2,715t]; Figure 11-15).

Multipliers and resulting buffers, and ABCs computed using Equation 3.3 for the AIGKC stock for values of P* ranging from 0.1 to 0.5 are given and compared with the 2009/10 AIGKC OFL and TAC in Table 11-14. The 2009/10 TAC for the AIGKC stock would not have been constrained by the ABCs determined by any of the values of P* considered here.

Scaling a multiplier (=1-buffer) by the ratio of the length of the time period used to compute the OFL to the life span of the species computed from the assumed 25-year lifespan for BSAI king crabs (Zheng and Siddeek 2009) and the 11-year time period for computing the AIGKC OFL results in the scaling factor of 11/25 = 0.44. Scaling any multiplier of 1.0 or less by this factor would lower the ABC for the AIGKC stock below the 2009/10 TAC (Figure 11-16). The maximum possible value for an ABC using this method is 4.04 million lbs [1,833t] (44% of the 2009/10 OFL and 68% of the 2009/10 TAC).

Buffers and ABCs for the AIGKC stock resulting from computing multipliers according to Equation 3.4 for each of four values of σ^2 determined by $\sigma = CV \cdot OFL$, for values of CV = 0.0, 0.2, 0.3, and 0.4 and for values of P* from 0.1 to 0.5 are given in Table 11-5. The 2009/10 AIGKC TAC would not have been constrained by applying $\sigma = 0.2 \cdot OFL$ at any values of P* considered here under this method for computing buffers, but would have been constrained by applying $\sigma = 0.3 \cdot OFL$ at P* = 0.1 and $\sigma = 0.4 \cdot OFL$ at P* ≤ 0.2.

Results for use of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period used to compute the 2009/10 AIGKC OFL according to Equation 3.5 for values of P* from 0.1 to 0.5 are given in Table 11-6. Scaling $s_{\bar{x}}$ by $(1+l/n)$ reduces the buffers for the AIGKC stock, but the resulting ABCs would not have constrained the 2009/10 TAC (5.985 million lbs [2,715t]) at any of the P* values considered here.

Values of P* corresponding with fixed buffers for the AIGKC stock with values ranging from 0% to 90% resulting from multipliers (=1-buffer) as computed under the assumptions for Equation 3.3 (no additional uncertainty added), Equation 3.4 (additional uncertainty with specified CV), and Equation 3.5 (added uncertainty to account for time lag since the last year of the time period used to compute the OFL) are given in Table 11-17.

11.4.5 Medium-term and Long-term Tier 5 implications

Assuming that the AIGKC OFL, AIGKC TAC in SOA regulations, and time period for computing the AIGKC OFL remain constant through 2018/19, buffers and ABCs and their effect on constraining the TAC will be unchanged from the short-term implications for all P*-based approaches except for the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL.

Buffers and ABCs determined under the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL are shown for 2009/10–2018/19 in Figure 11-17. Buffers will decrease (i.e., multipliers will increase) in each future year and ABCs (retained catch, tonnes) are non-increasing functions of year for fixed values of P*. However, over the period considered, the ABC would constrain the TAC only using a P* value of 0.1 and beginning in 2014/2015.

The more detailed medium-term biological and economic implications cannot be assessed for the Tier 5 scenario due to the lack of a stock assessment model and stock biomass estimates.

11.5 Tables and Figures

Table 11-1 Values for catch-related quantities for 2009/10 for each of the alternatives for Dutch Harbor golden king crab under Tier 4. The column P* in (a) shows the relationship between each multiplier and P* for different values for the extent of additional uncertainty. The SSC recommended additional uncertainty is shaded. The output from the SOA harvest control rule for this stock is 1,429t. Revenues reported are median and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	P * (additional uncertainty					Revenue	
			None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	12,519	11,875	0.50	0.50	0.5	0.50	0.50	158	0
Multiplier = 0.9	11,267	10,687	0.07	0.40	0.47	0.50	0.50	142	10
Multiplier = 0.8	10,016	9,500	0.00	0.18	0.32	0.40	0.50	126	20
Multiplier = 0.7	8,764	8,312	0.00	0.07	0.16	0.26	0.42	111	30
Multiplier = 0.6	7,512	7,125	0.00	0.01	0.07	0.16	0.32	95	40
Multiplier = 0.5	6,260	5,937	0.00	0.00	0.03	0.07	0.20	79	50
Multiplier = 0.4	5,008	4,750	0.00	0.00	0.00	0.03	0.11	63	60
Multiplier = 0.3	3,756	3,562	0.00	0.00	0.00	0.00	0.05	47	70
Multiplier = 0.2	2,,504	2,375	0.00	0.00	0.00	0.00	0.01	31	80
Multiplier = 0.1	1252	1,187	0.00	0.00	0.00	0.00	0.00	16	90

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
P^* = 0.5	12,519[&]	11,875	1

P^* = 0.4	12,105	11,504	0.97
P^* = 0.3	11,916	11,299	0.95
P^* = 0.2	11,662	11,067	0.93
P^* = 0.1	11,403	10,816	0.91

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
P^* = 0.5	12,519[&]	11,875	1
P^* = 0.4	11,264	10,685	0.90
P^* = 0.3	10,773	10,207	0.86
P^* = 0.2	10,108	9,593	0.81
P^* = 0.1	9,284	8,790	0.74

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier	Revenue	
				Millions $	%Change
P^* = 0.5	12,519[&]	11,875	1	148	0
P^* = 0.4	10,632	10,077	0.85	137	7
P^* = 0.3	9,948	9,426	0.79	126	15
P^* = 0.2	9,147	8,688	0.73	115	22
P^* = 0.1	7,951	7,545	0.64	100	32

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
P^* = 0.5	12,519[&]	11,875	1
P^* = 0.4	9,992	9,487	0.80
P^* = 0.3	9,060	8,597	0.72
P^* = 0.2	8,109	7,,681	0.65
P^* = 0.1	6,769	6,421	0.54

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot} (t)	ABC_{dir} (t)	Multiplier
P^* = 0.5	12,519[&]	11,875	1
P^* = 0.4	8,498	8,062	0.68
P^* = 0.3	7,312	6,934	0.58
P^* = 0.2	6,219	5,882	0.50
P^* = 0.1	4,768	4,519	0.38

& - set to the point estimate

Table 11-2 Values for catch-related quantities for 2009/10 for each of the alternatives for Adak golden king crab under Tier 4. The column P* in (a) shows the relationship between each buffer and P* for different values for the extent of additional uncertainty. The additional uncertainty value used in this analysis is shaded. The output from the SOA harvest control rule for this stock is 1,286t. Revenues reported are median and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009.

(a) ACL = OFL * Multiplier

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	P * (additional uncertainty					Revenue	
			None	0.2	0.3	0.4	0.6	Millions $	%Change
Multiplier = 1	8,976	8,255	0.50	0.50	0.50	0.50	0.50	109	0
Multiplier = 0.9	8,078	7,429	0.36	0.42	0.45	0.49	0.50	98	10
Multiplier = 0.8	7,181	6,604	0.16	0.25	0.35	0.39	0.48	87	20
Multiplier = 0.7	6,283	5,778	0.03	0.12	0.19	0.29	0.39	76	30
Multiplier = 0.6	5,386	4,953	0.00	0.05	0.1	0.16	0.32	65	40
Multiplier = 0.5	4,488	4,,127	0.00	0.01	0.04	0.09	0.21	54	50
Multiplier = 0.4	3,590	3,302	0.00	0.00	0.01	0.03	0.12	43	61
Multiplier = 0.3	2,693	2,476	0.00	0.00	0.00	0.00	0.05	33	70
Multiplier = 0.2	1,795	1,651	0.00	0.00	0.00	0.00	0.01	22	80
Multiplier = 0.1	898	825	0.00	0.00	0.00	0.00	0.00	11	90

(b) ACL defined by P* (no additional uncertainty)

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	Multiplier
P^* = 0.5	8,976[&]	8,255	1
P^* = 0.4	8,212	7,577	0.91
P^* = 0.3	7,890	7,235	0.88
P^* = 0.2	7,384	6,770	0.82
P^* = 0.1	6,870	6,289	0.77

& - set to the point estimate

(c) ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	Multiplier
P^* = 0.5	8,976[&]	8,255	1
P^* = 0.4	7,955	7,328	0.89
P^* = 0.3	7,412	6,762	0.83
P^* = 0.2	6,875	6,308	0.77
P^* = 0.1	6,153	5,661	0.69

& - set to the point estimate

(d) ACL defined by P* (additional uncertainty = 0.3)

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	Multiplier	Revenue	
				Millions $	%Change
P^* = 0.5	8,976[&]	8,255	1	105	0
P^* = 0.4	7,648	7,036	0.85	98	7
P^* = 0.3	6,952	6,383	0.77	90	14
P^* = 0.2	6,336	5,825	0.71	82	22
P^* = 0.1	5,360	4,917	0.6	72	31

& - set to the point estimate

(e) ACL defined by P* (additional uncertainty = 0.4)

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	Multiplier
$P^* = 0.5$	8,976[&]	8,255	1
$P^* = 0.4$	7,261	6,680	0.81
$P^* = 0.3$	6,332	5,813	0.71
$P^* = 0.2$	5,,661	5,206	0.63
$P^* = 0.1$	4,654	4,276	0.52

& - set to the point estimate

(f) ACL defined by P* (additional uncertainty = 0.6)

Alternative	ABC_{tot} ('000 t)	ABC_{dir} ('000 t)	Multiplier
$P^* = 0.5$	8,976[&]	8,255	1
$P^* = 0.4$	6,383	5,858	0.71
$P^* = 0.3$	5,191	4,783	0.58
$P^* = 0.2$	4,380	4,026	0.49
$P^* = 0.1$	3,333	3,069	0.37

& - set to the point estimate

Table 11-3 Breakdown of the 2009/2010 OFL for AIGKC among the sources of mortality included in the OFL.

(a) Dutch Harbor golden king crab

Component	Catch (t)
Retained males	11,874
Discarded males	645
Total	12,519

(b) Adak golden king crab

Component	Catch (t)
Retained males	8,254
Discarded males	721
Total	8,976

Table 11-4 Posterior means and 90% intervals for key parameters of the population dynamics model used for projection purposes under the Tier 4 management scenario.

(a) Dutch Harbor golden king crab

Parameter	Distribution
Virgin MMB	143.5 (134.0, 154.0)
Steepness, h	0.522 (0.516, 0.529)
FMSY (= M)	0.252 (0.226, 0.280)
BMSY (mean MMB)	47.8 (44.5, 51.1)
σ_R	1.024 (0.889, 1.166)

(b) Adak golden king crab

Parameter	Distribution
Virgin MMB	204.0 (161.3, 250.3)
Steepness, h	0.400 (0.371, 0.426)
FMSY (M)	0.264 (0.244, 0.284)
BMSY	75.5 (58.5, 94.3)
σ_R	1.365 (1.184, 1.560)

Table 11-5 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P*=0.4, 0.3, 0.2, and 0.1) for Dutch Harbor golden king crab under Tier 4. The point estimates are medians and the intervals 90% intervals. The results in the table are based on σ_b=0.3.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	11.5 (6.9-19.1)	10.9 (6.6-18.1)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	11.0 (6.6-18.3)	10.5 (6.3-17.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	10.8 (6.5-18.3)	10.2 (6.1-17.3)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	10.7 (6.3-18.2)	10.1 (6.0-17.2)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	10.9 (6.3-19.3)	10.3 (5.9-18.2)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	11.0 (5.9-21.7)	10.4 (5.6-20.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	9.2 (5.6-15.3)	8.7 (5.3-14.5)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	8.8 (5.3-14.7)	8.4 (5.0-13.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	8.6 (5.2-14.6)	8.2 (4.9-13.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	8.5 (5.1-14.6)	8.1 (4.8-13.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	8.7 (5.0-15.5)	8.2 (4.7-14.6)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	8.8 (4.7-17.3)	8.3 (4.5-16.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.9 (4.2-11.4)	6.5 (4.0-10.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	6.6 (4.0-11.0)	6.3 (3.8-10.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	6.5 (3.9-11.0)	6.1 (3.7-10.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	6.4 (3.8-10.9)	6.1 (3.6-10.3)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	6.5 (3.8-11.6)	6.2 (3.6-10.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	6.6 (3.6-13.0)	6.3 (3.4-12.3)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	4.6 (2.8- 7.6)	4.4 (2.6- 7.2)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	4.4 (2.6- 7.3)	4.2 (2.5- 6.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	4.3 (2.6- 7.3)	4.1 (2.4- 6.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	4.3 (2.5- 7.3)	4.0 (2.4- 6.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	4.3 (2.5- 7.7)	4.1 (2.4- 7.3)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	4.4 (2.4- 8.7)	4.2 (2.2- 8.2)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	11.5 (6.9-19.1)	10.9 (6.6-18.1)	1.4 (1.4- 1.4)	10.9 (6.6-18.2)	106 (90-119)	0.416
2010	9.5 (6.1-13.6)	9.0 (5.8-12.8)	1.4 (1.4- 1.4)	9.0 (5.8-12.9)	88 (69-107)	0.403
2011	7.6 (5.4-10.9)	7.2 (5.1-10.3)	1.4 (1.4- 1.4)	7.2 (5.1-10.3)	80 (61-103)	0.412
2012	6.8 (4.6-10.6)	6.4 (4.4- 9.9)	1.4 (1.4- 1.4)	6.4 (4.4- 9.9)	76 (58-101)	0.407
2013	6.5 (3.9-12.3)	6.1 (3.6-11.5)	1.4 (1.4- 1.4)	6.1 (3.6-11.5)	75 (55-112)	0.410
2014	6.6 (3.4-14.9)	6.2 (3.2-13.9)	1.4 (1.4- 1.4)	6.2 (3.2-13.9)	76 (54-140)	0.411

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	9.2 (5.6-15.3)	8.7 (5.3-14.5)	1.4 (1.4- 1.4)	8.7 (5.3-14.5)	110 (97-121)	0.176
2010	7.9 (5.0-11.9)	7.5 (4.7-11.2)	1.4 (1.4- 1.4)	7.5 (4.7-11.3)	95 (77-112)	0.175
2011	6.8 (4.6- 9.7)	6.4 (4.3- 9.2)	1.4 (1.4- 1.4)	6.4 (4.3- 9.2)	86 (68-109)	0.175
2012	6.2 (4.1- 9.4)	5.8 (3.9- 8.8)	1.4 (1.4- 1.4)	5.8 (3.9- 8.8)	82 (65-108)	0.170
2013	5.8 (3.5-10.7)	5.5 (3.3-10.0)	1.4 (1.4- 1.4)	5.5 (3.3-10.0)	82 (61-121)	0.177
2014	6.0 (3.1-12.7)	5.6 (2.9-11.8)	1.4 (1.4- 1.4)	5.6 (2.9-11.8)	82 (58-150)	0.174

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.9 (4.2-11.4)	6.5 (4.0-10.9)	1.4 (1.4- 1.4)	6.5 (3.9-10.9)	114 (102-124)	0.022
2010	6.2 (3.8- 9.6)	5.8 (3.6- 9.1)	1.4 (1.4- 1.4)	5.8 (3.6- 9.1)	102 (85-118)	0.028
2011	5.6 (3.6- 8.3)	5.3 (3.4- 7.9)	1.4 (1.4- 1.4)	5.3 (3.4- 7.9)	94 (77-116)	0.028
2012	5.2 (3.4- 7.9)	4.9 (3.2- 7.4)	1.4 (1.4- 1.4)	4.9 (3.2- 7.4)	91 (72-117)	0.026
2013	4.9 (3.0- 8.9)	4.6 (2.9- 8.3)	1.4 (1.4- 1.4)	4.6 (2.9- 8.3)	90 (68-131)	0.026
2014	5.0 (2.7-10.3)	4.7 (2.5- 9.7)	1.4 (1.4- 1.4)	4.7 (2.5- 9.6)	90 (65-163)	0.029

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	4.6 (2.8- 7.6)	4.4 (2.6- 7.2)	1.4 (1.4- 1.4)	4.3 (2.6- 7.2)	119 (108-128)	0.000
2010	4.2 (2.6- 6.8)	4.0 (2.5- 6.4)	1.4 (1.4- 1.4)	4.0 (2.5- 6.4)	109 (95-124)	0.000
2011	4.0 (2.5- 6.3)	3.8 (2.4- 5.9)	1.4 (1.4- 1.4)	3.7 (2.4- 5.9)	103 (86-124)	0.000
2012	3.8 (2.4- 5.9)	3.6 (2.3- 5.6)	1.4 (1.4- 1.4)	3.6 (2.3- 5.5)	101 (82-125)	0.000
2013	3.8 (2.3- 6.6)	3.6 (2.1- 6.2)	1.4 (1.4- 1.4)	3.6 (2.1- 6.1)	100 (77-142)	0.000
2014	3.8 (2.1- 7.4)	3.6 (2.0- 6.9)	1.4 (1.4- 1.4)	3.6 (2.0- 6.9)	101 (73-174)	0.000

(i) P*=0.1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	10.7 (6.4-17.7)	10.1 (6.1-16.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	10.2 (6.1-17.0)	9.7 (5.8-16.1)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	10.0 (6.0-17.0)	9.5 (5.7-16.0)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	9.9 (5.9-16.9)	9.4 (5.6-16.0)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	10.1 (5.8-17.9)	9.5 (5.5-16.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	10.2 (5.5-20.1)	9.7 (5.2-18.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(j) P*=0.1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	9.8 (5.9-16.3)	9.3 (5.6-15.5)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	9.4 (5.6-15.7)	8.9 (5.4-14.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	9.2 (5.5-15.6)	8.7 (5.2-14.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	9.1 (5.4-15.5)	8.6 (5.1-14.7)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	9.3 (5.4-16.5)	8.8 (5.1-15.6)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	9.4 (5.1-18.5)	8.9 (4.8-17.5)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(k) P*=0.2; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	8.9 (5.4-14.8)	8.5 (5.1-14.0)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	8.6 (5.1-14.2)	8.1 (4.9-13.5)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	8.4 (5.0-14.2)	7.9 (4.7-13.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	8.3 (4.9-14.1)	7.8 (4.7-13.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	8.4 (4.9-15.0)	8.0 (4.6-14.1)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	8.6 (4.6-16.8)	8.1 (4.4-15.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(l) P*=0.1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.8 (4.7-13.0)	7.4 (4.5-12.3)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	125 (115-134)	0.000
2010	7.5 (4.5-12.5)	7.1 (4.3-11.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	119 (107-132)	0.000
2011	7.3 (4.4-12.4)	6.9 (4.2-11.8)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (101-136)	0.000
2012	7.3 (4.3-12.4)	6.9 (4.1-11.7)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	115 (96-142)	0.000
2013	7.4 (4.3-13.1)	7.0 (4.0-12.4)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	116 (91-161)	0.000
2014	7.5 (4.0-14.7)	7.1 (3.8-13.9)	1.4 (1.4- 1.4)	1.4 (1.4- 1.4)	118 (85-195)	0.000

(m) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	10.7 (6.4-17.7)	10.1 (6.1-16.8)	1.4 (1.4- 1.4)	10.1 (6.1-16.8)	107 (93-119)	0.314
2010	9.0 (5.7-13.1)	8.5 (5.4-12.4)	1.4 (1.4- 1.4)	8.5 (5.4-12.4)	91 (72-109)	0.313
2011	7.4 (5.1-10.6)	7.0 (4.9-10.0)	1.4 (1.4- 1.4)	7.0 (4.8-10.0)	82 (64-105)	0.314
2012	6.6 (4.5-10.1)	6.2 (4.2- 9.5)	1.4 (1.4- 1.4)	6.2 (4.2- 9.5)	78 (61-104)	0.313
2013	6.3 (3.8-11.7)	5.9 (3.5-11.0)	1.4 (1.4- 1.4)	5.9 (3.5-11.0)	77 (57-115)	0.311
2014	6.4 (3.3-14.1)	6.0 (3.1-13.1)	1.4 (1.4- 1.4)	6.0 (3.1-13.1)	78 (55-145)	0.311

(n) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	9.8 (5.9-16.3)	9.3 (5.6-15.5)	1.4 (1.4- 1.4)	9.3 (5.6-15.5)	109 (95-121)	0.221
2010	8.4 (5.3-12.4)	7.9 (5.0-11.7)	1.4 (1.4- 1.4)	7.9 (5.0-11.7)	93 (75-111)	0.230
2011	7.1 (4.8-10.1)	6.7 (4.5- 9.5)	1.4 (1.4- 1.4)	6.7 (4.5- 9.5)	84 (66-107)	0.225
2012	6.4 (4.3- 9.7)	6.0 (4.0- 9.1)	1.4 (1.4- 1.4)	6.0 (4.0- 9.1)	80 (63-107)	0.225
2013	6.0 (3.6-11.2)	5.7 (3.4-10.4)	1.4 (1.4- 1.4)	5.7 (3.4-10.4)	80 (59-118)	0.225
2014	6.2 (3.2-13.2)	5.8 (3.0-12.3)	1.4 (1.4- 1.4)	5.8 (3.0-12.4)	80 (57-147)	0.225

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	8.9 (5.4-14.8)	8.5 (5.1-14.0)	1.4 (1.4- 1.4)	8.5 (5.1-14.1)	110 (98-122)	0.147
2010	7.7 (4.9-11.6)	7.3 (4.6-11.0)	1.4 (1.4- 1.4)	7.3 (4.6-11.0)	96 (78-113)	0.156
2011	6.7 (4.5- 9.6)	6.3 (4.2- 9.0)	1.4 (1.4- 1.4)	6.3 (4.2- 9.0)	87 (69-110)	0.153
2012	6.1 (4.0- 9.2)	5.7 (3.8- 8.7)	1.4 (1.4- 1.4)	5.7 (3.8- 8.7)	83 (65-109)	0.149
2013	5.8 (3.5-10.6)	5.4 (3.3- 9.9)	1.4 (1.4- 1.4)	5.4 (3.3- 9.9)	83 (61-122)	0.151
2014	5.9 (3.0-12.4)	5.5 (2.9-11.6)	1.4 (1.4- 1.4)	5.5 (2.9-11.6)	83 (59-151)	0.153

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.8 (4.7-13.0)	7.4 (4.5-12.3)	1.4 (1.4- 1.4)	7.4 (4.5-12.3)	113 (100-123)	0.074
2010	6.9 (4.3-10.5)	6.5 (4.1-10.0)	1.4 (1.4- 1.4)	6.5 (4.1-10.0)	99 (82-116)	0.072
2011	6.1 (4.0- 9.0)	5.8 (3.8- 8.5)	1.4 (1.4- 1.4)	5.8 (3.8- 8.5)	91 (73-113)	0.075
2012	5.6 (3.7- 8.5)	5.3 (3.5- 8.0)	1.4 (1.4- 1.4)	5.3 (3.5- 8.0)	87 (69-113)	0.074
2013	5.3 (3.3- 9.7)	5.0 (3.1- 9.1)	1.4 (1.4- 1.4)	5.0 (3.1- 9.1)	86 (65-127)	0.071
2014	5.5 (2.9-11.3)	5.1 (2.7-10.5)	1.4 (1.4- 1.4)	5.1 (2.7-10.5)	87 (62-157)	0.070

Table 11-6 Summary of the medium-term consequences of a subset of the alternatives (multipliers of 1, 0.8, 0.6 and 0.4; P*=0.4, 0.3, 0.2, and 0.1) for Adak golden king crab under Tier 4. The point estimates are medians and the intervals 90% intervals. The results in the table are based on σ_b=0.3.

(a) Multiplier = 1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} '000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	8.4 (4.6-15.3)	7.7 (4.2-14.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	10.3 (6.1-18.2)	9.4 (5.6-16.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	12.4 (7.5-22.1)	11.4 (7.0-20.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	14.5 (8.5-25.8)	13.4 (7.8-23.7)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	16.3 (9.5-29.2)	15.0 (8.7-26.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	16.7 (9.7-29.1)	15.3 (8.9-26.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(b) Multiplier = 0.8; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.7 (3.7-12.3)	6.2 (3.4-11.3)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	8.2 (4.9-14.6)	7.6 (4.5-13.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	9.9 (6.0-17.7)	9.1 (5.6-16.3)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	11.6 (6.8-20.6)	10.7 (6.3-19.0)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	13.0 (7.6-23.4)	12.0 (6.9-21.5)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	13.3 (7.8-23.3)	12.3 (7.2-21.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(c) Multiplier = 0.6; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	5.1 (2.7- 9.2)	4.6 (2.5- 8.5)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	6.2 (3.7-10.9)	5.7 (3.4-10.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	7.5 (4.5-13.3)	6.9 (4.2-12.2)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	8.7 (5.1-15.5)	8.0 (4.7-14.2)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	9.8 (5.7-17.5)	9.0 (5.2-16.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	10.0 (5.8-17.5)	9.2 (5.4-16.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(d) Multiplier = 0.4; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	3.4 (1.8- 6.1)	3.1 (1.7- 5.6)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	4.1 (2.4- 7.3)	3.8 (2.2- 6.7)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	5.0 (3.0- 8.8)	4.6 (2.8- 8.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	5.8 (3.4-10.3)	5.4 (3.1- 9.5)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	6.5 (3.8-11.7)	6.0 (3.5-10.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	6.7 (3.9-11.7)	6.1 (3.6-10.7)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(e) Multiplier = 1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	8.4 (4.6-15.3)	7.7 (4.2-14.1)	1.3 (1.3- 1.3)	7.7 (4.2-14.2)	70 (58- 90)	0.443
2010	9.0 (5.7-14.1)	8.3 (5.3-12.9)	1.3 (1.3- 1.3)	8.3 (5.3-12.9)	72 (62- 87)	0.456
2011	10.2 (6.7-15.6)	9.4 (6.2-14.2)	1.3 (1.3- 1.3)	9.4 (6.2-14.3)	77 (65- 89)	0.446
2012	11.8 (7.5-17.7)	10.8 (6.9-16.1)	1.3 (1.3- 1.3)	10.8 (6.9-16.2)	82 (69- 95)	0.453
2013	13.5 (8.4-20.6)	12.4 (7.7-18.8)	1.3 (1.3- 1.3)	12.4 (7.7-18.9)	88 (72-103)	0.459
2014	13.1 (8.5-18.1)	12.0 (7.8-16.5)	1.3 (1.3- 1.3)	12.0 (7.8-16.6)	87 (70-102)	0.459

(f) Multiplier = 0.8; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.7 (3.7-12.3)	6.2 (3.4-11.3)	1.3 (1.3- 1.3)	6.2 (3.4-11.3)	72 (59- 92)	0.199
2010	7.5 (4.7-12.0)	6.9 (4.3-11.0)	1.3 (1.3- 1.3)	6.9 (4.3-11.0)	75 (65- 91)	0.199
2011	8.6 (5.5-13.3)	7.9 (5.1-12.2)	1.3 (1.3- 1.3)	7.9 (5.1-12.3)	81 (70- 93)	0.198
2012	9.9 (6.2-15.3)	9.1 (5.7-14.0)	1.3 (1.3- 1.3)	9.1 (5.7-14.0)	86 (74-100)	0.204
2013	11.3 (7.0-18.0)	10.4 (6.4-16.4)	1.3 (1.3- 1.3)	10.3 (6.4-16.4)	93 (79-108)	0.200
2014	11.1 (7.0-16.3)	10.2 (6.5-14.9)	1.3 (1.3- 1.3)	10.2 (6.4-14.9)	92 (77-109)	0.200

(g) Multiplier = 0.6; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	5.1 (2.7- 9.2)	4.6 (2.5- 8.5)	1.3 (1.3- 1.3)	4.6 (2.5- 8.5)	73 (60- 94)	0.050
2010	5.8 (3.6- 9.5)	5.3 (3.3- 8.7)	1.3 (1.3- 1.3)	5.3 (3.3- 8.7)	78 (68- 95)	0.045
2011	6.8 (4.3-10.8)	6.2 (4.0- 9.9)	1.3 (1.3- 1.3)	6.2 (4.0- 9.9)	85 (74- 98)	0.051
2012	7.8 (4.8-12.8)	7.2 (4.4-11.7)	1.3 (1.3- 1.3)	7.2 (4.4-11.7)	91 (80-104)	0.055
2013	8.8 (5.4-14.8)	8.1 (4.9-13.5)	1.3 (1.3- 1.3)	8.1 (4.9-13.5)	99 (86-113)	0.055
2014	8.8 (5.5-13.6)	8.0 (5.0-12.5)	1.3 (1.3- 1.3)	8.0 (5.0-12.5)	99 (84-115)	0.045

(h) Multiplier = 0.4; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	3.4 (1.8- 6.1)	3.1 (1.7- 5.6)	1.3 (1.3- 1.3)	3.1 (1.7- 5.6)	75 (61- 97)	0.000
2010	4.0 (2.4- 6.7)	3.7 (2.2- 6.2)	1.3 (1.3- 1.3)	3.6 (2.2- 6.2)	81 (70- 99)	0.001
2011	4.7 (2.9- 7.8)	4.3 (2.7- 7.2)	1.3 (1.3- 1.3)	4.3 (2.7- 7.2)	89 (79-104)	0.000
2012	5.5 (3.3- 9.1)	5.0 (3.0- 8.3)	1.3 (1.3- 1.3)	5.0 (3.0- 8.3)	97 (86-110)	0.001
2013	6.1 (3.7-10.4)	5.7 (3.4- 9.6)	1.3 (1.3- 1.3)	5.6 (3.4- 9.6)	106 (94-120)	0.001
2014	6.2 (3.7-10.1)	5.6 (3.4- 9.3)	1.3 (1.3- 1.3)	5.6 (3.4- 9.3)	107 (93-123)	0.001

(i) P*=0.4; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.8 (4.2-14.2)	7.2 (3.9-13.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	9.5 (5.7-16.9)	8.8 (5.2-15.6)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	11.5 (7.0-20.5)	10.6 (6.4-18.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	13.5 (7.9-23.9)	12.4 (7.2-22.0)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	15.1 (8.8-27.1)	13.9 (8.0-24.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	15.5 (9.0-27.0)	14.2 (8.3-24.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(j) P*=0.3; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.2 (3.9-13.1)	6.6 (3.6-12.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	8.8 (5.2-15.6)	8.1 (4.8-14.3)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	10.6 (6.4-18.9)	9.8 (5.9-17.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	12.4 (7.2-22.0)	11.4 (6.7-20.3)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	13.9 (8.1-25.0)	12.8 (7.4-23.0)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	14.2 (8.3-24.9)	13.1 (7.6-22.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(k) P*=0.2; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.5 (3.6-11.9)	6.0 (3.3-11.0)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	8.0 (4.7-14.1)	7.3 (4.3-13.0)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	9.6 (5.9-17.2)	8.9 (5.4-15.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	11.3 (6.6-20.0)	10.4 (6.1-18.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	12.7 (7.3-22.7)	11.7 (6.7-20.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	12.9 (7.5-22.6)	11.9 (6.9-20.8)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(l) P*=0.1; Impose SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	5.7 (3.1-10.4)	5.2 (2.9- 9.6)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	77 (62-101)	0.000
2010	7.0 (4.1-12.4)	6.4 (3.8-11.4)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	86 (73-105)	0.000
2011	8.5 (5.1-15.0)	7.8 (4.7-13.9)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	96 (84-111)	0.000
2012	9.9 (5.8-17.5)	9.1 (5.3-16.1)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	106 (94-120)	0.000
2013	11.1 (6.4-19.9)	10.2 (5.9-18.3)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	118 (106-132)	0.000
2014	11.3 (6.6-19.8)	10.4 (6.1-18.2)	1.3 (1.3- 1.3)	1.3 (1.3- 1.3)	121 (108-136)	0.000

(m) P*=0.4; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.8 (4.2-14.2)	7.2 (3.9-13.1)	1.3 (1.3- 1.3)	7.2 (3.9-13.1)	70 (58- 91)	0.352
2010	8.5 (5.4-13.4)	7.8 (4.9-12.2)	1.3 (1.3- 1.3)	7.8 (4.9-12.3)	73 (63- 88)	0.354
2011	9.6 (6.3-14.8)	8.8 (5.8-13.6)	1.3 (1.3- 1.3)	8.8 (5.8-13.6)	78 (67- 90)	0.349
2012	11.2 (7.1-16.9)	10.2 (6.5-15.4)	1.3 (1.3- 1.3)	10.2 (6.5-15.4)	84 (71- 97)	0.352
2013	12.7 (7.9-19.7)	11.7 (7.3-18.0)	1.3 (1.3- 1.3)	11.7 (7.2-18.0)	90 (74-104)	0.350
2014	12.4 (8.0-17.4)	11.4 (7.3-16.0)	1.3 (1.3- 1.3)	11.4 (7.3-16.0)	89 (73-104)	0.357

(n) P*=0.3; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	7.2 (3.9-13.1)	6.6 (3.6-12.1)	1.3 (1.3- 1.3)	6.6 (3.6-12.1)	71 (59- 91)	0.255
2010	7.9 (5.0-12.6)	7.3 (4.6-11.5)	1.3 (1.3- 1.3)	7.3 (4.6-11.5)	74 (64- 90)	0.246
2011	9.0 (5.9-13.9)	8.3 (5.4-12.8)	1.3 (1.3- 1.3)	8.3 (5.4-12.8)	80 (69- 92)	0.249
2012	10.5 (6.6-16.0)	9.6 (6.1-14.6)	1.3 (1.3- 1.3)	9.6 (6.1-14.7)	85 (73- 98)	0.249
2013	11.9 (7.4-18.7)	11.0 (6.8-17.1)	1.3 (1.3- 1.3)	10.9 (6.7-17.1)	92 (77-106)	0.249
2014	11.7 (7.4-16.8)	10.8 (6.8-15.4)	1.3 (1.3- 1.3)	10.8 (6.8-15.5)	91 (75-107)	0.251

(o) P*=0.2; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	6.5 (3.6-11.9)	6.0 (3.3-11.0)	1.3 (1.3- 1.3)	6.0 (3.3-11.0)	72 (59- 92)	0.174
2010	7.3 (4.5-11.7)	6.7 (4.2-10.7)	1.3 (1.3- 1.3)	6.7 (4.2-10.7)	76 (65- 91)	0.180
2011	8.4 (5.4-13.1)	7.7 (5.0-12.0)	1.3 (1.3- 1.3)	7.7 (5.0-12.0)	81 (70- 93)	0.184
2012	9.7 (6.1-15.0)	8.9 (5.6-13.7)	1.3 (1.3- 1.3)	8.9 (5.6-13.7)	87 (75-100)	0.176
2013	11.0 (6.8-17.6)	10.1 (6.2-16.1)	1.3 (1.3- 1.3)	10.1 (6.2-16.1)	94 (79-108)	0.177
2014	10.9 (6.8-16.0)	10.0 (6.3-14.7)	1.3 (1.3- 1.3)	9.9 (6.3-14.7)	93 (78-109)	0.177

(p) P*=0.1; No SOA control rule

Year	ABC_{tot} ('000 t)	ABC_{ret} ('000 t)	SOA ('000 t)	C_{ret} ('000 t)	MMB/B_{MSY}	Prob (overfishing)
2009	5.7 (3.1-10.4)	5.2 (2.9- 9.6)	1.3 (1.3- 1.3)	5.2 (2.9- 9.6)	73 (60- 93)	0.091
2010	6.5 (4.0-10.5)	6.0 (3.7- 9.7)	1.3 (1.3- 1.3)	6.0 (3.7- 9.7)	77 (67- 93)	0.092
2011	7.5 (4.8-11.9)	6.9 (4.4-10.9)	1.3 (1.3- 1.3)	6.9 (4.4-10.9)	83 (72- 96)	0.095
2012	8.7 (5.4-13.8)	8.0 (5.0-12.7)	1.3 (1.3- 1.3)	8.0 (4.9-12.7)	89 (77-102)	0.094
2013	9.8 (6.0-16.1)	9.0 (5.5-14.8)	1.3 (1.3- 1.3)	9.0 (5.5-14.9)	97 (83-111)	0.090
2014	9.7 (6.1-14.8)	8.9 (5.6-13.6)	1.3 (1.3- 1.3)	8.9 (5.6-13.6)	96 (81-112)	0.092

Table 11-7 Summary of the long-term consequences of the alternatives for Dutch Harbor golden king crab under Tier 4. The column "retained catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2038. The results in the table are based on σ_b=0.3.

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Summer catch (t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Summer catch (t)
Multiplier = 1		0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.240	0.028	0.410	8.1 (2.9-19.4)
Multiplier = 0.9		0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.164	0.018	0.277	8.0 (2.9-18.5)
Multiplier = 0.8		0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.110	0.011	0.174	7.7 (3.0-17.6)
Multiplier = 0.7		0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.063	0.006	0.084	7.3 (3.0-16.7)
Multiplier = 0.6		0.004	0.000	0.000	0.999	1.4 (1.4- 1.4)	0.036	0.003	0.028	6.8 (2.9-15.6)
Multiplier = 0.5		0.003	0.000	0.000	0.999	1.4 (1.4- 1.4)	0.025	0.002	0.006	6.2 (2.7-14.4)
Multiplier = 0.4		0.003	0.000	0.000	0.997	1.4 (1.4- 1.4)	0.011	0.001	0.000	5.4 (2.5-12.5)
Multiplier = 0.3		0.003	0.000	0.000	0.988	1.4 (1.4- 1.4)	0.005	0.000	0.000	4.5 (2.1-10.4)
Multiplier = 0.2		0.001	0.000	0.000	0.926	1.4 (1.4- 1.4)	0.001	0.000	0.000	3.3 (1.6- 7.7)
Multiplier = 0.1		0.000	0.000	0.000	0.504	1.4 (.9- 1.4)	0.000	0.000	0.000	1.8 (.9- 4.3)
P* = 0.5	1.0	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.240	0.028	0.410	8.1 (2.9-19.4)
P* = 0.45	0.963	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.203	0.023	0.357	8.1 (3.0-18.9)
P* = 0.4	0.927	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.179	0.020	0.310	8.0 (2.9-18.6)
P* = 0.35	0.891	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.154	0.017	0.266	8.0 (2.9-18.5)
P* = 0.3	0.854	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.135	0.014	0.225	7.9 (3.0-18.2)
P* = 0.25	0.816	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.116	0.011	0.190	7.7 (3.0-17.7)
P* = 0.2	0.776	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.094	0.009	0.151	7.6 (3.0-17.5)
P* = 0.15	0.732	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.075	0.007	0.108	7.5 (3.0-17.0)
P* = 0.1	0.680	0.004	0.000	0.000	1.000	1.4 (1.4- 1.4)	0.058	0.005	0.072	7.3 (3.0-16.5)
P* = 0.05	0.610	0.004	0.000	0.000	0.999	1.4 (1.4- 1.4)	0.036	0.003	0.031	6.9 (2.9-15.7)

Table 11-8 Summary of the long-term consequences of the Tier 4 alternatives for Adak golden king crab under Tier 4. The column "retained catch" lists the posterior mean and 90% intervals for the catch of legal males in the directed fishery in 2038. The results in the table are based on σ_b=0.3.

Alternative	Multiplier for P*	With SOA control rule					No SOA control rule			
		Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Prob (SOA)	Retained catch (2038) ('000t)	Prob (Overfished) A	Prob (Overfished) B	Prob (overfishing)	Retained catch (2038) ('000t)
Multiplier = 1		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.006	0.000	0.451	13.2 (10.1-16.8)
Multiplier = 0.9		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.005	0.000	0.313	12.9 (9.6-16.4)
Multiplier = 0.8		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.200	12.4 (9.0-15.8)
Multiplier = 0.7		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.108	11.7 (8.2-15.3)
Multiplier = 0.6		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.001	0.000	0.049	10.8 (7.4-14.6)
Multiplier = 0.5		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.001	0.000	0.011	9.7 (6.5-13.5)
Multiplier = 0.4		0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.001	0.000	0.001	8.3 (5.4-12.2)
Multiplier = 0.3		0.001	0.000	0.000	0.998	1.3 (1.3- 1.3)	0.001	0.000	0.000	6.7 (4.3-10.3)
Multiplier = 0.2		0.001	0.000	0.000	0.984	1.3 (1.3- 1.3)	0.001	0.000	0.000	4.8 (3.0- 7.7)
Multiplier = 0.1		0.001	0.000	0.000	0.817	1.3 (1.3- 1.3)	0.001	0.000	0.000	2.7 (1.9- 3.9)
P* = 0.5	1.0	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.006	0.000	0.451	13.2 (10.1-16.8)
P* = 0.45	0.963	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.005	0.000	0.402	13.1 (9.9-16.6)
P* = 0.4	0.927	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.005	0.000	0.354	13.0 (9.7-16.5)
P* = 0.35	0.890	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.004	0.000	0.297	12.8 (9.5-16.4)
P* = 0.3	0.854	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.250	12.7 (9.3-16.1)
P* = 0.25	0.816	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.213	12.5 (9.1-15.9)
P* = 0.2	0.776	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.179	12.2 (8.8-15.7)
P* = 0.15	0.732	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.003	0.000	0.136	12.0 (8.5-15.5)
P* = 0.1	0.680	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.001	0.000	0.093	11.6 (8.1-15.1)
P* = 0.05	0.609	0.001	0.000	0.000	1.000	1.3 (1.3- 1.3)	0.001	0.000	0.055	10.9 (7.5-14.7)

Table 11-9 Summary of medium-term economic impacts of a subset of the ACL alternatives for Dutch Harbor golden king crab under Tier 4. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2009-2014, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty (σ_b=0.3). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show the results with and without SOA control rule, respectively.

(a) These projections apply the Tier 4 control rule (model based OFL).

		Present Value of Total Revenue, 2009-2014 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.8	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.6	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.4	104(63,138)	98(59,130)	89(55,118)	0	0
0.3	Multiplier = 1	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.8	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.6	104(63,138)	98(59,130)	89(55,118)	0	0
	Multiplier = 0.4	104(63,138)	98(59,130)	89(55,118)	0	0
0.3	P* = 0.5	104(63,138)	98(59,130)	89(55,118)	0	0
	P* = 0.4	104(63,138)	98(59,130)	89(55,118)	0	0
	P* = 0.3	104(63,138)	98(59,130)	89(55,118)	0	0
	P* = 0.2	104(63,138)	98(59,130)	89(55,118)	0	0
	P* = 0.1	104(63,138)	98(59,130)	89(55,118)	0	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2014 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	605(363,879)	575(347,828)	533(327,759)	0	0
	Multiplier = 0.8	518(308,742)	491(295,698)	455(276,640)	15	0
	Multiplier = 0.6	416(247,591)	394(236,556)	363(220,507)	31	0
	Multiplier = 0.4	297(176,418)	280(168,392)	258(156,356)	51	0
0.3	Multiplier = 1	575(312,975)	547(298,914)	506(279,841)	5	0
	Multiplier = 0.8	491(262,834)	466(249,790)	430(228,724)	19	15
	Multiplier = 0.6	393(203,678)	372(192,636)	343(179,580)	35	32
	Multiplier = 0.4	278(141,489)	262(135,463)	241(123,422)	54	52
0.3	P* = 0.5	575(312,975)	547(298,914)	506(279,841)	5	0
	P* = 0.4	546(294,922)	519(281,869)	480(261,799)	10	5
	P* = 0.3	515(276,871)	489(263,822)	451(242,759)	15	11
	P* = 0.2	481(255,819)	456(242,775)	420(222,708)	21	17
	P* = 0.1	434(227,742)	410(215,697)	380(198,639)	29	25

Table 11-10 Summary of medium-term economic impacts of a subset of the ACL alternatives for Adak golden king crab under Tier 4. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the six year period 2009-2014, and percentage differences in revenues relative to a zero buffer with and without additional uncertainty (σ). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty (σ_b=0.3). Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rue, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.8	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.6	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.4	93(57,125)	88(54,117)	80(50,106)	0	0
0.3	Multiplier = 1	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.8	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.6	93(57,125)	88(54,117)	80(50,106)	0	0
	Multiplier = 0.4	93(57,125)	88(54,117)	80(50,106)	0	0
0.3	P* = 0.5	93(57,125)	88(54,117)	80(50,106)	0	0
	P* = 0.4	93(57,125)	88(54,117)	80(50,106)	0	0
	P* = 0.3	93(57,125)	88(54,117)	80(50,106)	0	0
	P* = 0.2	93(57,125)	88(54,117)	80(50,106)	0	0
	P* = 0.1	93(57,125)	88(54,117)	80(50,106)	0	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2014 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	742(454,1058)	693(426,986)	628(390,888)	0	0
	Multiplier = 0.8	621(379,882)	579(355,821)	524(323,739)	16	0
	Multiplier = 0.6	485(296,688)	453(277,639)	408(252,577)	35	0
	Multiplier = 0.4	337(204,478)	314(192,444)	283(174,399)	55	0
0.3	Multiplier = 1	724(360,1205)	678(340,1128)	613(309,1019)	2	0
	Multiplier = 0.8	602(299,1037)	563(281,968)	510(253,866)	19	17
	Multiplier = 0.6	471(230,828)	440(215,768)	400(195,688)	37	35
	Multiplier = 0.4	328(156,586)	307(146,546)	277(133,490)	56	55
0.3	P* = 0.5	724(360,1205)	678(340,1128)	613(309,1019)	2	0
	P* = 0.4	682(339,1148)	638(319,1073)	576(289,966)	8	6
	P* = 0.3	637(316,1087)	596(297,1015)	538(269,907)	14	12
	P* = 0.2	586(291,1014)	549(273,944)	498(246,848)	21	19
	P* = 0.1	523(259,913)	489(242,853)	445(218,766)	29	28

Table 11-11 Summary of long-term economic impacts of a subset of the ACL alternatives for Dutch Harbor golden king crab under Tier 4. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the 30-year period 2009-2038, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ_b). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4), and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b=0.3. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.8	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.6	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.4	506(247,727)	354(178,505)	226(119,318)	0	0
0.3	Multiplier = 1	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.8	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.6	506(247,727)	354(178,505)	226(119,318)	0	0
	Multiplier = 0.4	506(247,727)	354(178,505)	226(119,318)	0	0
0.3	P* = 0.5	506(247,727)	354(178,505)	226(119,318)	0	0
	P* = 0.4	506(247,727)	354(178,505)	226(119,318)	0	0
	P* = 0.3	506(247,727)	354(178,505)	226(119,318)	0	0
	P* = 0.2	506(247,727)	354(178,505)	226(119,318)	0	0
	P* = 0.1	506(247,727)	354(178,505)	226(119,318)	0	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	3169(1346,5653)	2204(964,3814)	1390(671,2338)	0	0
	Multiplier = 0.8	2859(1209,5040)	1964(863,3385)	1235(591,2043)	11	0
	Multiplier = 0.6	2424(1020,4255)	1661(722,2826)	1025(490,1679)	25	0
	Multiplier = 0.4	1846(785,3202)	1248(546,2111)	760(365,1232)	43	0
0.3	Multiplier = 1	3066(1212,5808)	2110(868,3906)	1341(591,2445)	4	0
	Multiplier = 0.8	2731(1080,5290)	1877(767,3573)	1170(506,2236)	15	11
	Multiplier = 0.6	2310(881,4615)	1573(625,3102)	976(412,1908)	29	25
	Multiplier = 0.4	1741(641,3537)	1184(455,2423)	723(298,1434)	46	44
0.3	P* = 0.5	3066(1212,5808)	2110(868,3906)	1341(591,2445)	4	0
	P* = 0.4	2945(1166,5650)	2035(833,3829)	1283(562,2380)	8	4
	P* = 0.3	2818(1120,5450)	1946(800,3679)	1219(532,2305)	12	8
	P* = 0.2	2685(1058,5213)	1841(753,3518)	1149(494,2197)	16	13
	P* = 0.1	2504(958,4884)	1705(686,3291)	1055(451,2049)	23	19

Table 11-12 Summary of long-term economic impacts of a subset of the ACL alternatives for Adak golden king crab under Tier 4. Economic impacts are estimated as discounted present value of forecasted gross wholesale revenues over the 30-year period 2009-2038, and percentage differences in revenues relative to a zero buffer, with and without additional uncertainty (σ_b). Alternatives include fixed buffers (multipliers of 1, 0.8, 0.6 and 0.4) and P* levels (0.5, 0.4, 0.3, 0.2, and 0.1) and reflect effects of additional uncertainty, σ_b=0.3. Point estimates are medians and ranges are 90% confidence intervals. Tables (a) and (b) show results with and without SOA control rule, respectively.

(a) Results reflect the effect of the SOA control rule as a constraint.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.8	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.6	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.4	455(228,654)	319(164,455)	204(110,286)	0	0
0.3	Multiplier = 1	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.8	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.6	455(228,654)	319(164,455)	204(110,286)	0	0
	Multiplier = 0.4	455(228,654)	319(164,455)	204(110,286)	0	0
0.3	P* = 0.5	455(228,654)	319(164,455)	204(110,286)	0	0
	P* = 0.4	455(228,654)	319(164,455)	204(110,286)	0	0
	P* = 0.3	455(228,654)	319(164,455)	204(110,286)	0	0
	P* = 0.2	455(228,654)	319(164,455)	204(110,286)	0	0
	P* = 0.1	455(228,654)	319(164,455)	204(110,286)	0	0

(b) Results are exclusive of SOA control rule effect.

		Present Value of Total Revenue, 2009-2038 ($ Million)			**Percentage (%) Reduction in Gross Revenue Relative to Two Baseline Alternatives,**	
σ_b	**Alternative**	**r=0**	**r=2.7%**	**r=7.0%**	Baseline A :Multiplier=**1**, σ_b =**0.0**	Baseline B: Multiplier=**1**, σ_b =**0.3**
0	Multiplier = 1	4364(2171,6657)	2990(1522,4476)	1840(981,2738)	0	0
	Multiplier = 0.8	3859(1909,5901)	2618(1324,3936)	1597(847,2371)	12	0
	Multiplier = 0.6	3201(1575,4890)	2152(1086,3246)	1300(687,1929)	28	0
	Multiplier = 0.4	2369(1159,3616)	1577(793,2384)	941(495,1401)	47	0
0.3	Multiplier = 1	4195(1911,6745)	2860(1322,4642)	1763(834,2871)	4	0
	Multiplier = 0.8	3690(1640,6138)	2504(1139,4207)	1531(716,2558)	16	12
	Multiplier = 0.6	3055(1332,5347)	2065(916,3571)	1247(577,2141)	31	28
	Multiplier = 0.4	2273(971,4036)	1522(668,2686)	904(414,1595)	49	47
0.3	P* = 0.5	4195(1911,6745)	2860(1322,4642)	1763(834,2871)	4	0
	P* = 0.4	4024(1813,6593)	2743(1253,4506)	1677(793,2776)	8	4
	P* = 0.3	3841(1720,6359)	2608(1200,4336)	1595(750,2661)	13	9
	P* = 0.2	3621(1617,6117)	2451(1111,4150)	1502(701,2510)	18	14
	P* = 0.1	3329(1478,5736)	2255(1004,3872)	1375(635,2313)	25	21

Table 11-13 Years and values of retained catch (pounds and tonnes) used to compute the 2009/10 AIGKC Tier 5 retained-catch OFL and sample statistics (sample size, mean, standard deviation, and standard error of the mean and CV=ratio of standard error of mean to the mean).

Years	Retained Catch (pounds)	Retained Catch (tonnes)
1985/86	12,734,212	5776.2
1986/87	14,738,744	6685.5
1987/88	9,257,005	4198.9
1988/89	10,627,042	4820.4
1989/90	12,022,052	5453.2
1990/91	6,950,362	3152.7
1991/92	7,702,141	3493.7
1992/93	6,291,197	2853.7
1993/94	5,551,143	2518.0
1994/95	8,128,511	3687.1
1995/96	6,960,406	3157.2
n	11	11
Mean	9,178,438	4163.3
Std. dev.	2,973,391	1348.7
Std. error	896,511	406.7
CV	0.10	0.10

Table 11-14 Tier 5 ABCs (retained catch, tonnes) and buffers for alternative values of P* between 0.1 and 0.50 in increments of 0.1 computed for the AIGKC by assuming that the sample mean of retained catch for the chosen period of n = 11 years has a t-distribution with n-1 degrees of freedom (see Equation 3.3); for comparison, the 2009/10 AIGKC Tier 5 OFL was 9.18-million lbs (4,164t) of retained catch and TAC was 5.985 million lbs (2,715t).

P*	ABC	Multiplier	Buffer	Revenue ($Millions)
0.5	4,164	1.00	0%	
0.4	4,060	0.97	3%	
0.3	3,942	0.95	5%	
0.2	3,806	0.91	9%	
0.1	3,606	0.87	13%	

Table 11-15 Effect of use of an extra variance term, σ_2, added to the measure of uncertainty (standard error of mean) to compute buffers for the AIGKC stock and resulting Tier 5 ABCs (retained catch, tonnes) when applied to the 2009/10 Tier 5 OFL for each of four values of σ_2, determined by $\sigma = CV \cdot OFL$, for values of CV = 0 (i.e., no extra variance term added), 0.2, 0.3, and 0.4, , and values of P* from 0.1 to 0.5 in increments of 0.1 (see Equation 3.4); for comparison, the 2009/10 AIGKC Tier 5 OFL was 9.18 million lbs (4,164t) of retained catch and TAC was 5.985-million pounds (2,715t).

	CV=0				CV=0.2				CV=0.3				CV=0.4			
P*	Multiplier	Buffer	ABC	Revenue ($Million)	Multiplier	Buffer	ABC	Revenue ($Million)	Multiplier	Buffer	ABC	Revenue ($Million)	Multiplier	Buffer	ABC	Revenue ($Million)
0.5	1.00	0%	4,164		1.00	0%	4,164		1.00	0%	4,164		1.00	0%	4,164	
0.4	0.97	3%	4,060		0.94	6%	3,924		0.92	8%	3,819		0.89	11%	3,719	
0.3	0.95	5%	3,942		0.88	12%	3,661		0.83	17%	3,452		0.78	22%	3,234	
0.2	0.91	9%	3,806		0.80	20%	3,348		0.72	28%	3,007		0.64	36%	2,658	
0.1	0.87	13%	3,606		0.69	31%	2,894		0.57	43%	2,359		0.43	57%	1,810	

Table 11-16 Buffers for the AIGKC stock computed according to Equation 3.1.3.2.3 and resulting Tier 5 ABCs (retained catch, tonnes) for alternative values of P* between 0.1 and 0.50 in increments of 0.1 with buffers computed from Equation 3.5 provided for comparison; n = number of years in time period used to compute the OFL; l = the time lag since the last year in the time period used to compute the OFL. For comparison, the 2009/10 AIGKC Tier 5 OFL was 9.18-million pounds (4,164) of retained catch and TAC was 5.985 million lbs (2,715t).

n =	11			
l =	13			
(1+*l*/*n*) =	2.18			
P*	Multiplier	Buffer	ABC	Revenue ($Million)
0.5	1.00	0%	4,164	
0.4	0.94	6%	3,933	
0.3	0.88	12%	3,683	
0.2	0.81	19%	3,384	
0.1	0.71	29%	2,944	

Table 11-17 Values of P* computed for fixed buffers with values ranging from 0.1 to 1.0 in increments of 0.1 as computed under the assumptions for Equation 3.3 (P*, no additional uncertainty added), Equation 3.4 (P*σ, CV, additional uncertainty with specified CV), and Equation 3.5 (P^*_l, added uncertainty to account for time lag since the last year of the time period used to compute the OFL) for the AIGKC stock under Tier 5. For comparison, the ratio of the 2009/10 AIGKC TAC (5.985 million lbs = 2,715t) to the 2009/10 AIGKC Tier 5 OFL (9.18 million lbs = 4,164t of retained catch) [the buffer] was 0.652.

Multiplier	Buffer	P*	$P^*_{\sigma,CV=0.2}$	$P^*_{\sigma,CV=0.3}$	$P^*_{\sigma,CV=0.4}$	$P^*_{\sigma,CV=0.6}$	P^*_l
1	0%	0.500	0.500	0.500	0.500	0.500	0.500
0.9	10%	0.165	0.331	0.379	0.407	0.436	0.324
0.8	20%	0.034	0.195	0.270	0.319	0.374	0.185
0.7	30%	0.006	0.104	0.182	0.241	0.316	0.095
0.6	40%	0.001	0.051	0.117	0.177	0.263	0.045
0.5	50%	0.000	0.024	0.072	0.126	0.215	0.020
0.4	60%	0.000	0.011	0.043	0.088	0.173	0.009
0.3	70%	0.000	0.005	0.025	0.060	0.138	0.004
0.2	80%	0.000	0.002	0.015	0.040	0.109	0.002
0.1	90%	0.000	0.001	0.009	0.027	0.085	0.001

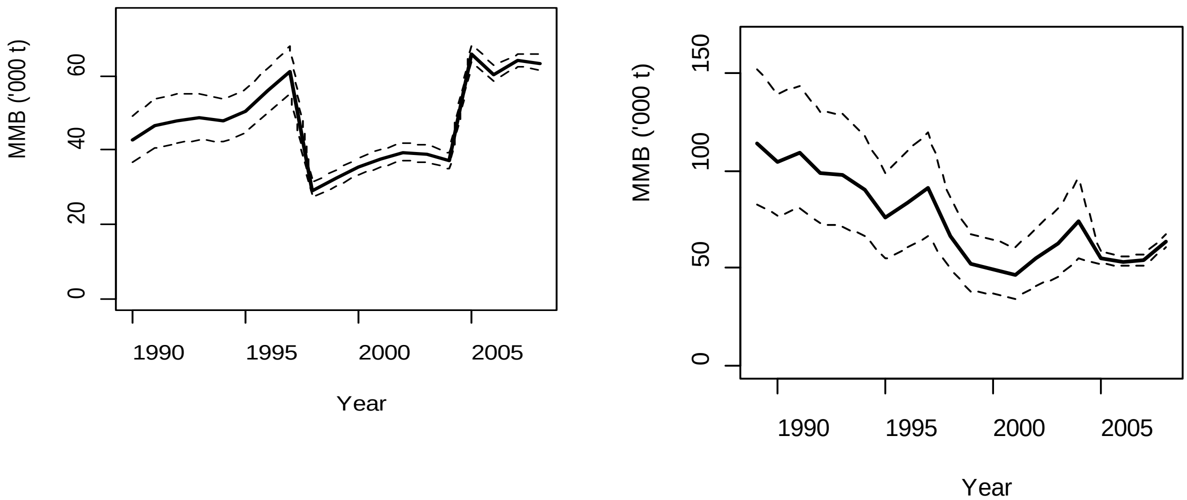


Figure 11-1 Time-trajectory of mature male biomass (MMB) at the time of mating for Dutch Harbor golden king crab (left panel) and Adak golden king crab (right panel) under Tier 4.

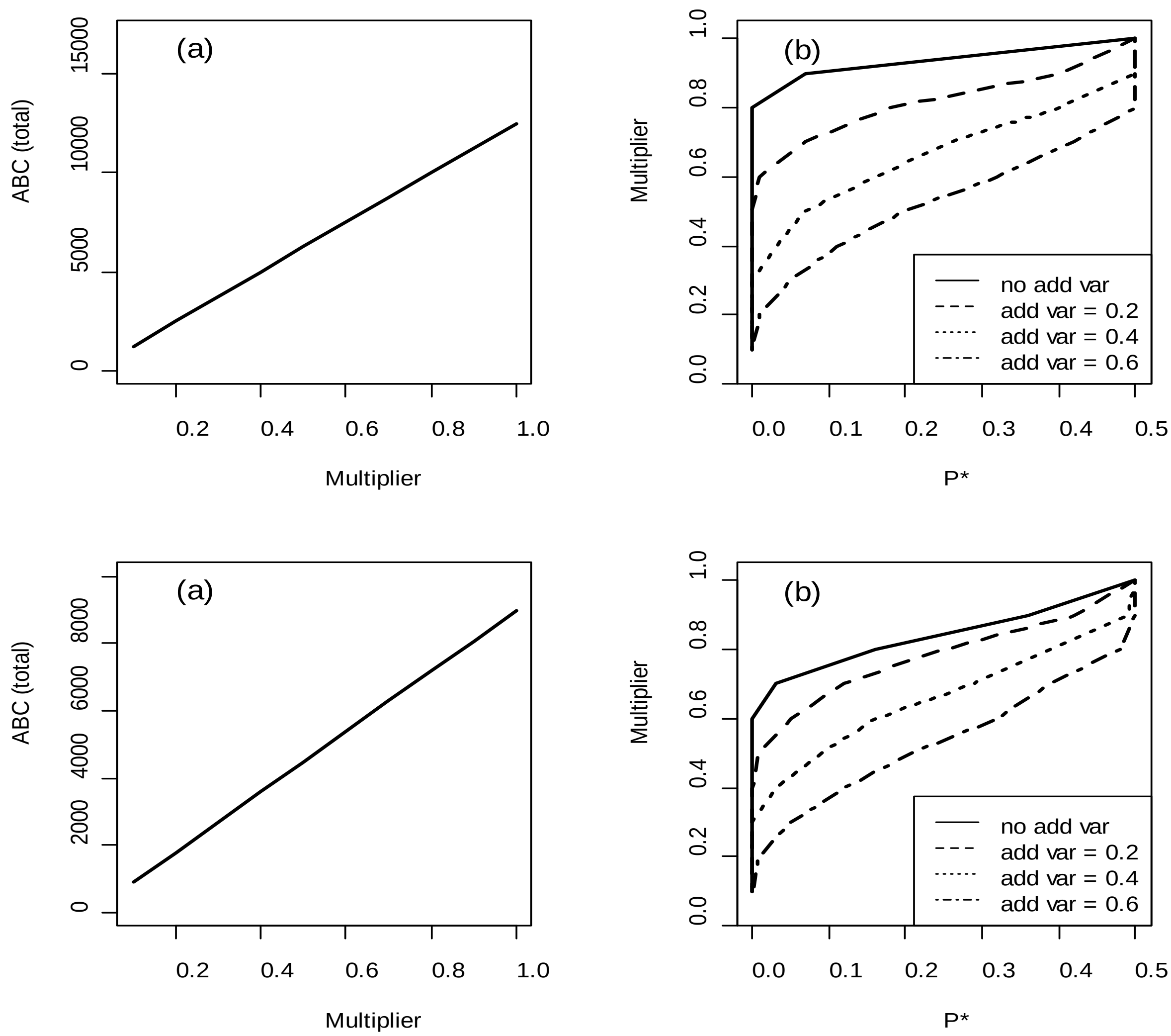


Figure 11-2 Relationship between the multiplier and the Tier 4 ABC (a), and the relationships between P* and the multiplier for four values for the extent of additional uncertainty (b). Results are shown for Dutch Harbor golden king crab in the upper panels and for Adak golden king crab in the lower panels.

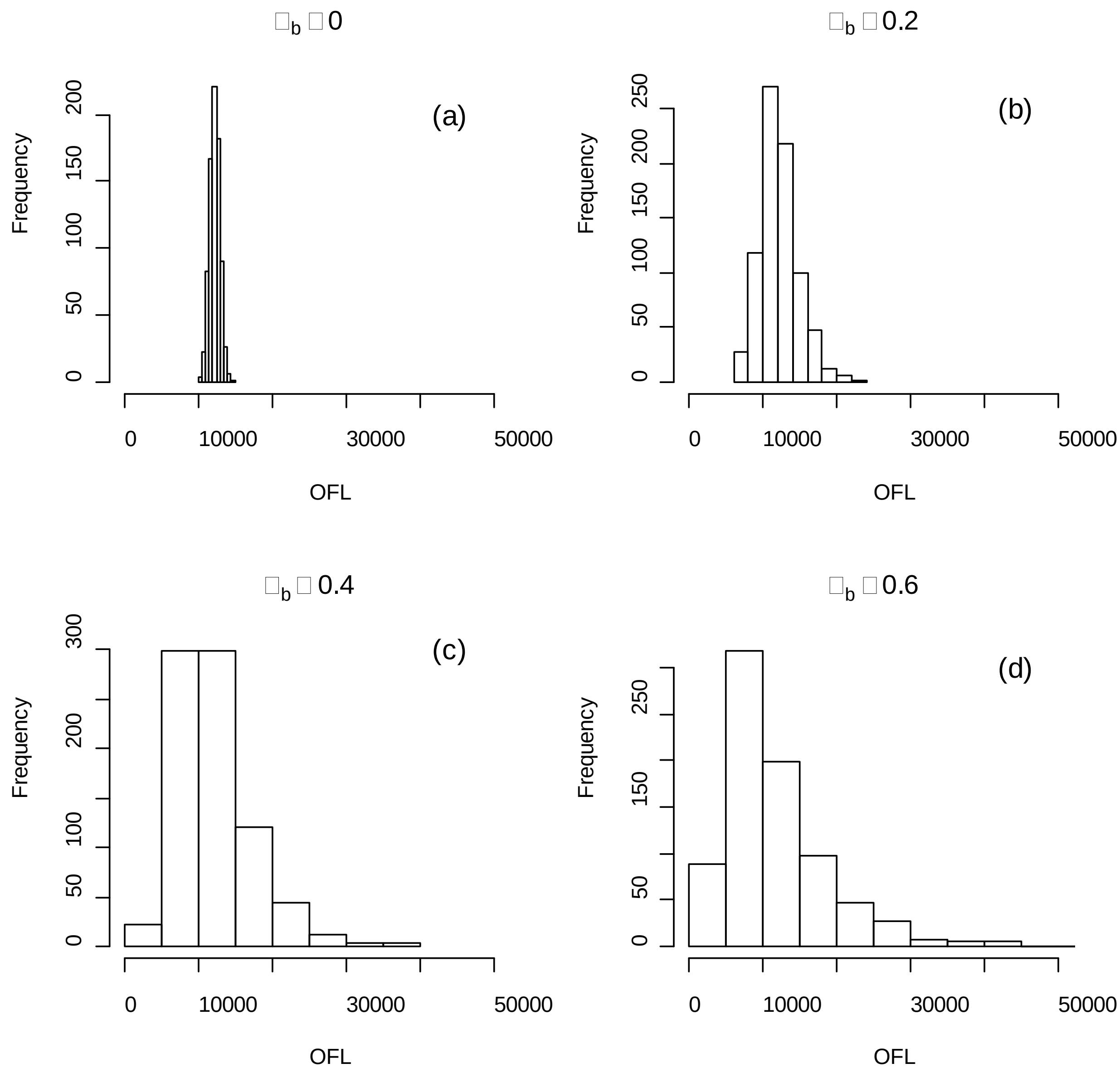


Figure 11-3 Distribution of Tier 4 OFL values as a function of the assumed extent of additional uncertainty (σ_b) for Dutch Harbor golden king crab.

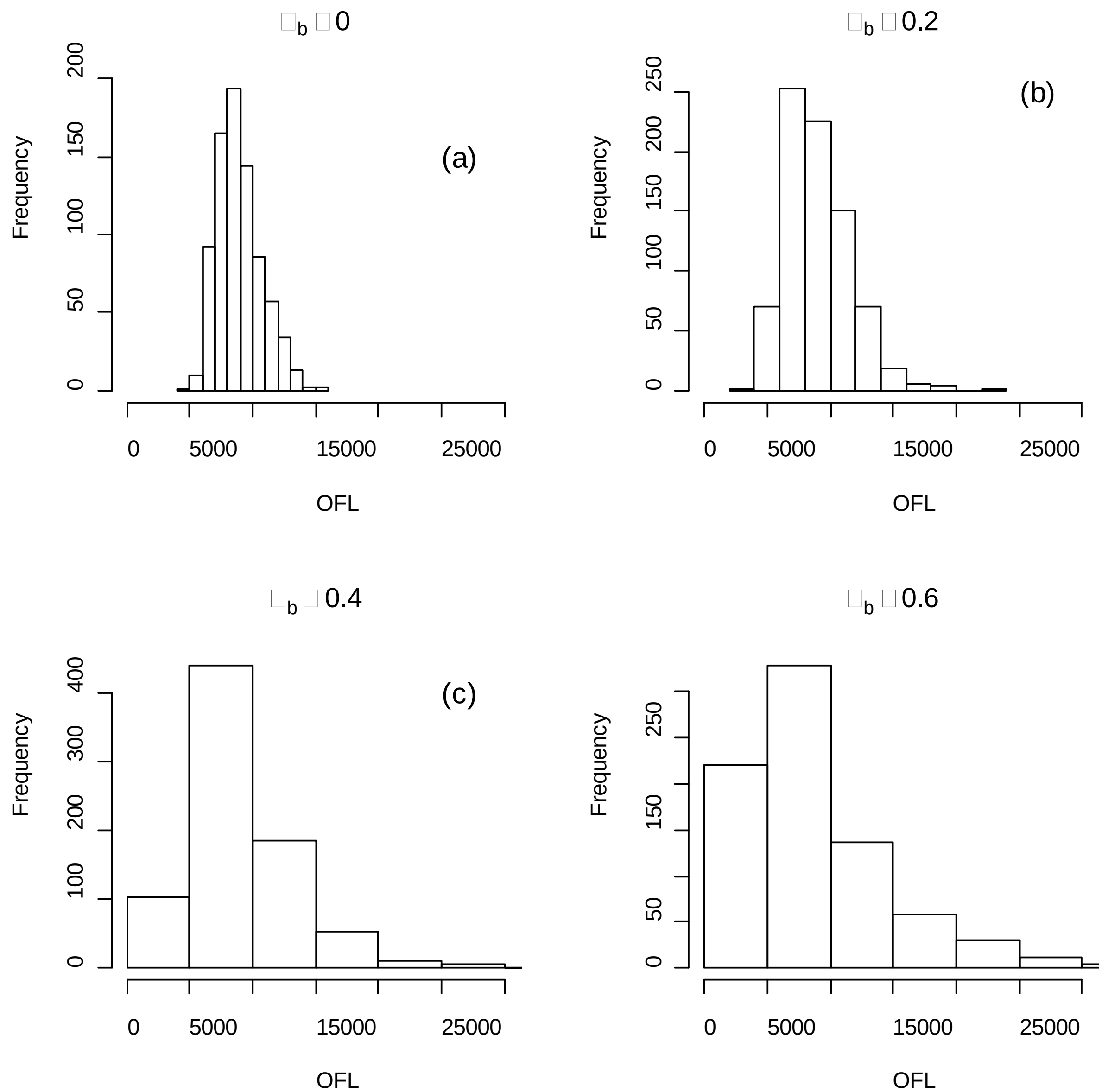


Figure 11-4 Distribution of Tier 4 OFL values as a function of the assumed extent of additional uncertainty (σ_b) for Adak golden king crab.

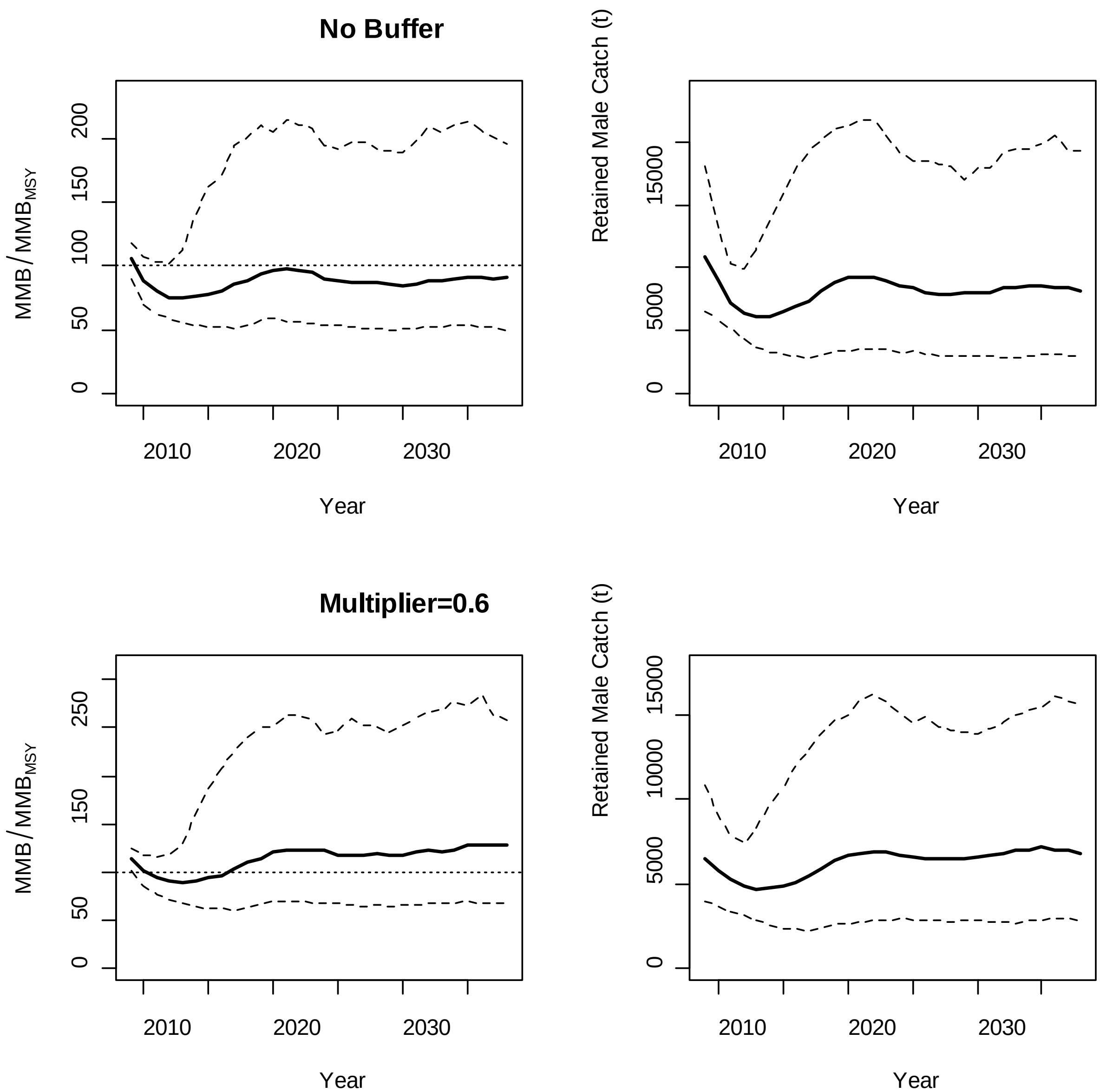


Figure 11-5 Time-trajectories of MMB at mating relative to the proxy for B_{MSY} (mean MMB) and catch, for projections based on two choices for the buffer between the Tier 4 OFL and the ABC for Dutch Harbor golden king crab. The results in the figure are based on σ_b=0.3 and on not applying the SOA control rule.

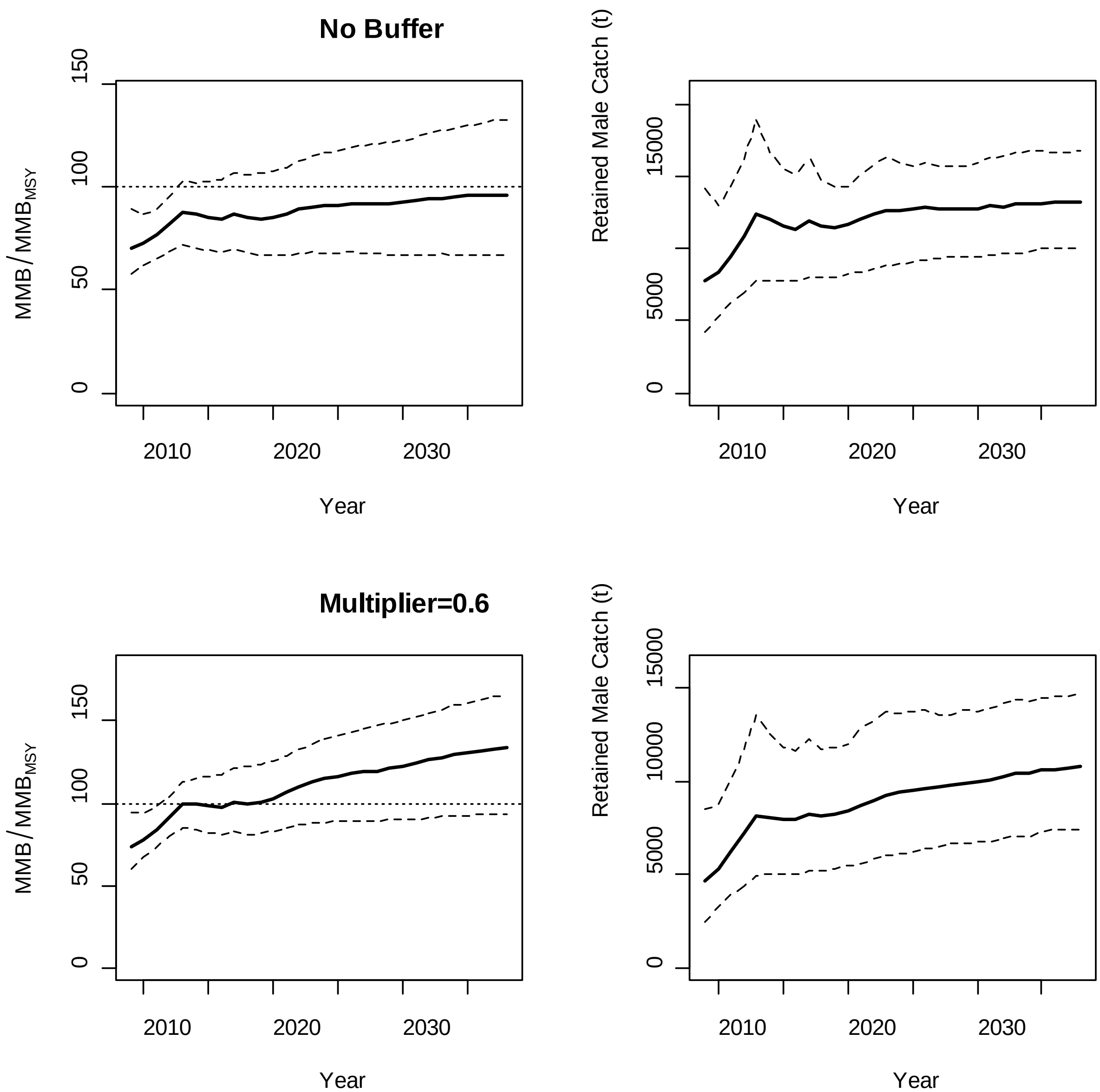


Figure 11-6 Time-trajectories of mature male biomass (MMB) at mating relative to the proxy for B_{MSY} (mean MMB) and catch, for projections based on two choices for the buffer between the Tier 4 OFL and the ABC for Adak golden king crab. The results in the figure are based on σ_b=0.3 and on not applying the SOA control rule.

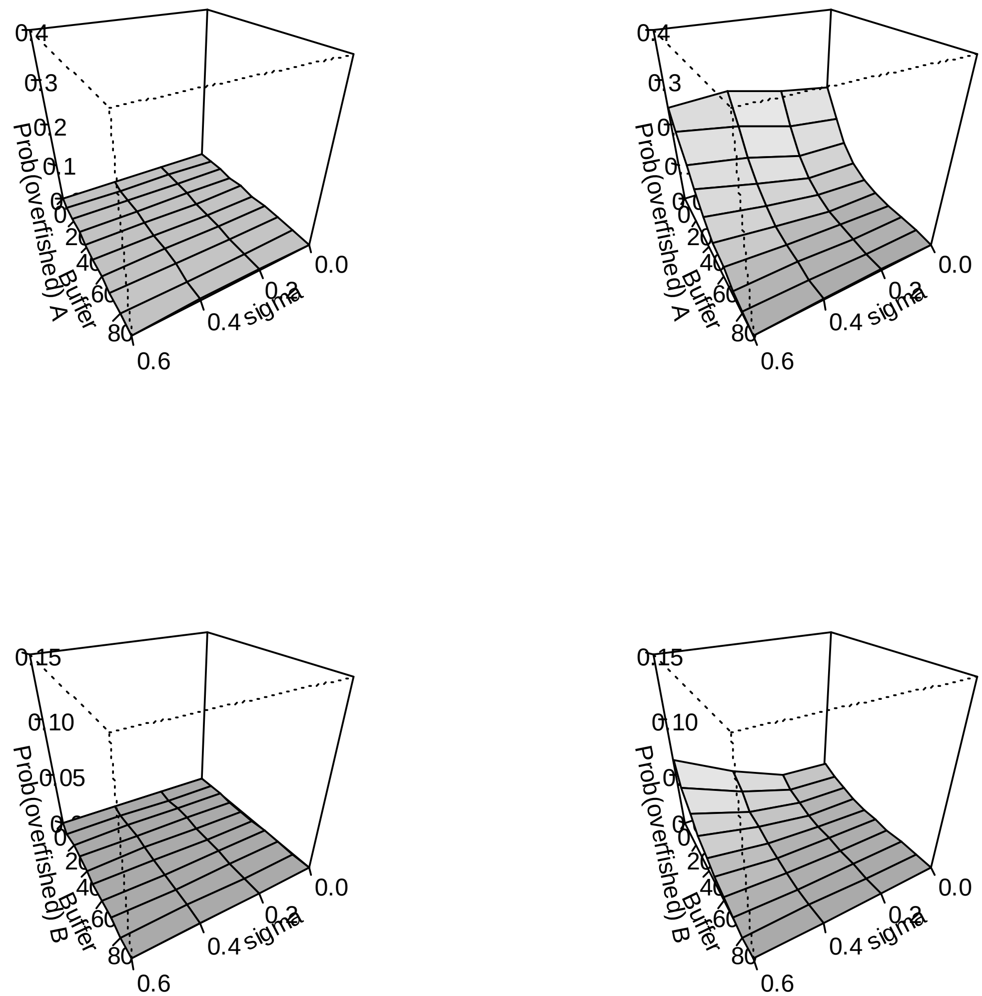


Figure 11-7 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Dutch Harbor golden king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

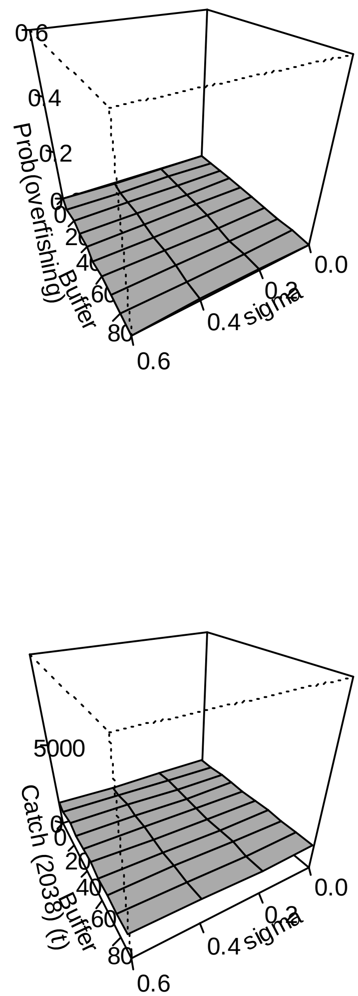


Figure 11-8 Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Dutch Harbor golden king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.

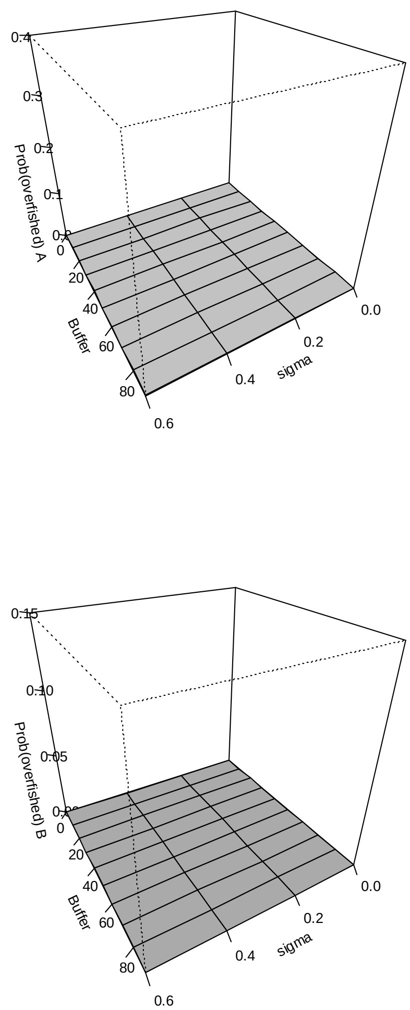


Figure 11-9 **Relationships between the probability of being overfished (once in the 30-year projection period; upper panels) and on annual basis (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Adak golden king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

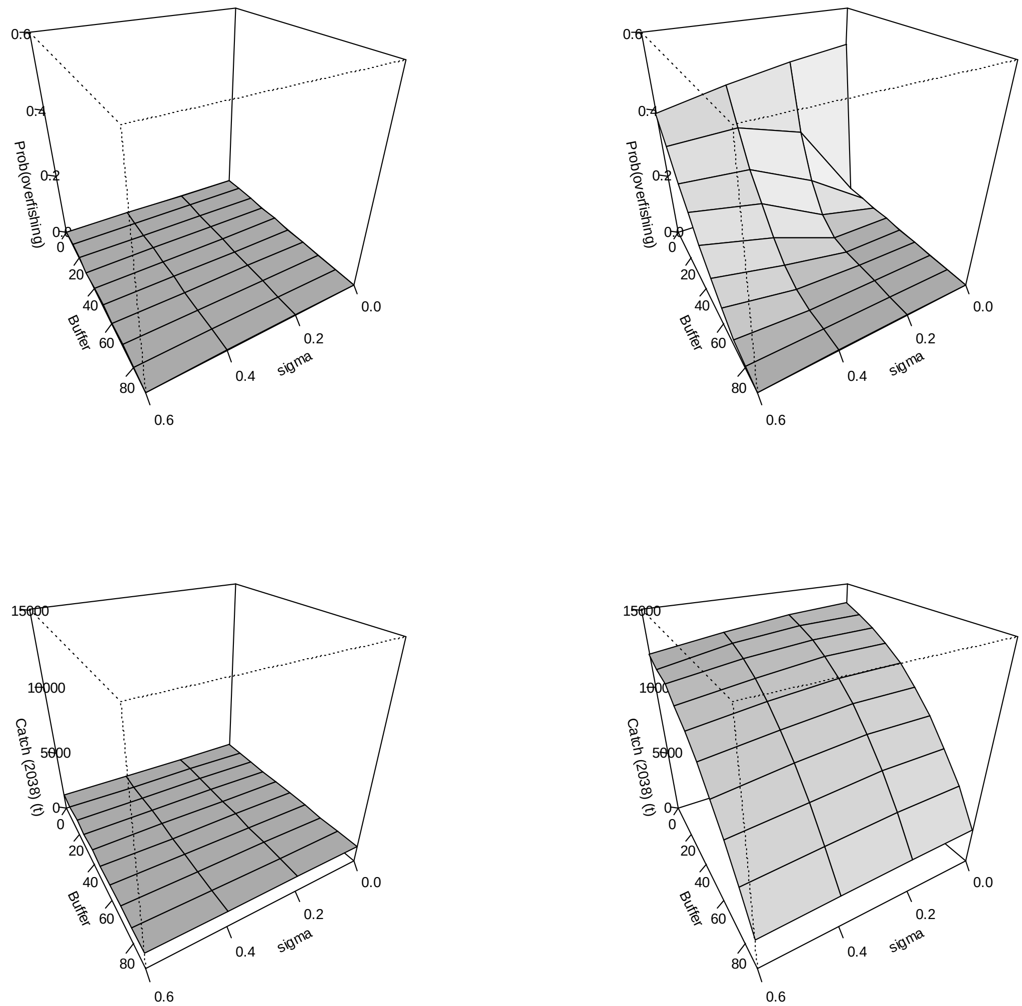


Figure 11-10 **Relationships between the probability of overfishing occurring on annual basis (upper panels) and catch (lower panels) and the extent of additional uncertainty and the buffer between the ABC and the OFL for Adak golden king crab. Results are shown in the left panels when the SOA control rule is imposed and in the right columns when this control rule is ignored.**

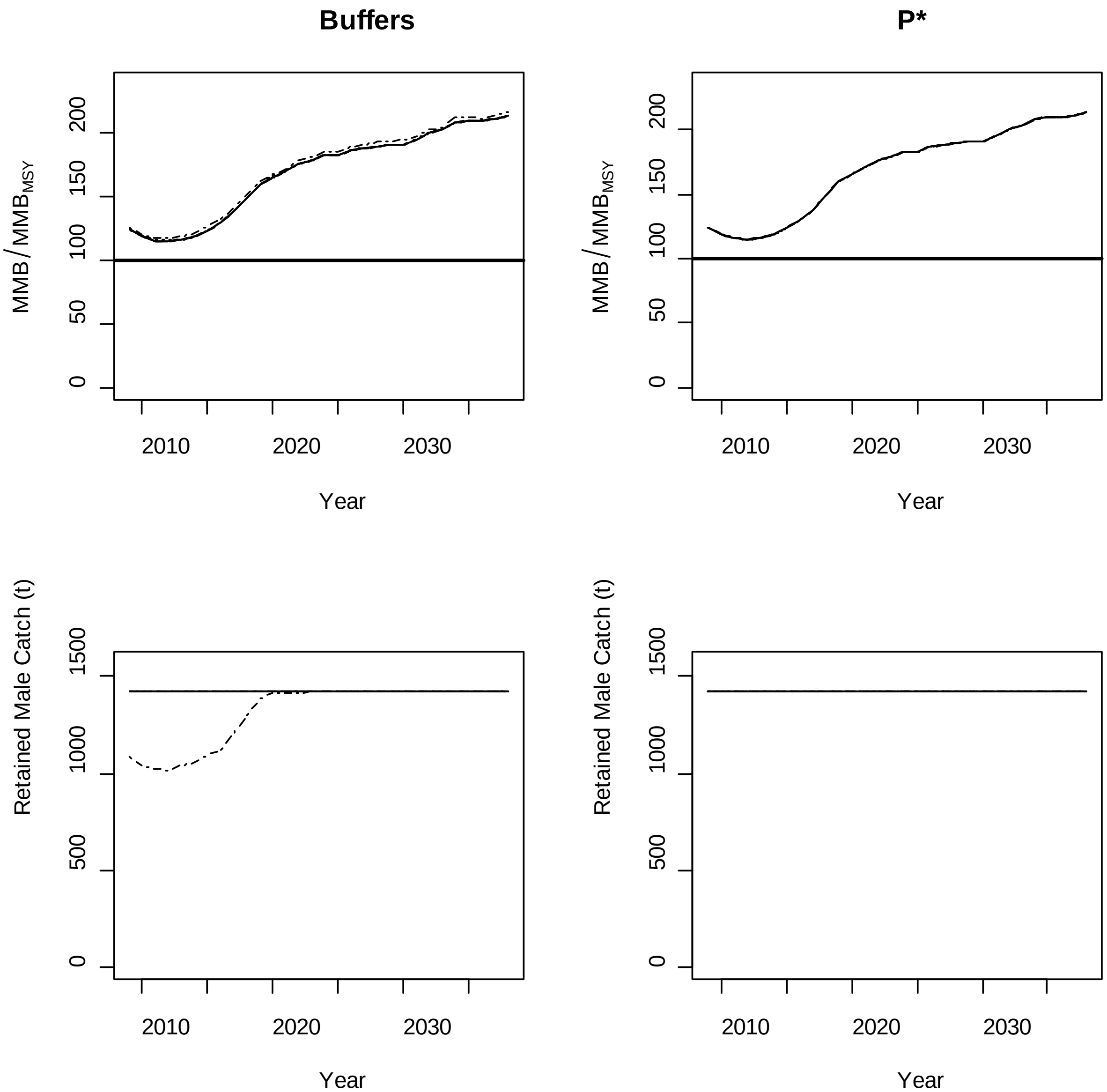


Figure 11-11 Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (mean MMB) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are for Dutch Harbor golden king crab and are based on σ_b=0.3 and imposing the SOA control rule.

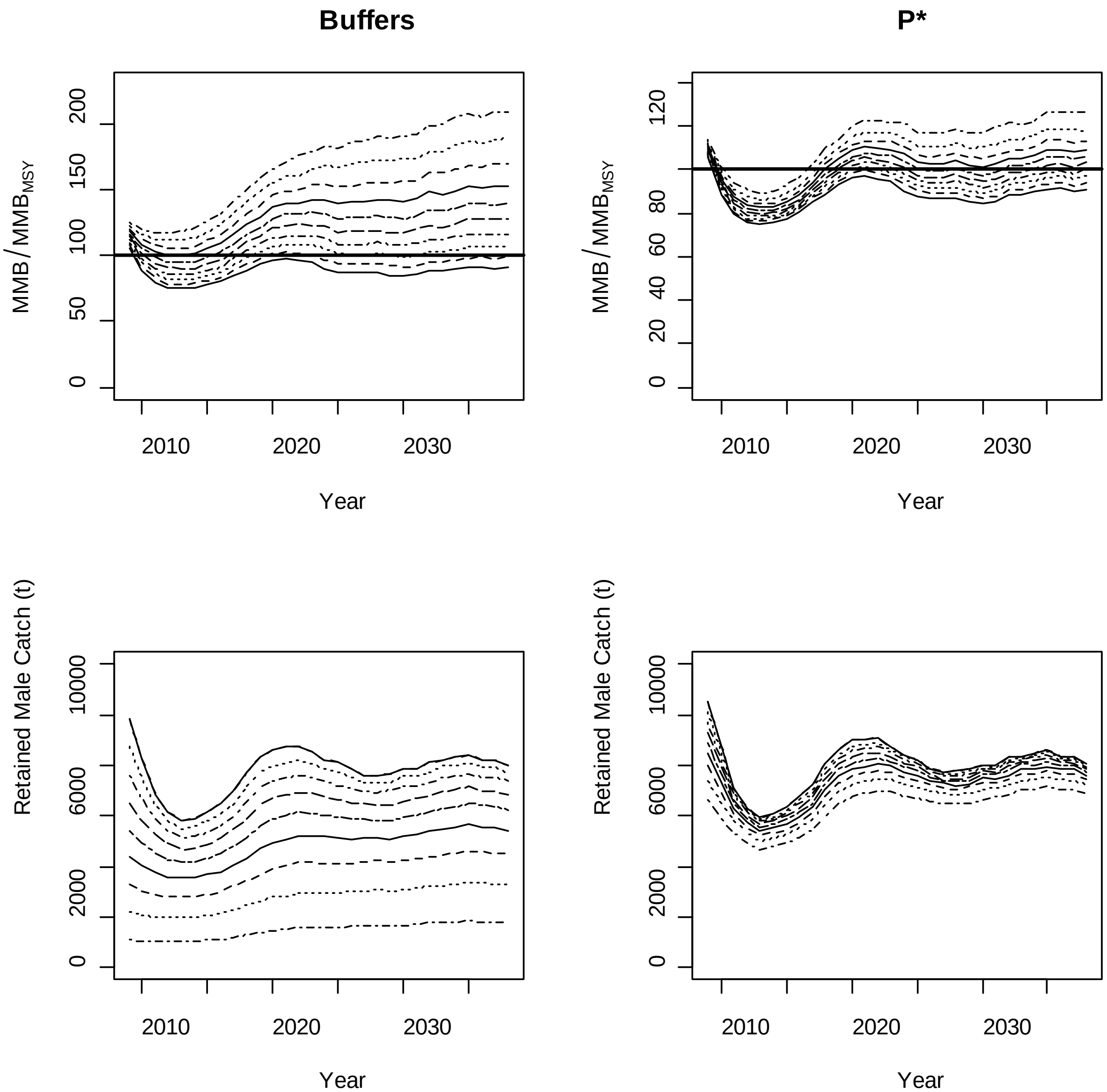


Figure 11-12 Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (mean MMB) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are for Dutch Harbor golden king crab and are based on σ_b=0.3 and not imposing the SOA control rule.

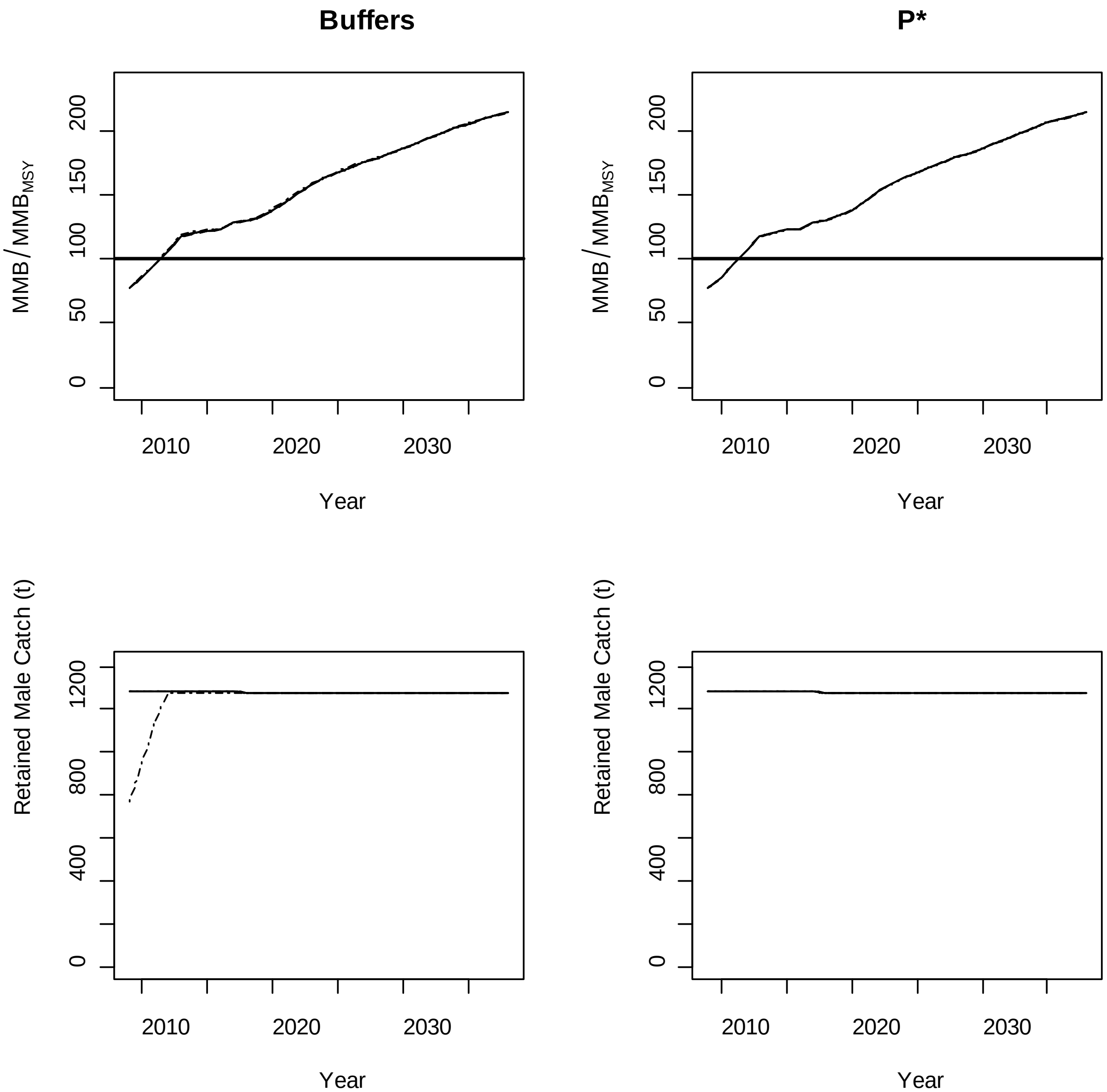


Figure 11-13 Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for BMSY (mean MMB) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are for Adak golden king crab and are based on σ_b=0.3 and imposing the SOA control rule.

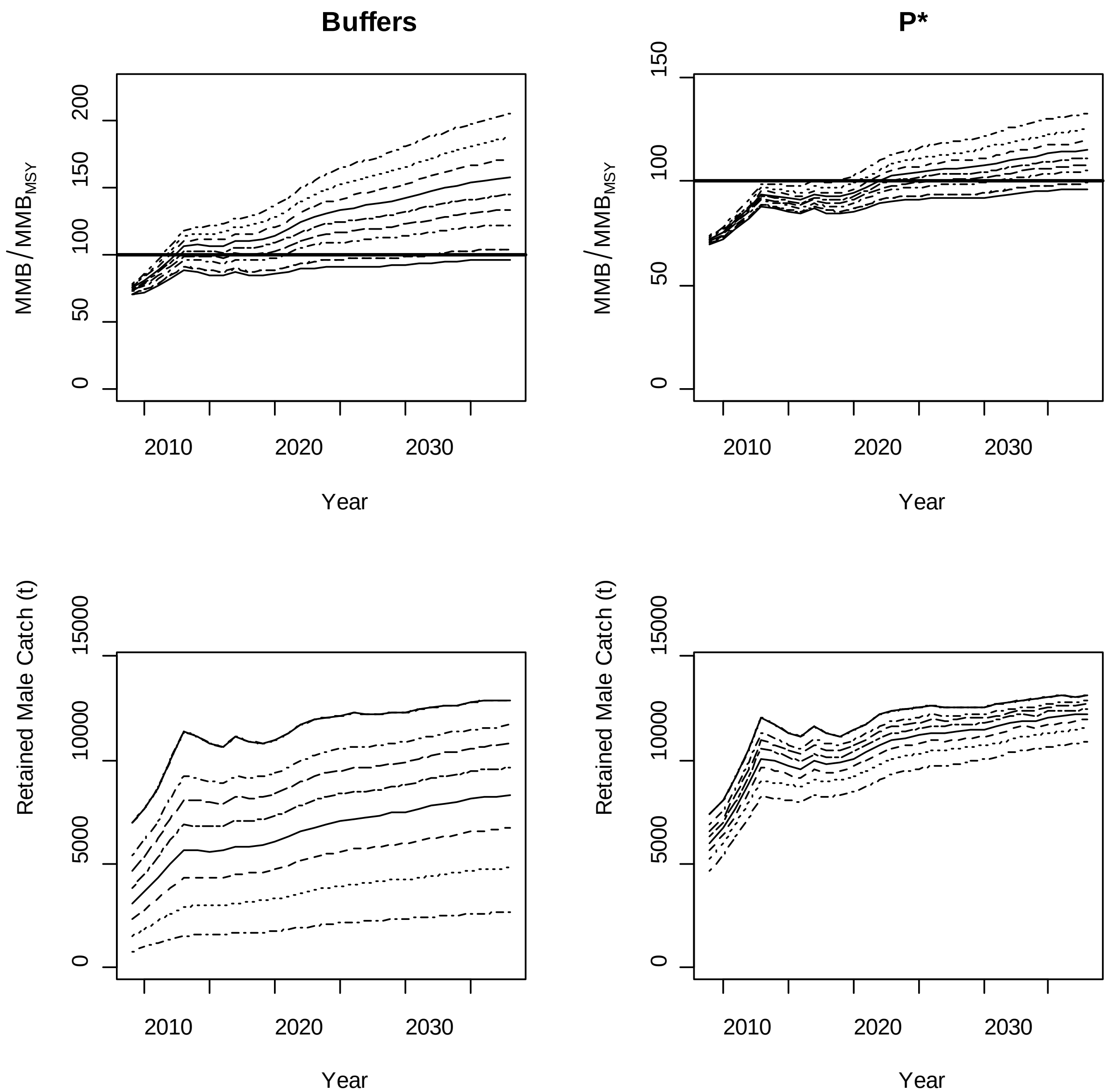


Figure 11-14 **Median time-trajectories of mature male biomass (at the time of mating) relative to the proxy for B_{MSY} (mean MMB) and median time-trajectories of the catch of legal males in the directed fishery for 10 multiplier values and 10 choices for P*. The results in the figure are for Adak golden king crab and are based on σ_b=0.3 and not imposing the SOA control rule.**

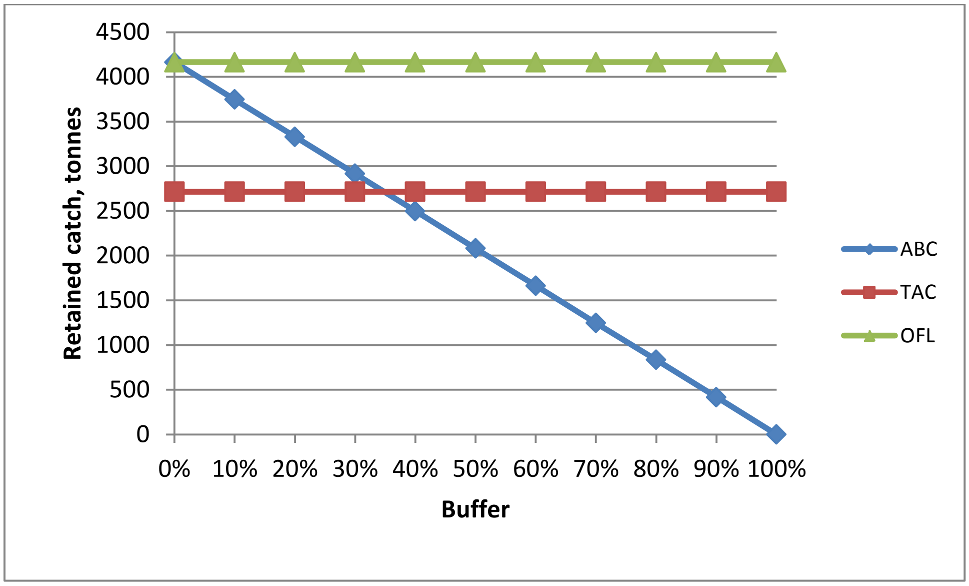


Figure 11-15 Effects of values of buffers, *B*, from 0% to 100% on the Tier 5 ABC (retained catch, tonnes) for AIGKC stock relative to the 2009/10 Tier 5 OFL and TAC expressed in tonnes.

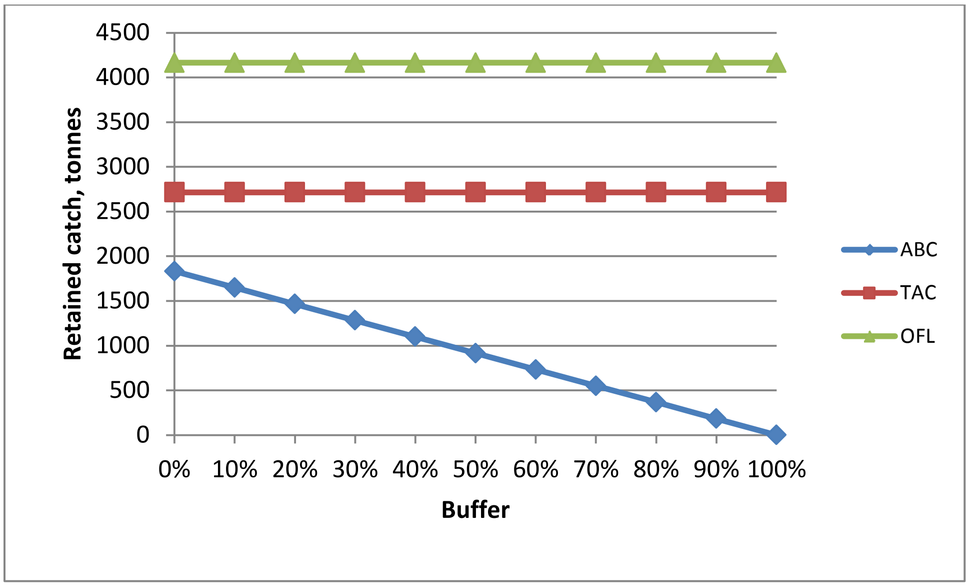


Figure 11-16 Effects of scaling multipliers (=1-buffer) by the ratio of the years in time period used for computing the 2009/10 AIGKC Tier 5 ABC (retained catch, tonnes) to the estimated life span of the species for the values of buffers, *B*, from 0.1 to 1.0 in increments of 0.1 on the ABC (retained catch, tonnes) for AIGKC stock relative to the 2009/10 Tier 5 OFL and TAC expressed in tonnes.

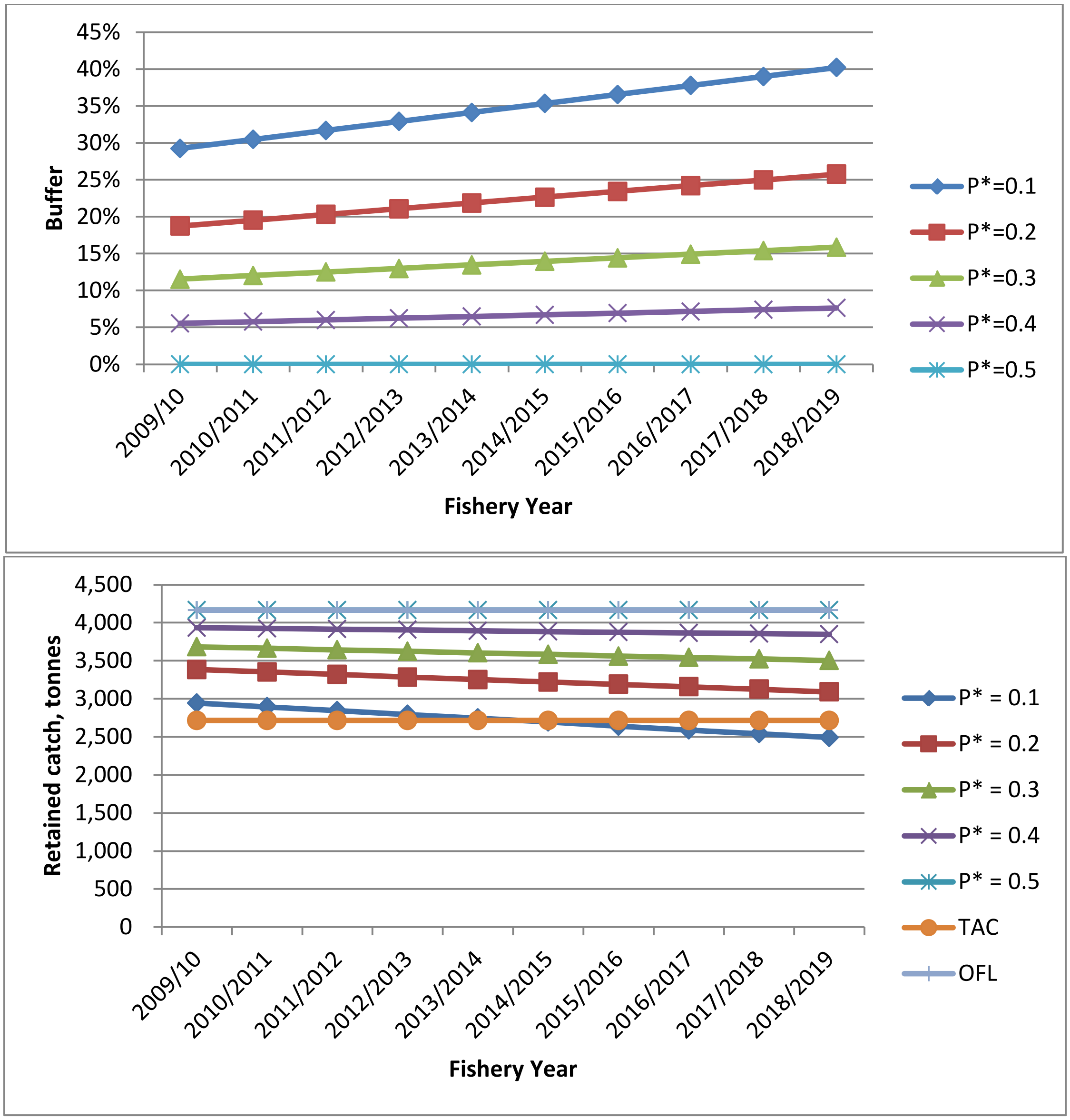


Figure 11-17 Effects on buffers (top panel) and Tier 5 ABCs (retained catch, tonnes; bottom panel) of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period (assumed to be 1993–1998) used to compute the AIGKC Tier 5 OFL for each year in 2009/10–2018/19 according to Equation 3.5 for given values of P* as compared to the 2009/10 OFL and TAC; the OFL and TAC are assumed to remain constant during 2009/10–2018/19 and are expressed in tonnes.

12 Pribilof Island Golden King Crab

The Pribilof Islands golden king (PIGKC) crab stock boundary is defined by the boundaries of the Pribilof District of Registration Area Q (Figure 1). Bowers et al. (2008, page 84) define those boundaries:

> The Bering Sea king crab Registration Area Q has as its southern boundary a line from 54° 36' N lat., 168° W long., to 54° 36' N lat., 171° W long., to 55° 30' N lat., 171° W. long., to 55° 30' N lat., 173° 30' E long., as its northern boundary the latitude of Point Hope (68° 21' N lat.), as its eastern boundary a line from 54° 36' N lat., 168° W long., to 58° 39' N lat., 168° W long., to Cape Newenham (58° 39' N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991. Area Q is divided into the Pribilof District, which includes waters south of Cape Newenham, and the Northern District, which incorporates all waters north of Cape Newenham.

Commercial fishing for golden king crab in the Pribilof District has been concentrated in the Pribilof Canyon. Results of the 2002, 2004, and 2008 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009) and of the 2004 survey presented by Hoff and Britt (2005) show the estimated biomass, number, and density (kg/ha and number/ha) of golden king crabs on the eastern Bering Sea continental slope to be higher in the southern areas than in the northern areas. Highest estimates of densities, biomass, and abundance of golden king crabs in the Bering Sea occur in the Pribilof Canyon (Hoff and Britt 2005, Haaga et al. 2009), as does most of the commercial catch of golden king crabs (Bowers et al. 2008, Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006).

Commercial fishing for golden king crabs in the Bering Sea typically occurs at depths of 100–300 fathoms (183–549 m; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006); average depth of pots fished in the PIGKC fishery during the 2002 fishery (the most recently prosecuted fishery for which fishery observer data are not confidential) was 214 fathoms (391 m). Results of the 2002, 2004, and 2008 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009) and of the 2004 survey presented by Hoff and Britt (2005) show the majority of golden king crabs on the eastern Bering Sea continental slope occurring in the 200–400 m and 400–600 m depth ranges.

The commercial fishery is managed on a calendar year basis and is not rationalized so that the fishery is managed by the SOA towards a GHL that is established preseason, rather than towards a TAC.

12.1 Assessment overview

The 2010 OFL for PIGKC was established as 0.17-million pounds (77 tonnes) of retained catch (October 2009 SSC minutes). That OFL was computed as the average of the annual retained catch during 1993–1998 (173,722 pounds, or 79 tonnes), rounded to the nearest 0.01-million pounds.

No assessment model for the PIGKC stock exists and none is in development. Accordingly, it has been recommended by NPFMC (2007) and by the CPT and SSC in 2008 and 2009 that the PIGKC stock be managed as a Tier 5 stock. For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST without an estimate of biomass, and "the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock" (NMFS 2008). No B_{MSY} estimate or proxy and no overfished determination (i.e., MSST) is possible for this stock given the limited information and analysis on stock biomass; there are presently no estimates of mature male biomass or mature female biomass for this stock.

Standardized bottom trawl surveys to assess the groundfish and invertebrate resources of the eastern Bering Sea upper continental slope have been performed in 2002, 2004, and 2008 (Hoff and Britt 2005, Haaga et al. 2009). The data from those surveys have not been incorporated into the PIGKC assessment process, however, because only summaries of results and total stock biomass (all sizes, both sexes) estimates have been published for the 2004 survey (Hoff and Britt 2005) and reported for the 2002, 2004, and 2008 surveys (Hagga et al. 2009); estimation of abundance and biomass of golden king crab in the Pribilof District by relevant size, sex, and reproductive-status classes (e.g., mature male biomass, mature female biomass, legal-sized male biomass, etc) have yet to be performed. The selectivity for golden king crabs, by sex and size, by the currently-used survey gear is unknown and has not been estimated. Additionally, a pilot slope survey was also performed in 2000 and triennial surveys using a variety of nets, methods, vessels, and sampling locations were performed during 1979–1991 (Hoff and Britt 2005). However, the “degree of comparability between the post-2000 surveys and those conducted from 1979 to 1991 has yet to be determined due to the differences in sampling gear, survey design, sampling methodology, and species identification” (Hoff and Britt 2005).

12.1.1 Uncertainty in stock assessment

No assessment model for the PIGKC stock exists and none is in development. There is large uncertainty on whether the retained catch data and time period chosen to compute the retained-catch OFL actually provides data that are “representative of the production potential of the stock.” There is only limited fishery data available for the computing a retained-catch OFL for the PIGKC stock and only a restricted range of alternatives time periods that can be considered: In 10 of the 12 seasons prior to the 1993 season, there was either no fishery effort (five seasons) or the fishery data are confidential (five seasons) and in the seven completed seasons after 2002 (i.e., 2003–2009), fishery data for 2003–2005 are confidential and there was no fishery effort in 2006–2009. Uncertainty on the OFL for the PIGKC stock exists due to the short length of the time period (6 years) from which average retained catch was computed relative to the life span of the species (assumed to be 25 years following Zheng and Siddeek 2009). Moreover, there is qualitatively greater uncertainty on the productivity of the PIGKC stock relative to the other Tier 5 golden king crab stock (i.e., the Aleutian Islands stock) due to the limited history of participation in the PIGKC fishery participation and paucity of fishery data available for the PIGKC stock relative to the Aleutian Islands golden king crab stock. Additionally, the time (11 years) since the last year of the time period (1993–1998) used to compute the 2010 OFL increases uncertainty on the OFL because of uncertainty that the time period is applicable to present conditions of the stock and environment. Finally, the minimum value of the annual retained catch from the fishery since 1984 relative to the OFL also provides a qualitative measure of relative uncertainty on the OFL; the minimum of the annual retained catch from the PIGKC stocks was zero (Pengilly 2009c).

12.2 Impacts of alternatives

As described in Chapter 3, there are two alternatives under consideration for computing a Tier 5 retained-catch ABC for PIGKC: (a) the retained-catch OFL can be multiplied by a pre-specified multiplier (=1-buffer; Alternative 2 and Alternative 4), or (b) a distribution can be computed for the retained-catch OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternative 3).

The analyses of impacts in this chapter are based on the assumption that, like the OFL, the ACL and ABC are defined in terms of retained catch only and that the ACL equals the lower of the ABC and the retained catch corresponding to the GHL that has been specified preseason by SOA since 2000 (150,000 pounds, or 68 tonnes).

The short- and medium-term implications of the alternatives for calculating the ABC are evaluated in this chapter. The short-term implications are assessed by impact of the alternatives for the buffer and P* on the ABC which would have been advised for the 2010 fishery (assuming that ABCs had been specified for that fishery), whereas the medium-term implications are evaluated by projecting the impacts of alternative during the 2010–2019 fishery seasons under the assumptions that the retained catch equals the lower of the ABC and a 150,000-pound (68-tonne) GHL; the SOA has managed the fishery to a 150,000-pound (68-tonne) GHL since 2000 and would presumably continue to manage the fishery to that GHL through 2019 if not constrained by an ABC determined to be <0.15-million pounds (68 tonnes).

Due to the lack of an assessment model for the PIGKC stock and lack of reliable biomass estimates, the implications of a buffer (either the fixed buffer or the P*-based buffer) cannot be estimated in terms of effects to stock biomass beyond computing the removals from the unknown stock biomass due to the retained catch. Hence biological implications (e.g., effects to mature biomass and stock productivity) cannot be analyzed. Likewise, due to lack of an assessment model, long-term implications cannot be analyzed.

In this analysis it is assumed that OFL will be specified to the nearest 0.01-million pounds, as has been the case in past specifications (e.g., 0.17-million pounds for 2010), and, accordingly, it is assumed that the ABC will specified to the nearest 0.01-million pounds. In this analysis the rounding to the nearest 0.01-million pounds occurs after computations are completed to specify an ABC (i.e., data and statistics are not rounded to 0.01-million pounds prior to computing the ABC) so that the buffers and P* values pertain to results prior to rounding the ABC to the nearest 0.01-million pounds. The ABCs so calculated were then converted to tonnes and are reported here to the nearest whole tonne.

Data and relevant sample statistics for the PIGKC stock are in Table 12-1.

12.2.1 Short-term implications

The short-implications focus on the size of the retained-catch ABC for the 2010 fishing year relative to the GHL established for the fishery during 2002–2010, 150,000 pounds (68 tonnes).

Buffers ≥ 20% (i.e., multipliers ≤ 0.8) would result in ABCs less the 2010 GHL (0.15-million pounds, or 68 tonnes; Figure 12-1).

Multipliers and resulting buffers and ABCs computed using Equation 3.3 for the PIGKC stock for values of P* ranging from 0.1 to 0.5 are given and compared with the 2010 PIGKC OFL and GHL in Table 12-2. The 2010 GHL for the PIGKC stock would have been constrained by the ABCs determined for all values of P* examined except for P* = 0.4 and P* = 0.5 under this method.

Scaling a multiplier (=1-buffer) by the ratio of the length of the time period used to compute the OFL to the life span of the species computed from the assumed 25-year lifespan for BSAI king crabs (Zheng and Siddeek 2009) and the 6-year time period for computing the PIGKC OFL results in the scaling factor of 6/25 = 0.24. Scaling any multiplier of 1.0 or less by that factor would lower the ABC for the PIGKC stock below the 2010 GHL (Figure 12-2). The maximum possible value for an ABC using this method is 0.04-million pounds (18 tonnes; 24% of the 2010 OFL and 27% of the 2010 GHL).

Buffers and ABCs for the PIGKC stock resulting from computing multipliers computed according to Equation 3.4 for each of four values of σ^2, determined by $\sigma = CV \cdot OFL$, for values of CV = 0.0, 0.2, 0.3, and 0.4 and for values of P* from 0.1 to 0.5 are given in Table 12-3. The 2010 PIGKC GHL would have been constrained by the ABC for P* < 0.4 using added variances with CV=0.0, 0.2, 0.3, and 0.4.

Results for use of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period used to compute the 2010 PIGKC OFL according to Equation 3.5 are given in Table 12-4. Scaling the measure of uncertainty (i.e., the standard error of the mean) by (1+l/n) has a substantial effect in reducing the multipliers (i.e., increasing the buffers). The ABC is less than the 2010 GHL for P* values of 0.4 or less under this method. In fact, were ABCs to be determined using this method, at P* = 0.1 the ABC is 0.00-million pounds (0 tonnes) of retained catch and at P*=0.2, the ABC (0.03-million pounds, 14 tonnes, of retained catch) would be 20% of the 150,000-pound (68-tonne) GHL for 2010.

Values of P* corresponding with fixed buffers for the PIGKC stock with values ranging from 0% to 90% resulting from multipliers (=1-buffer) computed under the assumptions for Equation 3.3 (no additional uncertainty added), Equation 3.4 (additional uncertainty with specified CV), and Equation 3.5 (added uncertainty to account for time lag since the last year of the time period used to compute the OFL) are given in Table 12-5. Values of P* are 0.1 or less for: buffers ≥ 40% (multipliers ≤ 0.6) when P* is computed according to Equation 3.3; buffers ≥ 50% (multipliers ≤ 0.5) when P* is computed according to Equation 3.4 with CV =0.2; and buffers ≥ 60% (multipliers ≤ 0.4) when P* is computed according to Equation 3.4 with CV =0.4. Values of P* are 0.2 or less for: buffers ≥ 30% (multipliers ≤ 0.7) when P* is computed according to Equation 3.3 or according to Equation 3.4 with CV =0.2; buffers ≥ 40% (multipliers ≤ 0.6) when P* is computed according to Equation 3.4 with CV =0.4; and buffers ≥ 70% (multipliers ≤ 0.3) when P* is computed according to Equation 3.5. Values of P* are 0.3 or less for: buffers ≥ 20% (multipliers ≤ 0.8) when P* is computed according to Equation 3.3 or according to Equation 3.4 with CV =0.2; buffers ≥ 30% (multipliers ≤ 0.7) when P* is computed according to Equation 3.4 with CV =0.4; and buffers ≥ 40% (multipliers ≤ 0.6) when P* is computed according to Equation 3.5. Values of P* are 0.4 or less for: buffers ≥ 10% (multipliers ≤ 0.9) when P* is computed according to Equation 3.3 or according to Equation 3.4 with CV =0.2, 0.3 or 0.4; and buffers ≥ 20% (multipliers ≤ 0.8) when P* is computed according to Equation 3.5.

12.2.2 Medium-term and Long-term implications

Assuming that the PIGKC OFL, GHL and time period for computing the PIGKC OFL remain constant through 2019, buffers and ABCs and their effect on constraining the GHL will be unchanged from the short-term implications for all P*-based approaches except for the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL (i.e., by computing multipliers according to Equation 3.5).

Buffers and ABCs determined under the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL are shown for 2010–2019 in Figure 12-3. Buffers will increase (i.e., multipliers will decrease) in each future year and ABCs (retained catch, tonnes) are non-increasing functions of year for fixed values of P* < 0.5. Using a P* value of 0.2, the ABC would be 0.00-million pounds (0 tonnes) beginning with the 2014 season. Using a P* value of 0.3, the ABC will decrease from 0.09-million pounds (41 tonnes) in 2010 to 0.04-million pounds (18 tonnes) of retained catch in 2019 and using a P* value of 0.4 the ABC will decrease from 0.13-million pounds (59 tonnes) to 0.11-million pounds (50 tonnes) of retained catch in 2018.

More detailed medium-term biological and economic and the long-term biological and economic implications cannot be assessed due to the lack of a stock assessment model and stock biomass estimates.

12.3 Tables and Figures

Table 12-1 Years and values of retained catch (pounds) used to compute the 2010 PIGKC retained-catch OFL and sample statistics (sample size, mean, standard deviation, and standard error of the mean and CV=ratio of standard error of mean to the mean).

Years	Retained Catch (pounds)
1993	67,458
1994	88,985
1995	341,908
1996	329,009
1997	179,249
1998	35,722
N	6
Mean	173,722
Std. dev.	134,125
Std. error	54,756
CV	0.32

Table 12-2 ABCs (retained catch, tonnes), multipliers, and buffers (=1-multiplier) for alternative values of P* between 0.1 and 0.5 computed for the PIGKC stock by assuming that the sample mean of retained catch for the chosen period of n = 6 years has a t distribution with n-1 degrees of freedom (see Equation 3.3); for comparison, the 2010 PIGKC OFL was 0.17-million pounds (77 tonnes) of retained catch and the 2010 GHL was 150,000 pounds (68 tonnes). Revenues reported are median estimated gross revenue, using price forecast model results for 2009, applied to the ABC (note distinction from directed catch).

P*	ABC	Multiplier	Buffer	Revenue ($Millions)
0.5	77	1.00	0%	0.41 (0.32-0.49)
0.4	73	0.92	8%	0.39 (0.31-0.47)
0.3	64	0.82	18%	0.34 (0.27-0.41)
0.2	54	0.71	29%	0.29 (0.23-0.35)
0.1	41	0.53	47%	0.22 (0.17-0.26)

Table 12-3 Effect of use of an extra variance term, σ2, added to the measure of uncertainty (standard error of mean) to compute multipliers (=1-buffer) for the PIGKC stock and resulting ABCs (retained catch, tonnes) when applied to the 2010 OFL for values of σ2 determined by σ = CV·OFL, with CV = 0 (i.e., no extra variance term added), 0.2, 0.3, and 0.4, and values of P* from 0.1 to 0.5 (see Equation 3.4); for comparison, the 2010 PIGKC OFL was 0.17-million pounds (77 tonnes) of retained catch and GHL was 150,000 pounds (68 tonnes). Revenues reported are median estimated gross revenue, using price forecast model results for 2009, applied to the ABC (note distinction from directed catch).

	CV=0				CV=0.2			
P*	Multiplier	Buffer	ABC	Revenue ($Million)	Multiplier	Buffer	ABC	Revenue ($Million)
0.5	1.00	0%	77	0.41	1.000	0%	77	0.19
0.4	0.92	8%	73	0.39	0.90	10%	73	0.27
0.3	0.82	18%	64	0.34	0.79	21%	64	0.34
0.2	0.71	29%	54	0.29	0.66	34%	50	0.39
0.1	0.53	47%	41	0.22	0.45	55%	36	0.41

CV=0.3				CV=0.4			
Multiplier	Buffer	ABC	Revenue ($Million)	Multiplier	Buffer	ABC	Revenue ($Million)
1.00	0%	77		1.00	0%	77	0.41
0.88	12%	68		0.88	12%	68	0.36
0.77	23%	59		0.72	29%	54	0.29
0.58	42%	45		0.53	47%	41	0.22
0.35	65%	27		0.40	60%	18	0.1

a. Value computed according to Equation 3.4 is less than 0.

Table 12-4 Multipliers and buffers (=1-multiplier) for the PIGKC stock computed according to Equation 3.5 and resulting ABCs (retained catch, tonnes) for alternative values of P* between 0.1 and 0.5; n = number of years in time period used to compute the OFL; l = the time lag since the last year in the time period used to compute the OFL. For comparison, the 2010 PIGKC OFL was 0.17-million pounds (77 tonnes) of retained catch and GHL was 150,000 pounds (68 tonnes).

n =	6		
l =	11		
(1+l/n) =	2.83		
P*	Multiplier	Buffer	ABC
0.5	1.00	0%	77
0.4	0.92	8%	59
0.3	0.82	18%	41
0.2	0.71	29%	14
0.1	0.53	47%	0[a]

a. Value computed according to Equation 3.5 is less than 0.

Table 12-5 Values of P* computed for fixed multipliers and buffers (=1-multiplier) as computed under the assumptions for Equation 3.3 (P*, no additional uncertainty added), Equation 3.4 (P*σ,CV, additional uncertainty with specified CV), and Equation 3.5 (P^*_I, added uncertainty to account for time lag since the last year of the time period used to compute the OFL) for the PIGKC stock; for comparison, the ratio of the 2010 PIGKC GHL (0.15-million pounds = 68 tonnes) to the 2010 PIGKC OFL (0.17-million pounds, 77 tonnes, of retained catch) was 0.882.

Multiplier	Buffer	P*	$P^*_{\sigma,CV=0.2}$	$P^*_{\sigma,CV=0.3}$	$P^*_{\sigma,CV=0.4}$	P^*_I
1	0%	0.500	0.500	0.500	0.500	0.500
0.9	10%	0.382	0.400	0.414	0.426	0.458
0.8	20%	0.277	0.308	0.333	0.355	0.416
0.7	30%	0.192	0.229	0.261	0.291	0.375
0.6	40%	0.130	0.166	0.200	0.234	0.336
0.5	50%	0.087	0.119	0.151	0.186	0.300
0.4	60%	0.058	0.084	0.113	0.146	0.266
0.3	70%	0.039	0.060	0.084	0.114	0.234
0.2	80%	0.026	0.042	0.063	0.089	0.206
0.1	90%	0.018	0.030	0.047	0.069	0.180

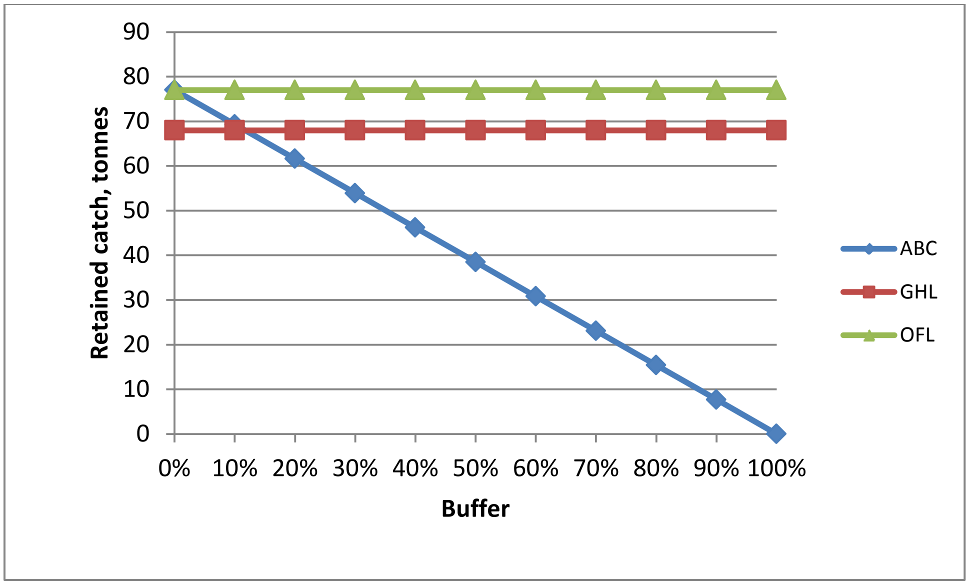


Figure 12-1 Effects of values of buffers from 0% to 100% on the ABC (retained catch, tonnes) for PIGKC stock relative to the 2010 OFL and GHL expressed in tonnes.

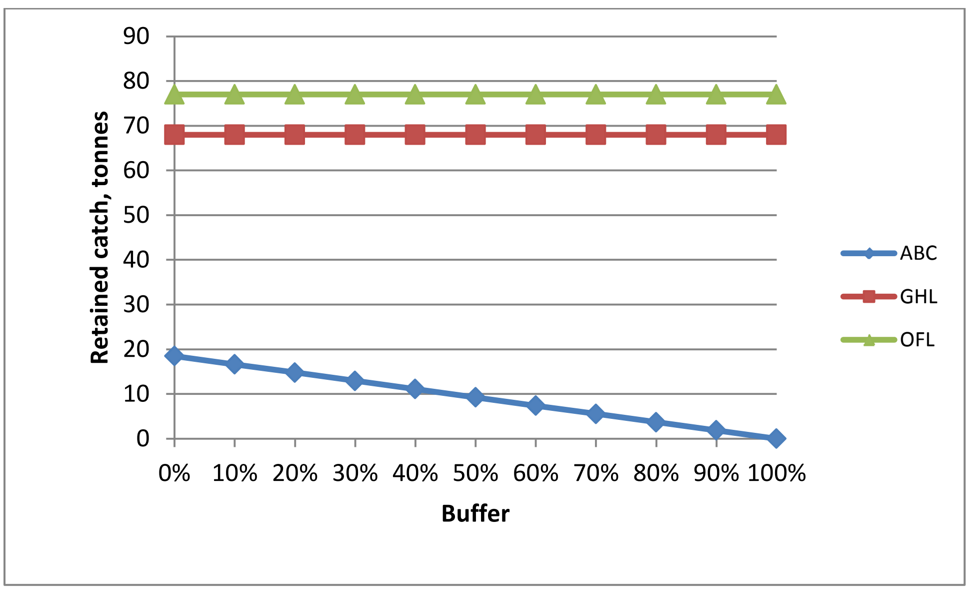


Figure 12-2 Effects of scaling multipliers (=1-buffer) by the ratio of the years in time period used for computing the 2010 PIGKC OFL to the estimated life span of the species on the ABC (retained catch, tonnes) for PIGKC stock relative to the 2010 OFL and GHL expressed in tonnes.

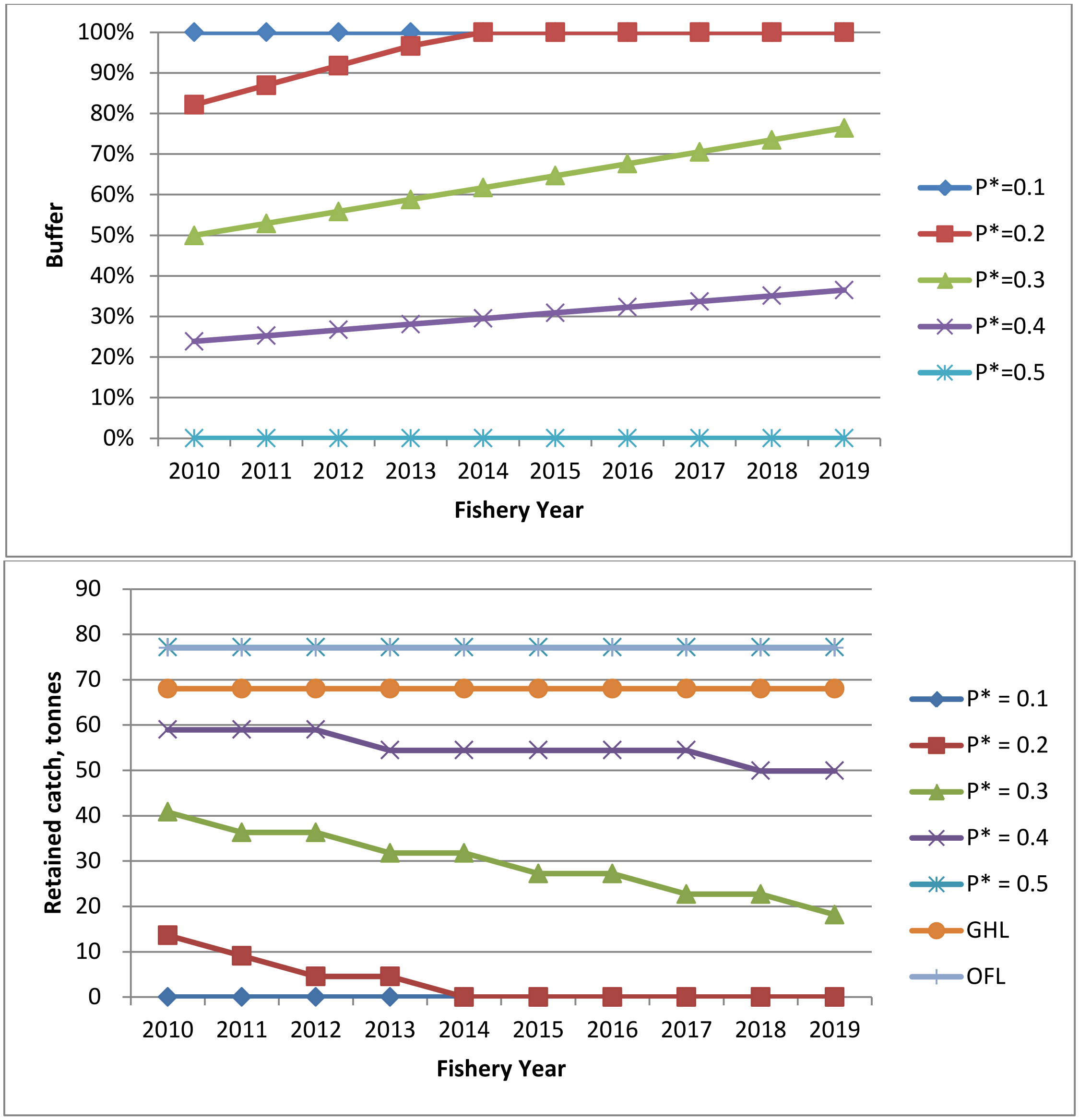


Figure 12-3 Effects on buffers (top panel) and ABCs (retained catch, tonnes; bottom panel) of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period (assumed to be 1993–1998) used to compute the PIGKC OFL for each year in 2010–2019 according to Equation 3.5 for given values of P* as compared to the 2010 OFL and GHL expressed in tonnes; the OFL and GHL are assumed to remain constant during 2010–2019.

13 Western Aleutian Islands ("Adak") Red King Crab

Commercial fishing on the Western Aleutian Islands red king crab (WAIRKC) stock during the last two prosecuted seasons (2002/03 and 2003/04) was opened only in the area between 179° W longitude and 179° E longitude and effort during those two seasons typically occurred at depths of 60–90 fathoms (110–165 m); average depth of pots fished in the Aleutian Islands area during the 2002/03 season was 68 fathoms (124 m; Barnard and Burt 2004) and during the 2003/04 season was 82 fathoms (151 m; Burt and Barnard 2005). In the 580 pot lifts sampled by observers during the 1996/97–2006/07 Aleutian Islands golden king crab fishery that contained one or more red king crab, depth was recorded for 578 pots. Of those, the deepest recorded depth was 266 fathoms (486 m) and 90% of pot lifts had recorded depths of 100–200 fathoms (183–366 m); no red king crabs were present in any of the 6,465 pot lifts sampled during the 1996/97–2006/07 Aleutian Islands golden king crab fishery with depths >266 fathoms (486 m; ADF&G observer database, Dutch Harbor, April 2008).

Although the Adak Registration Area is no longer defined in State regulation, the area west of 171° W longitude within the Aleutian Islands king crab Registration Area O is commonly referred to as the "Adak Area" and the WAIRKC stock is commonly referred to as the "Adak red king crab stock". The Aleutian Islands king crab Registration Area O is described by Bowers et al (2008, page 4) as follows:

> The Aleutian Islands king crab Registration Area O has as its eastern boundary the longitude of Scotch Cap Light (164° 44' W longitude), its northern boundary a line from Cape Sarichef (54° 36' N latitude) to 171° W longitude, north to 55° 30' N latitude, and as its western boundary the Maritime Boundary Agreement Line as that line is described in the text of and depicted in the annex to the Maritime Boundary Agreement between the United States and the Union of Soviet Socialist Republics signed in Washington, June 1, 1990. Area O encompasses both the waters of the Territorial Sea (0-3 nautical miles) and waters of the Exclusive Economic Zone (3-200 nautical miles).

From the 1984/85 season until the March 1996 Alaska Board of Fisheries meeting, the Aleutian Islands king crab Registration Area O as currently defined had been subdivided at 171° W longitude into the historic Adak Registration Area R and the Dutch Harbor Registration Area O. The geographic boundaries of the WAIRKC stock are defined here by the boundaries of the historic Adak Registration Area R; i.e., the current Aleutian Islands king crab Registration Area O, west of 171° W longitude.

The commercial fishery is rationalized and managed by the SOA towards a TAC in the area west of 179° W longitude, but is not rationalized and is managed by the SOA with a GHL in the area east of west of 179° W longitude.

13.1 Assessment overview

There is no regular survey of this stock. No assessment model for the WAIRKC stock exists and none is in development. Accordingly, it was recommended by NMFS (2008) and by the CPT and SSC in 2008 and 2009 that the WAIRKC stock be managed as a Tier 5 stock. For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST or B_{MSY} without an estimate of biomass, and "the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock" (NMFS 2008).

Only a single retained-catch OFL is established for the entire WAIRKC stock (although in recent fisheries only a portion of the total area has been fished by the commercial fleet or opened to commercial fishing by the SOA and the area west of 179° W longitude is rationalized, whereas the area east of 179° W longitude is not rationalized). The 2009/2010 OFL for WAIRKC was established as 0.50-million pounds (227 tonnes) of retained catch (October 2009 SSC minutes). That OFL was computed as the average of the annual retained catch during 1984/85–2007/08 (499,413 pounds), rounded to the nearest 0.01-million pounds.

Neither the TAC for the WAIRKC fishery in area west of 179° W longitude nor GHL for the area east of 179° W longitude is established in SOA regulations. The 2009/10 WAIRKC TAC for the area west of 179° W longitude was established by the SOA at zero (fishery closed) and the 2009/10 WAIRKC GHL for the area east of 179° W longitude was established by the SOA at zero (fishery closed). In fact, the entire WAIRKC stock (both east and west of 179° W longitude) has been closed to commercial fishing by the SOA each year during 2004/05–2009/10. Lacking a harvest strategy in SOA regulations, the SOA has set the TAC for the area west of 179° W longitude and the GHL for the area east of 179° W longitude on the basis of past fishery performance and catch levels and information on size distribution, stock distribution, and relative densities (catch per pot lift) obtained from either limited exploratory fishing or ADF&G-Industry pot surveys conducted under the restrictions of a commissioner's permit fishery, standardized pot surveys performed by ADF&G, and data on bycatch of red king crab during the Aleutian Islands golden king crab fishery. In the two most recent fishery seasons that the commercial fishery was opened (the 2002/03 and 2003/04 seasons) the GHL was established by the SOA at 500,000 pounds (227 tonnes) and was opened only in the area between 179° W longitude and 179° E longitude (Bowers et al. 2008).

13.1.1 Uncertainty in Tier 5 stock assessment

Lack of an assessment model for the WAIRKC stock results in a lack of estimates of mature biomass or of population and recruitment trends. Exploratory fishing or ADF&G-Industry pot surveys conducted under the restrictions of a commissioner's permit fishery and standardized pot surveys performed by ADF&G occur only irregularly and only within limited areas of the Aleutian Islands west of 171° W longitude. Surveys have been largely limited to the area between 179° W longitude and 179° E longitude since 2000/01 because effort and catch in the commercial has been largely limited to that area since 1990/91 (Pengilly 2009a).

Uncertainty in specification of the Tier 5 retained-catch OFL exists due to questions on whether the retained catch data and time period chosen to compute the retained-catch OFL actually provides data that are "representative of the production potential of the stock." The degree uncertainty may be gauged qualitatively to some extent by the difference between the time periods and OFLs that have been recommended for the WAIRKC stock by the CPT and those that have been recommended by the SSC. In 2008, for example, the CPT recommended a bycatch-only OFL for the WAIRKC stock of 0.0263-million pounds (12 tonnes) for 2008/09 based on the average annual bycatch during time period of 1999–2007, whereas the SSC recommended a retained-catch OFL of 0.46-million pounds (209 tonnes) for 2008/09 based on the average annual retained catch during the time period 1985/86–2007/08 (464,762 pounds) and rounded to the nearest 0.01-million pounds (NPFMC 2008). The CPT has "strongly" disagreed with the SSC's recommendations on the OFL for WAIRKC (September 2008 CPT report) and specifically noted that a 0.40-million pound (181-tonne) OFL is "too high given the historical performance of this fishery" (Draft CPT report, May 2008). The level of disagreement and the order of magnitude difference between the OFLs recommended by the CPT and SSC suggests that uncertainty on the OFL for the WAIRKC stock is high. The minimum value of the annual retained catch since 1983/84 relative to the 2009/10 OFL also provides a qualitative measure of relative uncertainty on the OFLs. The minimum of the annual retained catch from the WAIRKC stock was zero (Pengilly 2009a). In fact, the WAIRKC fishery was closed by the SOA due to conservation concerns for 9 of the 14 fishery seasons in 1996/97–2009/10 and was opened by the SOA with a GHL of only 15,000 pounds (7 tonnes) in 1998/99.

13.2 Impacts of alternatives

As described in chapter 3, there are two alternatives under consideration for computing a Tier 5 retained-catch ABC for WAIRKC: (a) the retained-catch OFL can be multiplied by a pre-specified multiplier (=1-buffer; Alternative 2 and Alternative 4), or (b) a distribution can be computed for the retained-catch OFL which accounts for uncertainty, and the ABC set to a pre-specified percentile of that distribution (Alternative 3).

The analyses of impacts in this section are based on the assumptions that: 1) like the OFL, the ABC is defined in terms of retained catch only; and 2) that the ACL equals the lower of the ABC and the retained catch corresponding to the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA.

The short- and medium-term implications of the alternatives for calculating the ABC are evaluated in this section. The short-term implications are assessed by impact of the alternatives for the buffers and P* values on the ABC which would have been advised for the 2009/10 fishery (assuming that ABCs had been specified for that fishery) relative to the retained catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established by the SOA for 2009/10 (retained catch = 0).

Given the lack of an established harvest control rule, assessing the medium-term implications is more difficult. In this analysis the medium-term implications are evaluated by projecting the impacts of alternative during the 2009/10–2018/19 fishery seasons under the assumptions that the retained catch equals the lower of the ABC and a catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) that may be established by the SOA to be as high as 500,000 pounds (227 tonnes) for 2010/11–2018/19, which corresponds with the catch level established by the SOA for the WAIRKC fishery in the two most-recent seasons that the commercial fishery was opened (the 2002/03 and 2003/04 seasons). Also, industry (September 2008 CPT report) and the SSC (June 2008 SSC minutes) have noted the desirability of OFLs not be set so low as to disallow ADF&G-Industry surveys conducted under provisions of a commissioner's permit. Such ADF&G-Industry surveys have resulted in retained catch as high as 153,961 pounds (70 tonnes). Accordingly, medium-term implications are also assessed relative to a 0.15-million pound (68-tonne) retained-catch level to allow for a future ADF&G-Industry survey.

Because an assessment model and reliable biomass estimates are lacking for the WAIRKC stock, the implications of a buffer (either a fixed buffer or a P*-based buffer) are not estimated in terms of effects to stock biomass beyond computing the removals from the unknown stock biomass due to the retained catch. Hence biological implications (e.g., effects to mature biomass and stock productivity) are not analyzed for Tier 5 stocks. Likewise, due to lack of an assessment model, the long-term implications are not analyzed.

In this analysis it is assumed that the OFL will be specified to the nearest 0.01-million pounds, as has been the case in past specifications (e.g., 0.50-million pounds for 2009/10), and, accordingly, it is assumed that the ABC will specified to the nearest 0.01-million pounds. In this analysis the rounding to the nearest 0.01-million pounds occurs after computations are completed to specify an ABC (i.e., data and statistics are not rounded to 0.01-million pounds prior to computing the ABC) so that the buffers and P* values pertain to results prior to rounding the ABC to the nearest 0.01-million pounds. The ABCs so calculated were then converted to tonnes and are reported here to the nearest whole tonne.

Data and relevant sample statistics for the WAIRKC stock are in Table 13-1.

13.2.1 Short-term implications

The short-implications focus on the size of the retained-catch ABC for the 2009/10 fishing year relative to the catch level of zero (sum of 2009/10 TAC for area west of 179° W longitude and 2009/10 GHL for area east of 179° W longitude) established for the fishery by the SOA for 2009/10.

Given that the WAIRKC fishery was closed (retained catch = 0) by the SOA in 2009/10, buffers between 0% and 100% (i.e., multipliers between 1.0 and 0.0) would not have resulted in ABCs less the catch level established by the SOA in 2009/10. Obviously, the ABC approaches a retained catch of zero as the buffer approaches 100% (i.e., as the multiplier approaches 0; Figure 13-1).

Multipliers and buffers (=1-mulitplier) and resulting ABCs computed using Equation 3.3 for the WAIRKC stock for values of P* ranging from 0.1 to 0.5 are given and compared with the 2009/10 WAIRKC OFL and the catch level (sum of 2009/10 TAC for area west of 179° W longitude and 2009/10 GHL for area east of 179° W longitude) established for the fishery by the SOA for 2009/10 in Table 13-2. The catch level established by the SOA for the WAIRKC stock in 2009/10 stock (zero) would not have been constrained by the ABCs determined by any of the values of P* considered here under this method for computing buffers.

Scaling a multiplier (=1-buffer) by the ratio of the length of the time period used to compute the OFL to the life span of the species computed from the assumed 25-year lifespan for BSAI king crabs (Zheng and Siddeek 2009) and the 24-year time period for computing the WAIRKC OFL results in the scaling factor of 24/25 = 0.96. Scaling any multiplier of 1.0 or less by this factor has a negligible effect on determination of the ABC for the WAIRKC stock relative to not scaling the multiplier (Figure 13-2 and compare with Figure 13-1).

Buffers for the WAIRKC stock resulting from multipliers (=1-buffer) computed according to Equation 3.4 for values of σ^2, determined by $\sigma = CV \cdot OFL$, for values of CV = 0.0, 0.2, 0.3, and 0.4 and for values of P* from 0.1 to 0.5 are given in Table 13-3. Given that the WAIRKC fishery was closed (retained catch = 0) by the SOA in 2009/10, the catch level established by the SOA would not have been constrained by applying this method using any of the values of σ^2 or P* considered here.

Results for use of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period used to compute the 2009/10 WAIRKC OFL according to Equation 3.5 for values of P* from 0.1 to 0.5 are given in Table 13-4. Scaling the measure of uncertainty (i.e., standard error of the mean) by $(1+l/n)$ has a negligible effect on determination of the ABC for the WAIRKC stock relative to not scaling the measure of uncertainty by $(1+l/n)$.

Values of P* corresponding with fixed buffers for the WAIRKC stock with values ranging from 0% to 90% in increments resulting from multipliers (=1-buffer) computed under the assumptions for Equation 3.1.3.2.1 (no additional uncertainty added), Equation 3.1.3.2.2 (additional uncertainty with specified CV), and Equation 3.1.3.2.3 (added uncertainty to account for time lag since the last year of the time period used to compute the OFL) are given in buffers of 50% or more (i.e., multipliers of 0.5 or less) are associated with P* values of approximately 0.2 or less for P* computed under the assumptions of all alternative approaches.

13.2.2 Medium-term and Long-term implications

Assuming that the WAIRKC OFL and time period for computing the WAIRKC OFL remain constant through 2018/19, multipliers/buffers and ABCs will be unchanged from those computed for the short-term implications for all P*-based approaches except for the approach of adding uncertainty to account

for time lag since the last year of the time period used to compute the OFL. Consideration by the SOA of a 500,000-pound (227-tonne) retained-catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) during 2010/11–2018/19 would be constrained by the ABC for all buffers > 0% (i.e., multipliers <1.0) and by methods for computing multipliers using P* values < 0.5 (Table 13-1 through
Table 13-5, Figure 13-1 through Figure 13-3).

Buffers ≥50% (i.e., multipliers ≤ 0.5) would constrain consideration by the SOA of retained-catch levels during 2010/11–2018/19 to be one-half or less than a 500,000-pound (227-tonne) retained catch level (i.e., ≤ 0.25-million pounds = 113 tonnes; Figure 13-1 and Figure 13-2). That would occur using P* =0.1 when added uncertainty, σ, is assumed to have a CV = 0.4 (Table 13-3). Buffers >70% (i.e., multipliers < 0.3) would constrain consideration by the SOA of retained retained-catch levels during 2010/11–2018/19 to be less than 0.15-million pounds (68 tonnes; Figure 13-1 and Figure 13-2). Therefore, the impacts of Alternative 4, Alternative 2 buffers larger that 50%, and Alternative 3 P* values less that 0.1 would be indistinguishable from Alternative 1, status quo.

Additional medium-term biological and economic and long-term biological and economic implications cannot be assessed for this stock due to the lack of a stock assessment model and stock biomass estimates.

13.3 Tables and Figures

Table 13-1 Years and values of retained catch used to compute the 2009/10 WAIRKC retained-catch OFL and sample statistics (sample size, mean, standard deviation, and standard error of the mean and CV=ratio of standard error of mean to the mean).

Years	Retained Catch (pounds)
1984/85	**1,296,385**
1985/86	868,828
1986/87	712,543
1987/88	1,213,892
1988/89	1,567,314
1989/90	1,105,971
1990/91	828,105
1991/92	951,278
1992/93	1,286,424
1993/94	698,077
1994/95	196,967
1995/96	38,941
1996/97	0[a]
1997/98	0[a]
1998/99	5,900[b]
1999/00	0[a]
2000/01	76,562[c]
2001/02	153,961[c]
2002/03	505,642
2003/04	479,113
2004/05	0[a]
2005/06	0[a]
2006/07	0[a]
2007/08	0[a]
n	24
Mean	499,413
Std. dev.	527,442
Std. error	107,664
CV	0.22

a. Fishery closed.
b. Harvest during limited exploratory fishing.
c. Harvest limited to retained catch during ADF&G-Industry stock survey.

Table 13-2 ABCs (retained catch, tonnes), multipliers, and buffers (=1-multiplier) for alternative values of P* between 0.1 and 0.5 in increments of 0.1 computed for the WAIRKC stock by assuming that the sample mean of retained catch for the chosen period of n = 24 years has a t distribution with n-1 degrees of freedom (see Equation 3.3); for comparison, the 2009/10 WAIRKC OFL was 0.50-million pounds (227 tonnes) of retained catch and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 was zero. Revenues reported are medians and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009, applied to the ABC (note distinction from directed catch).

P*	ABC	Multiplier	Buffer	Revenue ($Millions)
0.5	227	1.00	0%	1.68 (1.32-2.04)
0.4	213	0.94	6%	1.58 (1.24-1.91)
0.3	200	0.89	11%	1.48 (1.17-1.79)
0.2	186	0.82	18%	1.38 (1.09-1.67)
0.1	163	0.72	28%	1.21 (0.95-1.46)

Table 13-3 Effect of use of an extra variance term, σ2, added to the measure of uncertainty (standard error of mean) to compute multipliers and buffers (=1-multiplier) for the WAIRKC stock and resulting ABCs (retained catch, tonnes) when applied to the 2009/10 OFL for each of four values of σ2, determined by σ = CV·OFL and values of P* from 0.1 to 0.5 (see Equation 3.4); for comparison, the 2009/10 WAIRKC OFL was 0.50-million pounds (227 tonnes) of retained catch and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 was zero. Revenues reported are medians and 90% confidence intervals for estimated gross revenue, using price forecast model results for 2009, applied to the ABC (note distinction from directed catch).

		CV=0				CV=0.2		
P*	**Multiplier**	**Buffer**	**ABC**	**Revenue** ($Million)	**Multiplier**	**Buffer**	**ABC**	**Revenue** ($Million)
0.5	1.000	0%	227	1.68	1.000	0%	227	1.68
0.4	0.945	6%	213	1.58	0.925	8%	209	1.55
0.3	0.885	12%	200	1.48	0.844	16%	191	1.41
0.2	0.815	19%	186	1.38	0.748	25%	168	1.24
0.1	0.716	28%	163	1.21	0.612	39%	141	1.04

		CV= 0.3					CV=0.4				CV=0.6	
P*	**Multiplier**	**Buffer**	**ABC**	**Revenue** ($Million)	**P***	**Multiplier**	**Buffer**	**ABC**	**Revenue** ($Million)	**Multiplier**	**Buffer**	**ABC**
0.5	1.000	0%	227	1.68	0.5	1.000	0%	227	1.68	1.000	0%	227
0.4	0.899	10%	204	1.48	0.4	0.884	12%	200	1.48	0.860	14%	191
0.3	0.797	20%	181	1.27	0.3	0.758	24%	172	1.27	0.710	29%	150
0.2	0.678	32%	154	1.01	0.2	0.610	39%	136	1.01	0.533	47%	104
0.1	0.520	48%	118	0.67	0.1	0.400	60%	91	0.67	0.282	72%	36

Table 13-4 Multipliers and buffers (=1-multiplier) for computing ABC for the WAIRKC stock according to Equation 3.5 and resulting ABCs (retained catch, tonnes) for alternative values of P* between 0.1 and 0.5 in increments of 0.1; n = number of years in time period used to compute the OFL; l = the time lag since the last year in the time period used to compute the OFL. For comparison, the 2009/10 WAIRKC OFL was 0.50-million pounds (227 tonnes) of retained catch and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 was zero. Revenues reported are median estimated gross revenue, using price forecast model results for 2009, applied to the ABC (note distinction from directed catch).

n =	24			
l =	1			
(1+l/n) =	1.042			
P*	Multiplier	Buffer	ABC	Revenue ($Million)
0.5	1.00	0%	227	1.68
0.4	0.94	6%	213	1.58
0.3	0.88	12%	200	1.48
0.2	0.81	19%	181	1.34
0.1	0.70	30%	159	1.18

Table 13-5 Values of P* computed for fixed multipliers and buffers (=1-multiplier) as computed under the assumptions for Equation 3.3 (P*, no additional uncertainty added), Equation 3.4 (P*σ,CV, additional uncertainty with specified CV), and Equation 3.5 (P^*_l, added uncertainty to account for time lag since the last year of the time period used to compute the OFL) for the WAIRKC stock; for comparison, the ratio of the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 was zero to the 2009/10 WAIRKC OFL (0.50-million pounds, or 227 tonnes, of retained catch) was 0.000.

Multiplier	Buffer	P*	$P^*_{\sigma,CV=0.2}$	$P^*_{\sigma,CV=0.3}$	$P^*_{\sigma,CV=0.4}$	$P^*_{\sigma,CV=0.6}$	P^*_l
1	0%	0.500	0.500	0.500	0.500	0.500	0.500
0.9	10%	0.324	0.368	0.395	0.414	0.438	0.330
0.8	20%	0.182	0.252	0.297	0.332	0.378	0.191
0.7	30%	0.089	0.159	0.213	0.258	0.321	0.097
0.6	40%	0.038	0.093	0.145	0.194	0.268	0.044
0.5	50%	0.015	0.051	0.095	0.141	0.220	0.018
0.4	60%	0.005	0.026	0.059	0.100	0.178	0.007
0.3	70%	0.002	0.013	0.035	0.069	0.142	0.002
0.2	80%	0.001	0.006	0.020	0.046	0.111	0.001
0.1	90%	0.000	0.003	0.011	0.030	0.086	0.000

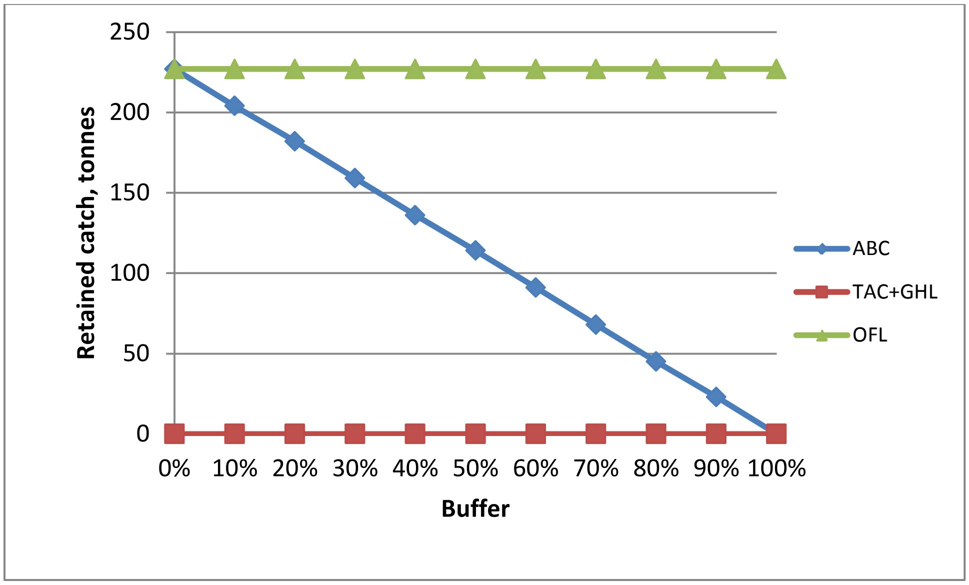


Figure 13-1 Effects of values of buffers from 0% to 100% on the ABC (retained catch, tonnes) for WAIRKC stock relative to the 2009/10 OFL and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 and expressed in tonnes.

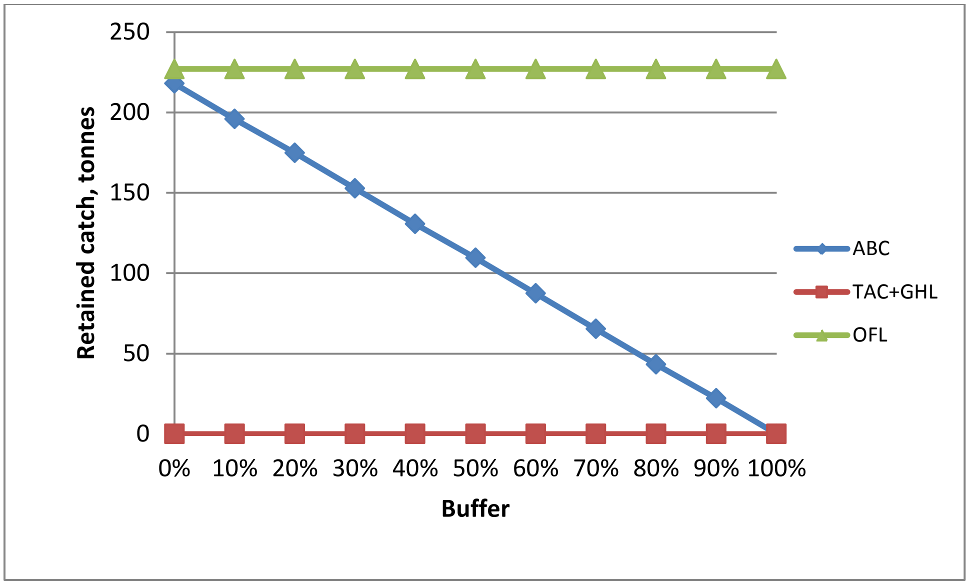
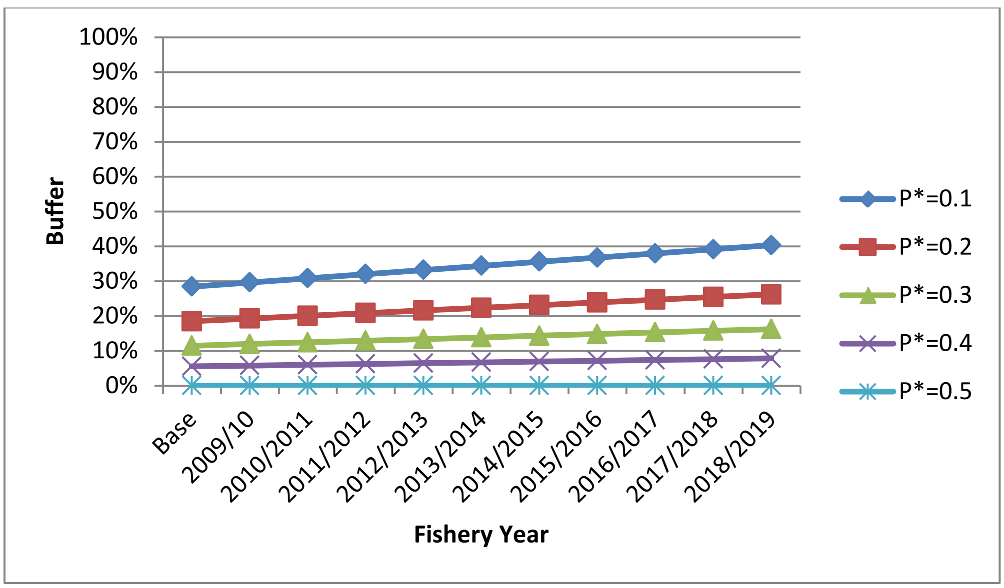


Figure 13-2 **Effects of scaling the multiplier (=1- buffer) by the ratio of the years in time period used for computing the 2009/10 WAIRKC OFL (24 years) to the estimated life span of the species (25 years) on the ABC (retained catch, tonnes) for WAIRKC stock relative to the 2009/10 OFL and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA in 2009/10 expressed in tonnes.**



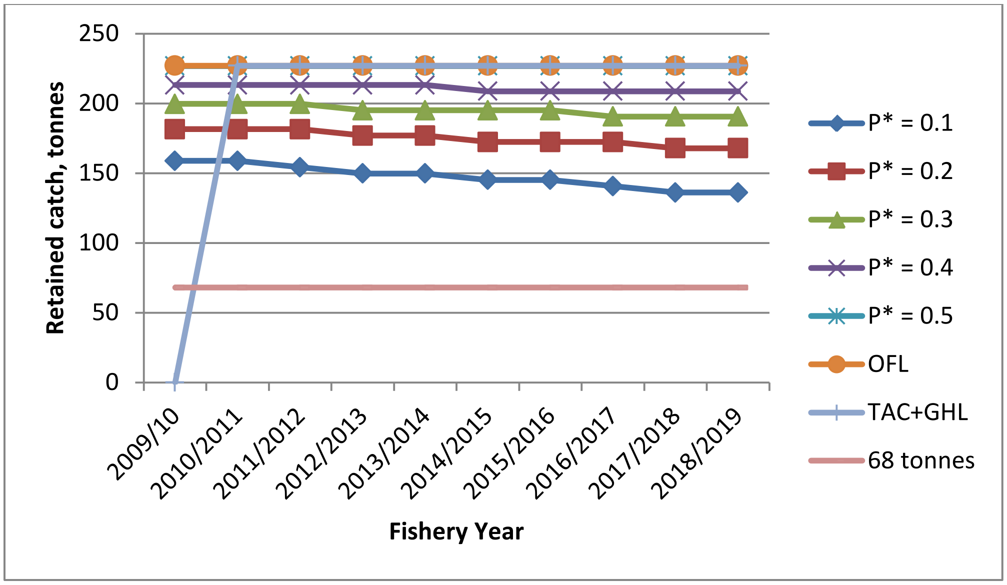


Figure 13-3 Effects on buffers (top panel) and ABCs (retained catch, tonnes; bottom panel) of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period (assumed to be 1993–1998) used to compute the WAIRKC OFL for each year in 2009/10–2018/19 according to Equation 3.1.3.2.3 for given values of P* as compared to the 2009/10 OFL and the catch level (sum of the TAC for area west of 179° W longitude and the GHL for area east of 179° W longitude) established for the fishery by the SOA. The OFL is assumed to remain constant during 2009/10–2018/19. The catch level established by the SOA for 2009/10 was zero, but ABCs in future years are compared with a catch level of 500,000 pounds (227 tonnes; the catch level established by the SOA in the last two seasons that the commercial fishery was opened); 0.15-million pounds (68 tonnes) corresponds with the highest retained catch that has occurred during ADF&G-Industry surveys of the WAIRKC stock.

14 Effects on Other Marine Resources

The purpose of this section is to analyze the environmental impacts on other marine resources of the two proposed federal actions, and associated alternatives and options: 1) to adopt and implement ACLs and AMs for ten BSAI crab stocks; and 2) to rebuild the EBS snow crab stock.

This section estimates the effects of the alternatives and associated options on the biological and physical environment, exclusive of crab stocks. Additional evaluations of the effects of crab fishing and crab harvest levels on the ecosystem are contained in the Crab EIS (NMFS 2004) and in the EA for Amendment 24 to the FMP (NMFS 2008), and are incorporated into this analysis by reference. The most recent review of the status of BSAI crab stocks may be found in the 2010 Crab SAFE (NPFMC 2010). The most recent review of the role and interactions of crab species in the marine ecosystem is contained in the Ecosystem Considerations Chapter, which is an appendix to the annual SAFE Report and available on the Council web site.[72] This analysis includes only those effects that are additional and attributable to establishing ACLs and AMs for all ten BSAI crab stocks and rebuilding EBS snow crab.

14.1 Incidental catch species, marine mammals, and seabirds

Under Action 1, the proposed ACL action, harvest levels in the directed crab fisheries would remain the same or would be constrained by the establishment of ACLs. Under the status quo, an OFL is established for each crab species and the State subsequently establishes harvest levels to ensure the OFL is not exceeded. Under Action 1, Alternatives 2, 3, and 4, an ABC would be established below the OFL and State harvest levels would now be set by the State so as not to exceed the ABC. TACs and GHLs are determined annually by the State based on the biomass of the crab species. Effective monitoring and enforcement would continue to ensure that the overall harvest levels are not exceeded. Therefore, total catch of crab species would not increase under the proposed ACL action (harvest levels continue to be constrained by the OFL) and the operation of the directed fishery would continue in the same manner as the present, except that overall effort in the crab fishery could be reduced if the ABC for a species is lower than the TAC or GHL would otherwise have been.

Under the EBS snow crab rebuilding plan, harvest levels of snow crab could be additionally constrained to allow the snow crab stock to rebuild within a designated time period. The alternatives and options in action 2 only evaluate constraints to the directed crab fishery catch. No additional changes to the pattern of the directed fishery are anticipated beyond a potential reduction in harvest level.

Changes in interactions with other fish species, marine mammals, and seabirds are linked to changes in target crab fishery efforts. As described above, overall fishing effort in the crab fishery is expected to remain the same or to decrease under Actions 1 and 2. The harvest levels for all crab species, under any Alternative, would remain the same or would be constrained. Further, no changes to the distribution of crab fisheries are anticipated under the proposed Actions. To the extent that crab fishing effort is reduced, and consequently adverse interactions with incidental catch species though bycatch or disturbance are also reduced, there could be some benefit to these species. Any effects on incidental catch species, however, should not be significant under either Action 1 or 2 with any associated Alternative and Option.

The effects of the two proposed actions on marine mammals, seabirds, and their habitat are considered insignificant and are not expected to alter the current rates of interaction beyond those already evaluated because overall fishing effort in the crab fishery is expected to remain the same or to decrease. Spatial

[72] http://www.alaskafisheries.noaa.gov/npfmc/membership/plan_teams/CPT/CRABSAFE2010_910.pdf

and temporal concentration effects by these fisheries, vessel traffic, gear moving through the water column, or underwater sound production which could affect marine mammal foraging behavior, would not increase under the proposed Actions and Alternatives. The effects of these federal Actions and Alternatives on seabirds are considered insignificant and are not expected to increase current rates of interaction. No changes in the indirect effects of fisheries on prey (forage fish) abundance and availability, benthic habitat as utilized by seabirds, and processing of waste and offal, all of which could affect seabirds, are expected under these Actions and Alternatives.

14.2 Habitat and ecosystem considerations

The marine waters and benthic substrates in the BSAI management area comprise the habitat of all marine species. Additionally the adjacent marine waters outside the EEZ, adjacent State waters inside the EEZ, shoreline, freshwater inflows, and atmosphere above the waters, constitutes habitat for prey species, other life stages, and species that move in and out of, or interact with, the fisheries' target species, marine mammals, seabirds, and the ESA listed species. A detailed discussion of the effects of crab fisheries on essential fish habitat (EFH) is included in the Final EIS for EFH identification and consideration in Alaska (NMFS 2005). That analysis concluded that the impacts of the crab pot fishery on habitat features in the Bering Sea and Aleutian Islands are negligible. The proposed actions and alternatives are not anticipated to have additional impacts on EFH beyond those identified in previous analyses discussed above, as none of the alternatives would result in an increase in fishing effort. Consequently, the impact of the proposed alternatives on habitat is insignificant.

Ecosystem characteristics of the BSAI management areas have been described annually since 1995 in the "Ecosystem Considerations" chapter of the annual SAFE reports (NPFMC 2009). The Ecosystem Considerations chapter is composed of three main sections. First, the Ecosystem Assessment portion of the document provides a historical overview of the physical and biological environment of the BSAI ecosystem utilized by crab species as well as aspects of crab life history such as survival, recruitment, growth, maturity and natural mortality which are known to be impacted by changes in the BSAI ecosystem. The second section, Current Status of Ecosystem Indicators, provides current information and updates on the status of the physical and biological components of the BSAI ecosystem. Physical components include pelagic and benthic habitat variables while biological components include prey availability and their abundance as well as distribution and abundance of competitors and predators. This section updates current research and identifies future research priorities for BSAI crab stocks with respect to ecosystem interactions. The final section, the Ecosystem-based Management Indicators, provides trends which could indicate early warning signals of direct fishery effects on crab-oriented BSAI ecosystem components, warranting management intervention or providing evidence of the efficacy of previous management actions. Specific indicators include the magnitude of directed fishery effects on BSAI habitat and resulting management efforts, and spatial and temporal removals of the target catch affecting other biological predators. This section also reviews potential fishery effects on crab biology such as changes in age and size at maturity, and reproduction.

Given that an overall increase in fishing activity is not expected under the two proposed actions, the potential effects of the actions on an ecosystem-wide scale are very limited. As a result, no significant adverse impacts on ecosystem relations are anticipated.

15 Cumulative Effects

Analysis of the potential cumulative effects of a proposed federal action and its alternatives is a requirement of the NEPA. Cumulative effects are those combined effects on the quality of the human environment that result from the incremental impact of the proposed actions 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 the cumulative effects analysis is to capture the total effects of many actions over time that would be missed if evaluating each action individually. Concurrently, the CEQ guidelines recognize that it is most practical to focus a cumulative effects analysis on only those effects that are truly meaningful.

The Crab EIS (NMFS 2004) and EA for Amendment 24 to the FMP (NMFS 2008) incorporated into this analysis by reference assess the potential direct and indirect effects of crab fishery harvest levels in combination with other factors that affect physical and biological resource components of the BSAI environment. This analysis includes only those effects that are additional and attributable to the adoption of an FMP amendment to establish ACLs for all ten BSAI crab stocks and revise the rebuilding plan for EBS snow crab. Summarizing the reasonably foreseeable actions identified in this analysis that are likely to have an impact on a resource component within the action area and timeframe, future actions that may affect the crab fisheries are:[73]

- Tanner crab rebuilding plan
- Pribilof Island blue king crab rebuilding plan
- Revisions to the Crab Rationalization Program
- Management measures to address crab bycatch in the groundfish fisheries

The Tanner crab and PIBKC rebuilding plans are currently under development by the Council and NMFS, and include alternatives that could further constrain the catch in those crab fisheries. The analyses for the rebuilding plans will follow the Council's adoption of a preferred alternative on ACLs and so will take into account any reductions in harvest levels attributable to the implementation of ACLs in the discussion of impacts. The mechanisms put into place under the proposed action were designed to adjust to changing stock conditions, such as stock rebuilding.

The Council is also continually adjusting the Crab Rationalization Program.[74] However, no revisions to that Program have been proposed which would change the basic structure or function of the Program or the environmental impacts of fishing under the Program. These pending actions would not change the understanding of the impacts of the proposed action because the proposed action sets up a process for annually calculating an ABC and measures to ensure accountability and nothing under consideration would change the proposed action or its impacts.

The Council is also considering a discussion paper evaluating crab bycatch in the groundfish fisheries. Currently, there are no hard quotas to cap crab bycatch in the groundfish fisheries, although area closures with associated catch limits are utilized to reduce bycatch. AMs are a required provision of the MSA in conjunction with provisions for ACL requirements. The intent of AMs are to further protect a crab stock

[73] "Actions" are understood to be human actions (e.g., rulemaking) as distinguished from natural events (e.g., ecological regime shift).
[74] Information on all proposed changes to the Program is posted on the Council's web page at http://www.fakr.noaa.gov/npfmc/current_issues/crab/crabcoop.htm.

from overfishing by providing for a transparent response mechanism in the event that the established ACLs are exceeded. Without further Council action, crab bycatch in the groundfish fisheries will be accounted for by reducing harvest in the directed crab fisheries. However, the Council did initiate an amendment analysis to consider alternative management measures for bycatch in the groundfish fisheries. Measures to limit bycatch in the groundfish fisheries would be an additional accountability measure to prevent exceeding the ACL and this may result in higher directed fishery catches as the directed catch is reduced by the expected bycatch amount. And, the composition of the catch may change as the directed fishery harvests predominantly legal males. Any stock conservation benefits from limiting bycatch would result in higher OFLs and ACLs. These potential changes would not change the understanding on the impacts of the proposed action and the mechanisms put into place under the proposed action were designed to adjust to changing stock conditions and total catch composition.

Beyond the cumulative impacts discussed above and documented in the referenced analyses, no additional past, present, or reasonably foreseeable cumulative negative impacts on the biological and physical environment (including fish stocks, essential fish habitat, ESA-listed species, marine mammals, seabirds, or marine ecosystems), fishing safety, or consumers have been identified that would accrue from the proposed actions. None of the alternatives change the general manner, timing, or location in which the crab fisheries operate.

15.1 Climate change and ocean acidification

While climate warming trends are being studied and increasingly understood at a global scale (IPCC 2007), the ability for fishery managers to forecast biological responses to changing climate continues to be difficult. The Bering Sea is subject to periodic climatic and ecological "regime shifts." These shifts change the values of key parameters of ecosystem relationships, and can lead to changes in the relative success of different species.

The Council and NMFS have taken actions that indicate a willingness to adapt fishery management to be proactive in the face of changing climate conditions. The Council currently receives an annual update on the status and trends of indicators of climate change in the Bering Sea through the presentation of the Ecosystem Assessment and Ecosystem Considerations Report (Boldt 2009) and the "Ecosystem Considerations" chapter of the annual crab SAFE reports (NPFMC 2010). Much of the impetus for Council and NMFS actions in the northern Bering Sea, where bottom trawling is prohibited in the Northern Bering Sea Research Area, and in the Alaskan Arctic, where the Council and NMFS have prohibited all fishing until further scientific study of the impacts of fishing can be conducted, derives from the understanding that changing climate conditions may impact the spatial distribution of fish, and consequently, of fisheries. In order to be proactive, the Council has chosen to close any potential loopholes to unregulated fishing in areas that have not previously been fished.

Consequently, it is likely that as other impacts of climate change become apparent, fishery management will also adapt in response. Because of the large uncertainties as to what these impacts might be, however, and our current inability to predict such change, it is not possible to estimate what form these adaptations may take.

Ocean acidification is documented to be occurring globally, and is likely to continue and increase given current trends in anthropogenic carbon emissions and projected release of deep water methane. It is projected that some subpolar surface waters will become undersaturated within the next 100 years (Orr et al. 2005). Shoaling of the calcite saturation horizon, where deep waters are undersaturated with calcium, and thus more acidic, while shallow waters are supersaturated, implies that deep-water species, including corals, may be influenced sooner. Oceanic/planktonic energy is very important in the oceanic food web. Consequences of small changes in pH can be severe for calcifying organisms, such as shelled pteropods, corals, foraminifera, and coccolithophors. We cannot predict which species will become extinct and which will adapt, but the impacts to the food web could be severe if many species of plankton (or a few key species) are affected. Effects could include significant declines in primary production and carrying capacity of the ecosystem.

The increase in carbon and a decrease in pH in the surface waters of a large section of the northeast Pacific Ocean is direct evidence of ocean acidification (Kleypas et al. 2006). This increase in acidification is attributed to anthropogenic sources (i.e., burning of fossil fuels). Increased acidification affects the calcification process utilized by calcium-secreting organisms, such as corals and zooplankton (Kleypas et al. 2006). Skeletal growth rates of these types of organisms are reduced by the increase in acidification, increased dissolution of carbonate and decreased $CaCO_3$ saturation state; however, the combined effect of acidification, lights, nutrients, and temperature are unknown (Kleypas et al. 2006).

Acidification could have implications, as yet unknown, for the food web of the northeast Pacific Ocean. Kleypas et al. (2006) outline one hypothesized ecosystem response to increased acidification: as the CO_2/carbonate chemistry of seawater changes, then calcifying species may undergo shifts in their latitudinal distributions and vertical depth ranges. Kleypas et al. (2006) points out that the potential impacts of increased CO_2 on planktonic ecosystem structure and functions are unknown because we do not known (1) whether planktonic calcifiers require calcification to survive, (2) the capacity for planktonic organisms to adapt to lower saturation states (or reduced calcification rates), and (3) the long-term impacts of elevated CO_2 on reproduction, growth, and survivorship of planktonic calcifying organisms. However, marine plankton is a vital food source for many marine species and their decline could have serious consequences for the marine food web.

However, a more acidic ocean might not be harmful to all organisms that produce calcium carbonate. Recent research indicates that increased carbon dioxide in the Earth's atmosphere is causing microscopic ocean plants to produce greater amounts of calcium carbonate (chalk) and that calcification by phytoplankton could double by the end of this century (Iglesias-Rodriguez et al. 2008). This is important because the majority of ocean calcification is carried out by coccolithophores. The Bering Sea experienced coccolithophore blooms in 1997 and 1998. Coccolithophore blooms occur when light intensity is high and nutrient levels are low and are evidence that the normal nutrient pump is not working.

Research is ongoing to better understand ocean acidification and the potential effects on fisheries from the changing chemical properties of the ocean. NOAA laboratories contribute to several international; and national research program that study ocean acidification. More information about ocean acidification is available on NOAA’s Ocean Acidification website at http://www.pmel.noaa.gov/co2/OA/. Additionally, Section 701 of the MSRA requires that the Secretary of Commerce request the National Research Council study of the acidification of the oceans and how this process affects the United States.

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APPENDIX 1: SSC MINUTES JUNE 2009 – JUNE 2010

October 2010

C-3 Crab ACL

Diana Stram (NPFMC) presented the final Environmental Assessment for proposed Amendments 38 and 39 to the Fishery Management Plan for the BSAI King and Tanner Crabs to comply with Annual Catch Limit requirements and to revise the rebuilding plan for EBS snow crab. The SSC reviewed the initial review draft in June 2010 and provided extensive comments at that point. The SSC commends the authors for extensive clarifications and additions to the document, which clearly lays out the issues and provides detailed guidance to the public and to the Council for choosing among the Alternatives. Public testimony was provided by Edward Poulsen (Alaska Bering Sea Crabbers) and Arni Thomson (PNCIAC and Alaska Crab Coalition).

The SSC provides the following comments and recommendations to inform the Council in its decision:

1. Choice of alternatives for establishing ACLs. The SSC has generally favored and previously recommended the P* approach for determining appropriate buffers between ACL and OFL where possible. Because of the difficulty in quantifying uncertainty in OFL for stocks in the lowest tier, **we support a blended approach using P* for Tiers 1-3 and constant buffers for Tier 5 and possibly for Tier 4 stocks.** For Tier 5 stocks, the distribution of OFL (and therefore the probability that ABC exceeds OFL) cannot be reliably estimated and is likely to be highly variable. Therefore, a constant buffer would provide for greater stability over time. For Tier 4 stocks, the SSC notes that a constant buffer may need to vary across stocks because of different levels of uncertainty, whereas a P* approach would implicitly account for different levels of uncertainty. In June 2010, the Council selected the status quo as the Preliminary Preferred Alternative and the revised EA now includes more details on this alternative.

2. Process for determining the appropriate level for "additional" uncertainty in the estimates of OFL. One of the key features of setting Annual Catch Limits is the consideration of the amount of scientific uncertainty in the point estimate of OFL to provide for an appropriate buffer between the ACL and the OFL that takes into account uncertainty in the OFL. Sources of uncertainty include both within-assessment uncertainty (σ_w), which can be directly quantified, and any additional sources of uncertainty (σ_b) that are much more difficult to quantify. The SSC recognizes that values for σ_b currently have relatively weak quantifiable scientific support. However, the EA provides context for the magnitude of additional uncertainty in other fisheries and the CPT has developed reasonable criteria for classifying stocks into those with low, intermediate, and high levels of additional uncertainty. An alternative approach whereby the determination of σ_b would be deferred to the State was discussed, but no details were given, nor was written analysis available to evaluate this process.

The SSC has previously discussed concerns that the default values for additional uncertainty in OFL might become fixed values that would be difficult to change. **The SSC recommends that the initial default values be evaluated annually by the assessment authors, CPT, and SSC and that the CPT further develop a process and criteria for how to determine the most appropriate levels for σ_b.** This process should draw on State and federal expertise in evaluating different sources of scientific uncertainty to ensure that the best available information is used.

Both the CPT and the public expressed concerns about "double" buffering or excessive levels of precaution that could result from a poorly designed process. For example, if assessment authors or the plan team are conservative in estimating the OFL, this would duplicate considerations of uncertainty if the same sources of uncertainty are also included in determining σ_b. To avoid this duplication, the OFL should always be set at the "best" (risk-neutral) point estimate and not at some conservative level. Consideration of scientific uncertainty in the level of OFL is appropriately applied through the specification of σ_w and σ_b. **The SSC feels that the public process established by the Council for reviewing stock assessments through the plan teams and the SSC provides the best forum for determining the appropriate level of scientific uncertainty in OFL for the purposes of establishing Annual Catch Limits.**

3. Skewed OFL distributions. The SSC notes that there is inconsistency in the use of the mean versus the median as the "best" estimate of OFL across stocks. This can have large implications for buffer sizes and P* values in the case of those stocks that have a skewed OFL distribution, as shown in the EA. The SSC suggests that in future assessment cycles, the authors and CPT clearly state whether the mean or median is used in a given assessment and that some justification be provided for the choice.

4. Timing of SSC recommendations: Several options are included in the document to ensure that the SSC recommendations for ABCs can be made prior to setting TACs. The SSC in June 2010 requested an analysis of the possible consequences of Option 4, which would have the SSC set ABC levels annually in June. The EA includes some analyses of the relative errors between using a one-year-ahead projection and using updated assessment results after all the survey data for the current year are included. The results clearly show that relative errors can be substantial and the SSC recommends against Option 4 because it does not make use of the best-available scientific information.

5. Snow crab rebuilding: The document has changed little since the initial draft. The SSC received information that a revised rebuilding plan might not be required because the current stock assessment model indicates that the stock never dropped below MSST in the past. However, the Council may choose to proceed with revising the rebuilding plan or accept status quo. The SSC suggested that current rebuilding plan is adequate to meet rebuilding targets. The SSC previously recommended that a revised rebuilding plan consider a one-year time-frame of being above the B_{MSY} threshold be used for considering the snow crab stock rebuilt and suggests that this could still be a consideration for a revised rebuilding plan or FMP amendment. More generally, the SSC recommends that stocks that have an assessment model and are under a rebuilding plan should be considered rebuilt if biomass exceeds B_{MSY} for one year. The rationale is that model-based biomass estimates are less variable than survey biomass estimates.

Additional SSC comments:
In June 2010, the SSC recommended that "the relative economic performance of the competing alternatives, as projected in the model, be characterized as percentage changes, rather than gross discounted present value estimates of foregone revenue." The document has been changed in response to this recommendation. In addition, the author's presentation of long-term nominal economic projections has been supplemented with the requested caveats and relative performance measures, expressed in 'percent change' from status quo–baseline information. The SSC appreciates the analysts' responsiveness to our concerns. The SSC also had a number of minor and editorial suggestions that will be communicated to the authors.

June 2010

C-2 (a) Initial review crab ACL and snow crab rebuilding

Diana Stram (NPFMC) presented the Initial Review Draft of the Environmental Assessment for two proposed amendments to the FMP for the Bering Sea and Aleutian Islands king and Tanner crab fisheries. Jack Turnock (AFSC) provided additional clarification and revision of the snow crab analyses including alternative snow crab models and rebuilding analysis. Public testimony was provided by Edward Poulsen (ICEPAC) and Arni Thomson (Alaska Crab Coalition).

The proposed actions in this EA consist of: (1) establishing ACLs for 10 crab stocks to meet requirements of the MSA; (2) revising the EBS snow crab rebuilding plan because snow crab were not rebuilt by the end of the existing rebuilding time frame (2009/10).

The SSC has reviewed several iterations of the analyses contained in this Initial Review Draft and provided comments and guidance on the analyses several times, most recently in April. We appreciate the tremendous amount of effort that went into revising the analyses and note that the analysts have been very responsive to our comments and concerns in a very short time frame. **The SSC recommends that the Initial Review Draft be released for public review after the comments and suggestions below have been addressed. The SSC also requests an opportunity to comment on the final draft document in October, 2010.**

The EA document, while providing adequate information for decision making, is highly technical and could benefit from simplified explanations and illustrations of the Alternatives. The document should clearly articulate to the Council and to the public how the proposed approaches differ, for example, from the current groundfish control rule and from crab control rules. Graphics depicting the control rules could be included in the document to illustrate the different approaches.

The document should emphasize that the choice of the probability that ABC exceed OFL (P*), which reflects the overall degree of risk aversion, is a policy choice by the Council. While it would facilitate the comparison of alternatives if the Council was to select a single P* to apply to all stocks, the Council's degree of risk aversion could depend on the economic or social importance of particular fisheries. The Council needs to clearly communicate its rationale for specification of P*. Similarly, the degree of uncertainty in the estimate of OFL needs to allow for flexibility to reflect our evolving understanding of uncertainty. Choosing an appropriate level of uncertainty is the primary means by which the P* approach provides for precautionary management. One advantage, as opposed to a constant buffer, of this approach is that it provides a strong incentive to reduce uncertainty in the estimates of OFL.

As part of the P* approach, the SSC endorsed the inclusion of a low, medium, and high levels of additional uncertainty to reflect sources of uncertainty that are not accounted for within the stock assessments. For the analyses to be finalized, values for the additional uncertainty (σ_b) have to be chosen by the SSC and will become defaults under the P* approach. However, the default values should be evaluated annually by the assessment authors, CPT, and SSC to reflect our evolving understanding of the true magnitude of uncertainty in the OFL. The level of uncertainty is expressed as the standard error of the log-transformed OFL, which is approximately equal to the coefficient of variation (CV) of OFL over the range of values considered here. The current draft uses values of σ_b = 0.2, 0.4, and 0.6, but following much SSC discussion **the SSC accepted the May 2010 CPT recommendation to use values of 0.2, 0.3 and 0.4 for stocks with low, medium, and high levels of additional uncertainty, as classified in Table 2-5.** We note that these levels are considerably lower than the uncertainty levels chosen for groundfish by the Pacific Council (0.367, 0.72, and 1.44 for groundfish stocks classified as data-rich, data moderate, and data poor, respectively), but are comparable to estimates of σ_b by Hanselman (2009) for North Pacific groundfish stocks, which ranged from 0.04 to 0.51 among stocks and between two different methods. The SSC provides the following rationale for the choice of σ_b = 0.2, 0.3, and 0.4:

- The CPT advised that levels up to 0.6, which implies a 95% confidence interval for OFL that ranges from 0.3*OFL to 3.3*OFL, were too large.
- These values are default values that can and should be changed as our understanding of uncertainty changes over time. In particular, uncertainty for stocks in the lower tiers (e.g., Tier 5) should be re-evaluated,if the P* approach is adopted, and may warrant different levels of uncertainty, particularly as new methods for determining the extra uncertainty are developed.

Key results of the analyses are included in Tables 2-11 and 2-12. Interpretation of results may be complicated by the fact that a given level of P* or a constant buffer could be associated with a probability of overfishing (ABC > OFL) that exceeds 50%. This is, in part, a consequence of the asymmetrical distribution of OFL (long right tail of the distribution), which implies that the median is smaller than the mean and Pr(ABC > mean OFL) is larger than 50%. There is further confusion resulting from inconsistencies among chapters in the use of either the mean or the median to describe central tendency. While consistent use of the median would avoid some of these issues, the interpretation of OFL as a median is not consistent with current practice, which interprets OFL as the mean of an assumed or estimated distribution. The SSC would like to see a brief explanation, including a graphic, of the effects of skewness in the distribution of OFL on the resulting buffer values and P* values to help readers interpret the results, as well as an explicit paragraph on whether the mean or the median was used in computing buffers in the individual chapters (with rationale).

While the results in Tables 2-11 and 2-12 appear to preclude the use of certain P* values or buffers for some stocks because they would result in a 50% or greater chance of overfishing, the SSC notes that this problem could be avoided by specifying a P* value <u>no greater than</u> 0.x or a buffer <u>no less than</u> x%. Adjustments for individual stocks could then be made to assure that the probability of overfishing does not exceed 50%.

The SSC discussed the alternatives and options and has the following recommendations:

- Regarding the alternatives, the SSC notes that the P* approach directly accounts for uncertainty in setting ACLs below the OFLs, as mandated by the MSA, and provides a strong incentive to reducing the uncertainty in OFL through improvement to our understanding of stock dynamics. The SSC recommends the P* approach because it is more directly responsive to changes in our understanding of uncertainty. The constant buffer approach provides a simpler and more easily understood approach to setting ABC below OFL and could be structured to provide an incentive to improve stock assessment by using increasing buffers for lower tiers. If the Council is not comfortable with the P* approach for data-poor stocks, a hybrid approach could be adopted that uses P* for Tier 1 - Tier 3 stocks and a constant buffer approach for stocks in the other tiers. However, such an approach would have to be carefully designed to ensure that the implied buffer increases with the tier level to reflect higher levels of uncertainty for data poor stocks and provide a continued incentive to move stocks into higher tiers.
- Regarding options for the review process, the SSC felt that option 3, which requires an additional SSC meeting, either in person or via teleconference, may not be viable due to scheduling difficulties. With regard to option 4, setting OFL in June may be a viable option for some stocks, but should not be used as a general approach for all stocks because of the lack of recent summer survey information in the determination of stock status.

Regarding the discussion of accountability measures, the SSC wishes to re-iterate concerns that there is currently no mechanism to limit bycatch in other fisheries for any of the crab stocks. Hence, if an ACL is exceeded, any necessary adjustments would currently come out of the directed fishery. The SSC was pleased to see that the Council is considering an analysis of PSC limits in groundfish fisheries and we look forward to seeing an analysis of such limits.

Snow crab rebuilding

The snow crab rebuilding analysis was folded into the ACL analyses to evaluate ACL alternatives under different rebuilding scenarios. The SSC notes that the rebuilding analyses should be updated with results from model 5, the recommended model for OFL determinations. The SSC discussed the choice of declaring stocks rebuilt after one or two years of exceeding the reference level. The 2-year requirement was selected in the original rebuilding plan because of the high interannual survey variability which was used at that time to assess stock status in the absence of an assessment model. **We recommend the use of a 1-year requirement for rebuilding, because the stock is now assessed using a size based model that dampens inter-annual variability in spawning biomass.** Thus, the rationale for the 2-year requirement no longer applies. Moreover, the 1-year requirement is standard in other rebuilding plans.

All alternatives in the rebuilding plan include a provision to annually update F to maintain the specified probability of rebuilding. The SSC requests that additional information be provided in the document on how these adjustments would be made.

The SSC offers the following minor/editorial comments to the authors of the Initial Review Draft:

- Under Alternative 2 (constant buffer approach), please clarify that ABC = (1-buffer)*OFL. In the listed options, it would be useful to clarify the implied buffer value in parentheses, e.g.:

  Option 3: ABC = 80% of OFL (20% buffer)

  Please check to make sure that 'buffer' is consistently used throughout the document. The text still uses 'buffer' instead of '1-buffer' in some places (e.g. 2.3.2.1). The use of "buffer level of 80%" when referring to the multiplier (= 100% - buffer) should be avoided.
- The structure of the Tanner crab chapter 5 should be made consistent with other chapters
- Plots of the probability of overfishing as a function of the buffer and the additional uncertainty (e.g. Fig. 6-7/6-8 on p. 149/150) should be made more legible by increasing the size of the graphs or using a 2-D contour plot instead of the 3-D surface.
- Text under 2.2.3 (top of p. 15) is erroneous or unclear. We suggest replacing this text with corresponding text from the executive summary or similar language.
- Section 2.3.1.2: Briefly explain how σ_b was determined in the analysis of groundfish stocks (p.19). Also, the columns labeled "buffer" actually contain "1-buffer" values, so should be relabeled.
- Section 5.2.1 (p. 116): Correct the calculation of σ_{tot}. If σ_w = 0.14 and σ_b = 0.4, then $\sigma_{tot}=\text{sqrt}(0.14^2 + 0.4^2) = 0.424$, which is different from the stated value (=0.403).
- P. 19 under Table 2-6: The estimated values σ_b do not agree with the table (should be 0.04 to 0.40 and 0.09 to 0.51). The value 0.09 comes from GOA ATF, not EBS pollock.
- Regarding the Pr(Overfished), briefly note what A and B refer to in each table header (e.g. Table 5-3).
- Fig. 5-4 appears to be identical to Fig. 5-3
- P. vii, first sentence of 2nd paragraph: Change "the most precise estimates of within assessment uncertainty" to "the lowest assessment uncertainty".
- Fig. 2-2: Use same x-axes in both panels for comparison.
- Table ES-3 and Table 2-4 have incomplete headers.
- P. 22: should be 'where x is the buffer level selected' should be replaced with "where 1-x is the buffer level selected".
- Fix references to other sections, which were frequently outdated.

Economic analyses

The SSC appreciates the efforts made by authors of the economic analyses to address our concerns with earlier drafts. The caveats pertaining to interpretation and application of the projected potential foregone gross revenues are critical additions to the narrative and should reduce the likelihood of misunderstanding of reported numerical results. The SSC recommends that the tabular displays of the relative economic performance of the competing alternatives, as projected in the model, be arrayed as percentage changes, rather than gross discounted present value estimates of foregone revenue. Before the ACL and overfishing analyses are released for public review, care needs to be taken to ensure that discussion of anticipated economic impacts are included for each stock and that 'placeholder' text be removed once the economic discussions have been added to the text.

April 2010

D-1 (a) Crab ACL analysis and BSAI snow and Tanner crab rebuilding

Diana Stram (NPFMC) presented an overview of the draft Environmental Assessment for three proposed amendments to the FMP for the Bering Sea and Aleutian Islands king and Tanner crabs. The EA covers analyses for three proposed actions that are contained in a single EA because they were on the same timeline and because rebuilding plans are affected by the implementation of Annual Catch Limits (ACLs). The actions consist of: (1) establishing ACLs to meet requirements of the MSA; (2) revising the EBS snow crab rebuilding plan because snow crab were not rebuilt by the end of the existing rebuilding time frame (2009/10); and (3) preparing a rebuilding plan for EBS Tanner crab because the stock has been determined to be approaching an overfished condition. The latter action may be removed from the EA and put on a different timeline. The SSC also received presentations from Jack Turnock (AFSC) on the ACL methodology, the new Tanner crab model, and the snow crab model. Brian Garber-Yonts (AFSC) presented a proposed methodology for economic projections and Forrest Bowers (Crab Plan team chair) presented Crab Plan Team recommendations.

Public testimony was provided by Leonard Herzog (Homer Crab Cooperative), Arni Thomson (Alaska Crab Coalition), Linda Kozak (Crab Group of Independent Harvesters), and Dick Tremaine (Siu Alaska Corporation).

The SSC expresses appreciation to the Crab Plan Team and the crab stock assessment scientists who have contributed extraordinary effort and participated in multiple meetings under tight timelines to prepare and review drafts of the ACL and rebuilding analyses. We are especially appreciative of the efforts of the Council staff and Crab Plan Team in moving this process along and for providing informative and succinct reports to the SSC.

Annual Catch Limits

The MSRA requires a mechanism to specify Annual Catch Limits that may not exceed the Acceptable Biological Catch recommended by the SSC to the Council. This proposed action examines two alternatives to the Status Quo that would annually establish ABCs below the estimated Overfishing Level (OFL) and then set ACL = ABC. The alternatives use either a constant buffer (ABC = x% of OFL) or a variable buffer approach to maintain the probability that ABC exceeds OFL at a specified value of P^*<50%.

The SSC commends the authors for developing a common template for the individual chapters. This consistency greatly facilitates review of a large volume of information and should be maintained to the extent possible.

The following comments and recommendations address the overall process, the structure of the document, and analytical aspects of the ACL analyses and rebuilding plans.

In addition to the proposed control rule, a modification of the crab specification setting process is required to allow the SSC to review assessments and recommend ABCs on an annual basis. Three options that could either delay TAC setting (Option 1) or would require a change in the timing of when the SSC makes its ABC recommendations (Options 2&3) are laid out in the document. A fourth option was suggested in public testimony: to complete ABC recommendations for all stocks in June. **The SSC recommends evaluating this additional option to assess the risks associated with not including the latest information (i.e. the summer survey data) when setting TACs for the following season. The SSC also suggests that the analysts consider the feasibility of a web-based meeting under option 3.**

The EA does not yet include a discussion of accountability measures (AM). The Crab Plan Team made a strong recommendation to provide AMs for all sources of mortality, which would require limits on bycatch in other fisheries where such limits do not currently exist. **The SSC agrees, the EA needs to include a discussion of AMs that would provide an incentive to keep total removals below the ACL.** Consideration of how to allocate catch and bycatch is largely a policy choice. The SSC notes that the monitoring and methods for enforcing AMs should be included in the EA. Because of the timeline for EA, a full analysis of options to limit bycatch across multiple fleets is not possible. Therefore, the SSC concurs with the Crab Plan Team recommendation to begin consideration of these issues on a species-by-species basis in upcoming rebuilding plans such as that for Pribilof Island blue king crab and Tanner crab. Care should be taken in the design of AMs applied to fisheries that induce incidental crab mortalities; ill-structured AMs could threaten benefits gained under rationalization.

The structure of the preliminary EA allows for a comparison of the alternatives in terms of their short-term, medium-term, and long-term implications for catches and revenue. The analyses are very technical and require a large volume of information to be presented. To facilitate public review, the SSC has the following recommendations.

- While the document contains a concise summary of the fixed-buffer and P^* methods, the comparison of alternatives should include a general discussion of the advantages and disadvantages of the two approaches in addition to comparing catches and revenues under different options. This should include a discussion of how each approach conceptually meets the MSA requirements (which are formulated in terms of a P^*-type approach), how adaptable each approach is to changes in our perception of uncertainty, the complexity of adopting the P^*approach compared to constant buffers, and how each approach differs in terms of variability in ABCs over time. For example the P* approach may result in higher variability in ABCs and catches over time if stock assessment uncertainty changes from year to year, while a constant buffer would not be affected by changes in uncertainty. Of course a central feature and advantage of the P* approach is its responsiveness to true changes in uncertainty and this should be highlighted.
- We encourage further development of summary tables and figures that allow easy comparisons of the consequences of alternatives and options. For individual stocks, contour or perspective plots of catch or revenue over a range of values for the buffer and for the additional uncertainty (0 to 0.6 to cover the full range of σ_b) similar to current Figure 6.14. To summarize results across stocks, a table showing the magnitude of the buffer for each stock (rows) at different levels of additional uncertainty (columns, e.g. 0, 0.2, 0.4, 0.6) at a given level of P* would be most useful. A similar table summarizing the implied P^* values at a given buffer size across stocks at different levels of uncertainty would be useful. These tables could highlight the proposed levels of additional uncertainty for each stock. We also suggest including two summary tables as follows:
    - A table of the implied buffer at a given level of P* and at the chosen value of σ_b for each stock
    - A table of the implied P* value at a given buffer and the chosen value of σ_b for each stock
- The levels of assumed additional uncertainty (σ_b) that are currently under consideration (0.2, 0.4 and 0.6) have a strong impact on the results; it is critical to provide a sound rationale for these values to the extent possible. The SSC offers the following suggestions to strengthen the rationale for the choice of σ_b:
    - As stated in our February 2010 SSC minutes, reference could be made to previous analyses of "typical levels" of retrospective bias, for example the analysis of

retrospective bias observed in West Coast groundfish stock assessments. Similar analyses may have been completed in other regions.

- The variety of snow crab models that are currently being considered offer an opportunity to illustrate the extent of variability in OFL estimates across models. An assessment of this variability across a variety of models <u>with good support</u> can provide a minimum estimate of additional uncertainty for this stock.
- **The SSC supports the CPT approach to classifying stocks into those with relatively low, intermediate, and high levels of additional uncertainty.** The relative ranking of stocks seems appropriate given our current understanding of uncertainties, but the rationale for the overall range of uncertainties considered should be strengthened.
- The SSC is concerned that default values for σ_b (as well as for other parameters such as γ) could become thought of as fixed values. The EA should clarify that these values can and should be re-evaluated and updated as our understanding of uncertainty changes. Perhaps the CPT and stock assessment authors could be encouraged or required to annually provide a brief justification for the current value of σ_b.

- While short-term results are presented in terms of the consequences on catch-related quantities of either a given value of the buffer or a given P^* value, medium-term results are primarily presented in terms of the different buffer sizes (and under different levels of uncertainty), albeit with the corresponding probability of overfishing. Therefore it is difficult to evaluate the consequences of a given P* value and this has the unintended effect of focusing the results on the constant buffer approach. The consequences of the P^* approach should be presented in the form of tables or plots that summarize catch-related quantities at several selected P^* values. The consequences for variability in ABC and TAC due to application of fixed buffer or constant P* approaches should be discussed.
- For the presentation of results in this document, it is very important to clearly communicate uncertainty and how to interpret the figures that show medians with lower and upper bounds. We suggest adding a short section before the stock-specific chapters that provides a primer on uncertainty across multiple projections. As a possible model for how to more effectively communicate uncertainty to the public, the SSC suggests examining relevant sections in the most recent IPCC report. For example, this section could include a figure that shows individual trajectories from multiple projections (<<800) with the median and lower and upper confidence bounds superimposed. The section should clearly describe how to interpret these bounds.
- The document could benefit from a table of definitions as suggested in public testimony.

Comments on ACL analyses

- **The SSC endorsed the general approach for projections presented by André Punt in February**. For several stocks, new models were used in the analyses that have not been reviewed or fully documented. Very little detail is included in the EA on these models and it is not obvious what relevant parameters are and how these parameters were chosen or estimated. Some of these parameters could have a large impact on the analyses, such as the presumed level of uncertainty in R (σ_R). The SSC realizes that the EA is not the appropriate place to document these models. **The SSC recommends that important assumptions and parameter values be included in the EA and that models be documented elsewhere and included by reference.** One option is to include a brief description as an appendix.
- Some of the key parameters of the projection model relate to recruitment and are summarized in a table for both the Ricker and Beverton-Holt relationships. The methodology chapter should include a brief description of the general approach used to estimate these parameters. In some cases, the projection used different parameter values than those estimated (σ_R, e.g. Table 7.2), this should be justified. **To minimize confusion, the SSC recommends that the EA include results for only one of the recruitment specifications.** While results differ between the Ricker and

Beverton-Holt models, the SSC believes that differences in the form of the stock-recruitment relationship may be one of the smaller sources of uncertainty and could be subsumed in the "additional uncertainty". An alternative would be to capture some of the uncertainty directly by randomly selecting either the Ricker or Beverton-Holt model for each of the 800 projections (assuming each is equally likely).

- The analysts examined four alternative approaches for quantifying uncertainty in OFL for Tier 5 stocks. The SSC recommends that these approaches be carried forward in the analyses.
- A consistent approach should be used to evaluate probability of the stock being in an overfished condition. The approach currently differs between snow/tanner crab projection model and the model used for other stocks.
- The relationship between standard deviation of log(MMB), the coefficient of variation of log(MMB), and variability in MMB should be clearly articulated in the document to avoid confusion. Generally, it appears that the standard error of log(MMB) is used as a proxy for its CV (a good approximation for values less than about 0.4-0.5).

Comments on Economic Analyses

The SSC believes that the proposed economic methodology appears to sufficiently comport with the identified ACL method for king and snow crab fisheries. The model may be appropriate as a general characterization for other stocks, but only to the extent that the price series of those other stocks is correlated with the king and snow crab price series. Care needs to be taken in the next revision of this analysis to clearly differentiate between costs and possible foregone first wholesale revenues. While it is important to characterize the full time path of first wholesale revenues for rebuilding analyses, it may be more appropriate to represent the distribution of annual first wholesale revenues for single time steps that represent short-, medium, and long-run projections in the ACL analyses. The SSC recommended in its February 2010 minutes that the analysts summarize output over a shorter time frame of 5 or 6 years because "the shorter time frame would be of more immediate interest to the public, would be less influenced by assumptions about future recruitment, and would provide more robust economic projections, given the large uncertainties about future macro- and micro-economic factors."
Careful documentation should be provided within each economic section of the analyses, to clearly identify the implicit and explicit assumptions employed in the derivations, as well as the implications for interpreting the "first wholesale gross revenue foregone" projections.

The SSC offers the following minor-editorial comments for the authors:

- Replace "Annual Catch Level" and "Overfishing Level" with "Annual Catch Limit" and "Overfishing Limit" throughout the document.
- Footnote 15 (p. 33) refers to 'Options 5-7'. Please clarify if this should refer to Alternatives 5-7?
- Table 3.2 appears incomplete and does not explain the parameter γ.
- Make sure to fix references to all tables and figures in next draft.
- Variables names should be consistent throughout document, e.g. B is generally used for the Buffer (or rather, 1-Buffer), whereas b is used for additional uncertainty in the assessment. However, b in the economic section (p. 52) refers to the buffer.
- Table 4.1: Clarify footnote ("& - set to the point estimate"), which erroneously implies that P^* is set to its point estimate. This should state that total ABC is set to the OFL point estimate for P^* = 0.5.
- Fix equation 3.4 (should be square root)
- Check all tables for accuracy as there are some counterintuitive results. For example, in Table 10-4 (p. 301), the MMB initially increases then decreases, while the ABC increases overall, but the catch greatly decreases over the 6 years of the projection.
- Add species names in headers of Chapters 4-10

- Some inconsistency among stocks in terms of summarizing medium-term projections. Start year is sometimes 2009, sometimes 2010. Sometimes actual catch was applied in 2009 and ABC=OFL (snow crab), whereas in others (e.g. NSRKC, p. 300), buffer was applied in 2009.

Snow crab:
The SSC received a presentation from Jack Turnock ((NMFS-AFSC)) on results from recent Bering Sea snow crab model runs requested by the Crab Plan Team and the SSC. **The SSC appreciates his presentation and efforts to explore model sensitivity.**
This analysis built on earlier model explorations by addressing implications of incorporating the results of the 2009 Bering Sea Fisheries Research Foundation (BSFRF) trawl survey into the snow crab assessment. In addition, the author explored implications of separate selectivity curves for males and females and assumptions regarding natural mortality, survey biomass weighting, survey selectivity and survey catchability.

The SSC supports Crab Plan Team recommendations for model runs that will be presented at the May, 2010 Crab Plan Team meeting. In an effort to more fully explore model sensitivity to alternative assumptions on growth and mortality, **the SSC recommends the author run a suite of models that assumes the Somerton selectivity curve and assumes a male natural mortality rate between 0.2 - 0.5 incrementing values by 0.05.** For these model runs, female mortality will be fixed at 0.23, growth, maturity probability and female selectivity will be re-estimated. **The SSC also recommends a model that assumes the Somerton selectivity curve, estimates growth, maturity probability and mortality with a prior based on Canadian tagging data.** Finally, the SSC requests that the methods used to estimate natural mortality (survivorship) are discussed in the assessment and to the extent possible; the SSC requests that the authors consider stage based mortality to address the likelihood that mortality varies with immature and mature (terminally molted) crabs..

EBS Tanner crab rebuilding
A new stock assessment model has been developed for Tanner crab, which was adapted from the existing snow crab model. Tanner crab rebuilding will be removed because it is now on a different timeline and only the ACL analyses within this EA will use the new Tanner crab model.
Several authors have documented temporal and spatial differences in maturity of Tanner crab (Somerton and Myers, 1983 and Pengilly and Zheng, 1982). The SSC encourages the analysts to consider these processes in future model versions. **The SSC agrees with Crab Plan Team recommendations for changing rebuilding options for snow crab under each of the alternatives**: Increase probability of rebuilding either by extending time frame (e.g. to 8 years) or increased probability of rebuilding at year Ttarget to 70% or 90%.

February 2010

C-3(d) ACL Methodology

The SSC received a report from Diana Stram (NPFMC) and presentations by André Punt (UW) on possible approaches for the crab ACL analyses. Specifically, the SSC received the following documents: (1) an updated description of alternatives for ACL and rebuilding analyses, (2) a draft ACL analysis for the Bristol Bay red king crab stock, (3) a brief summary of a data weighting workshop, and (4) a description and preliminary ACL analysis for Tier 5 stocks.

The SSC reviewed the current draft alternatives and options for the combined crab ACL and rebuilding analysis. There were few changes besides incorporating a previous SSC recommendation to extend the rebuilding time frame for snow crab to 8 years. The SSC believes that the alternatives and options as laid out in the revised document provide a reasonable foundation for the analyses and the SSC has no additional recommendations.

André Punt provided an overview incorporating additional uncertainty in the ACL analyses beyond parameter uncertainty captured in the model. He strongly urged the SSC to consider including additional variance beyond what would be captured in a standard retrospective analysis, although the amount of extra variance (buffer) to include is necessarily arbitrary. The SSC previously recommended use of a standard retrospective analysis (i.e. the current model is assumed to be the "correct" model and its performance in predicting future reference points is evaluated retrospectively, see Dec. 2009 minutes). **The SSC agrees that the analyses should attempt to account for additional uncertainty, as long as a consistent approach is used across stocks,** and has the following specific recommendations:

- Because of the short timeline for the current analyses and because of the lack of other options, we support the use of the relatively arbitrary, fixed levels of extra variance like those that were used in the Bristol Bay red king crab example ($\sigma = 0.2$ and $\sigma = 0.4$). These values roughly bracket the range of uncertainty from historical retrospective analyses for Alaska crab stocks and approach the levels reported for West Coast groundfish stocks (Steve Ralston, pers. comm.). The SSC requests that the ACL analyses and rebuilding plans clearly explain and, to the extent possible, provide a clear rationale for choosing the levels of extra variance.
- For consistency, the current analyses should use the same levels of extra variance across stocks unless a clear rationale can be developed to use different levels for different stocks. However, the SSC recommends comparing the analyses across tiers to check if the implied buffer sizes between ABC and OFL increase across tier levels (from Tier 1 to Tier 5), consistent with the idea that uncertainty about stock status increases from Tier 1 to Tier 5. Thus, the specified or implied buffer size for a Tier 4 stock should generally be larger than the buffer for a Tier 3 stock in the assessment context (under a given level of precaution). Of course, for the ACL analyses a range of buffer sizes and P^* values should be evaluated for each stock.
- The additional buffer appears to be required for simulating stock dynamics in the analysis to properly account for uncertainty within the simulations. This is due to sources of uncertainty, such as author's assumptions on parameters or choices of datasets that are not expressed in model uncertainty.

The SSC endorses the draft ACL impact analysis for the Bristol Bay red king crab stock presented by André Punt and recommends extending a similar analysis to other Tier 3 and Tier 4 stocks. The analysis, among other things, computes the probability that ABC exceeds the "true" OFL (assumed known in the simulation) in a given year, the probability that MMB is less than MSST (= $0.5*B_{MSY}$) by year, and catches by year. The analysis will be extended to include an economic impact analysis. With regard to summarizing population trajectories for evaluating population impacts, the SSC recommends that the analysts provide summary output over a shorter time frame of 5 or 6 years. The shorter time frame would be of more immediate interest to the public, would be less influenced by assumptions about future recruitment, and would provide more robust economic projections, given the large uncertainties about future macro- and micro-economic factors.

The SSC received a short presentation on a preliminary ACL analysis for Tier 5 stocks. We appreciate receiving a report on these analyses, which provide one possible approach to quantifying uncertainty in extremely data-poor stocks. These stocks use an MSY proxy that is based on average retained catch over some pre-specified time period. Uncertainty in the OFL proxy was estimated as the standard error of the selected catch time series. However, the amount of variance quantified by either the t-distribution or the bootstrap distribution is small relative to the overall uncertainty. Therefore, it makes little difference in the choice of method.

The analysis demonstrates the large variability in the resulting uncertainty across stocks, much of which is very likely unrelated to the reproductive capacity of the stocks. Because few reasonable options are available, the SSC recommends that this analysis be brought forward with the following additional options for quantifying uncertainty:

- If the average catch is a reasonable proxy for OFL, the length of the time series over which catches appeared to be sustainable, along with the longevity of the crab species, gives some indication of the uncertainty in OFL. Therefore, the fixed buffer or the P^* value could be scaled to the ratio of the length of the time series relative to the life span of the species.
- To reflect the large uncertainty in the OFL proxy of Tier 5 stocks, additional uncertainty should be incorporated, for example through an extra variance term that is at least as large as the extra variance used for stocks in higher tiers (i.e., those with more information).
- Consideration should be given to increasing the measure of uncertainty in proportion to the length of time since the last year of the reference period because uncertainty about a stock's OFL would increase over time

The plan team requested clarification on the SSC recommendation from December 2009 "…*that all of the alternatives include a performance measure to evaluate the probability that the stock does not rebuild by a certain year (for example after 10 years), similar to the B20% threshold for some groundfish. This would provide a stronger incentive to avoid a potential stock collapse.*" This comment applies to rebuilding calculations only and was intended to provide a measure of performance that would discourage applying a rebuilding strategy that is too optimistic and may imply a high risk of continued overfishing. We recommend that the analysts quantify the probability of overfishing (i.e. Pr(MMB < 0.5 B_{MSY}) for each year within the rebuilding time frame, and that this measure is presented along with the probability of rebuilding (i.e. Pr(MMB > B_{MSY})).

December 2009

C-6(c) ACL and rebuilding plans for crab

The SSC received a report from Diana Stram (NPFMC) and presentations by Jack Turnock (NMFS-AFSC) on the ACL analysis for crab and rebuilding plans for snow crab and Tanner crab.

Public testimony was provided by Edward Poulsen (ICEPAC), Steve Minor (North Pacific Crab Association), Mateo Paz-Soldan (City of St. Paul), Arni Thompson (Alaska Crab Coalition), and Leonard Herzog (Homer Crab Cooperative), Frank Kelty (City of Unalaska), and Linda Kozak (Crab Group of Independent Harvesters).

The SSC reviewed a draft outline of the combined ACL analysis and rebuilding plans, which will be part of a single document such that rebuilding alternatives for snow and Tanner crab (but not Pribilof Island blue king crab, which have a separate rebuilding plan) will be examined under each ACL alternative.

ACL considerations

An analysis was presented about a potential approach to evaluating scientific uncertainty in assessment results associated with determining OFL. This approach could be used in the P^* method for determining appropriate buffers between ABC and OFL for crab stocks. The SSC believes that some approach to incorporating additional uncertainty in OFL beyond within-model uncertainty is warranted but had serious concerns about the proposed approach. In particular, the approach is sensitive to the particular stock assessment history and the estimated variance component is likely to fluctuate widely due to numerous factors that are not related to "true" model uncertainty.

The SSC recommends that analysts consider other approaches to incorporating additional uncertainty, specifically:

- Assuming that stock assessment models improve over time and ideally converge on a model that is at least approximately "correct" and accounts for the major (known) sources of uncertainty, we recommend that analysts consider an approach based on standard retrospective analyses. That is, the current model could be assumed to be the "correct" model and its performance in predicting future reference points is evaluated retrospectively. While not accounting for full model uncertainty, it would avoid the dependence of the estimated uncertainty on somewhat arbitrary assessment histories. We note that this approach would also avoid ambiguities about the best way to calculate variability in biomass estimates because the estimates from the most up-to-date model would serve as a natural reference level for computing the log-ratio of past estimates of biomass to the reference biomass.

- To limit large differences in the estimated level of uncertainty among stocks, an appropriate level of uncertainty across all stocks, or across groups of stocks that have a similar levels of complexity, could be determined through a meta-analysis and the resulting level of uncertainty could be applied to all stocks (within a group, if appropriate). This would limit the large differences in the perceived level of uncertainty across stocks and their effects on the size of the resulting buffers between ABC and OFL.

Stock rebuilding

The snow crab projection model is based on the current assessment model and uses estimated average recruitment with first-order autocorrelated residuals to generate future recruitments. The SSC had some discussion about appropriate time frames to use for average recruitment and concerns about the apparent decadal-scale patterns in past recruitments. Nevertheless, given the relatively short time frame considered in the rebuilding analysis, combined with the long lag between fertilization and recruitment to the fishery, **the SSC believes that the proposed approach adequately captures past recruitment variability and offers a reasonable approach to capturing future recruitment uncertainty for the purposes of the rebuilding analysis.** However, the SSC requests that the analysis describe the use of autocorrelated recruitment deviations and include discussion about the apparent pattern of decadal variability of recruitment.

For Tanner crab, the analysts plan to use the snow crab projection model with appropriate modifications to account for differences in snow crab and Tanner crab dynamics. As a fallback, a simpler model (e.g., delay-difference model) may be used to complete the analyses by the next crab plan team meeting in March. There may not be sufficient time for a full review of the model by the Plan Team and SSC.

The SSC has recommendations for both the snow crab and Tanner crab models and projections. However, given the short time frame for the rebuilding analyses, we realize that it may not be possible to satisfactorily address these recommendations in these analyses. However, at a minimum, we request that these points be addressed in the context of the annual assessments:

- For snow crab, we reiterate our request from the October meeting that the rebuilding analysis consider spatial dynamics of the stock, particularly the potential importance of southern versus northern areas occupied by the stock in terms of source of recruits, regional harvest rates, etc. Specifically, the environmental ratchet hypothesis of Orensanz, Armstrong, and colleagues suggests that densities of spawning stocks at the southern end of the range are disproportionately important. However, owing to the distributions of sea ice and operational costs, the southern portion of the stock experiences the highest harvest rates.
- For Tanner crab, there is ample evidence for biological differences in Tanner crab between the eastern and western portions of the stock. When developing the new assessment model for Tanner crab, consideration should be given to incorporating such differences into the model. As a minimum, the assessment model should ultimately include differences in maturity-at-size parameters, which differ substantially between areas.
- The appropriate base years over which to estimate average recruitment for all crab stock projections, not just those for snow and Tanner crab, should be reviewed. As indicated above, the rebuilding analyses may not be very sensitive to alternative recruitment scenarios, but the choice of appropriate recruitment estimates needs to be evaluated in the stock assessment process. As was pointed out in public testimony, there is some evidence for a shift in average recruitment associated with the 1988/89 regime shift.

- To the extent possible, results from the net efficiency study should be incorporated into the rebuilding plan.

Alternatives for the snow and Tanner crab analysis are structured around different time frames for rebuilding. For snow crab, these range from T_{min}, the minimum number of years in which rebuilding to the B_{MSY} proxy could occur with 50% probability under no fishing, to T_{end}, the year in which rebuilding to the B_{MSY} proxy would occur with 50% probability if fishing at the maximum permissible rate (75% of F_{OFL}). The rebuilding plan will go into effect in 2011/12 (Year 1) and assumes that catches in 2009/10 and 2010/11 will be at 75% F_{OFL}.

The SSC concurs with the alternatives as outlined in the document but requests the following modifications:

- Because of the relatively short rebuilding time frame estimated by the model, concerns were expressed about the possibility of having to develop another revision to the rebuilding plans if environmental conditions result in a few more years of poor recruitment. The SSC requests that the analysis include an alternative for an 8-year rebuilding horizon. Given the current estimates of the probability of rebuilding (Table 1 in the snow crab rebuilding alternatives), this would correspond to a probability of approximately 70% in the example provided. The SSC recognizes the scenario in the final model may result in a different required probability of rebuilding. Therefore, the alternatives should be frameworked to describe that the probability of rebuilding for the 8 year option would be determined from a scenario based on a fishing mortality rate no greater than 0.75 F_{msy}.
- We recommend that all of the alternatives include a performance measure to evaluate the probability that the stock does not rebuild by a certain year (for example after 10 years), similar to the $B_{20\%}$ threshold for some groundfish. This would provide a stronger incentive to avoid a potential stock collapse.

Finally, the SSC requests that Council staff explore the possibility of placing additional harvest measures directly into the BSAI crab FMP for crab stocks that experience repeated “overfished” and “not overfished” designations owing to environmental changes despite conservative harvest control rules. These measures could include fishery closure below specified thresholds and would be designed in such a way as to avoid repeated overfished designations. In the case of Tanner crab, the fishery fell below the state’s harvest threshold and was closed during 1997 to 2004. Once a Tanner crab stock assessment model is built, an informative modeling exercise would be to examine the effects of the directed Tanner crab fishery during 2005-2009, as well as Tanner crab bycatch during 1997-2009, on the current status of this stock approaching the overfished condition.

October 2009

D-2 (a) Annual Catch Limit (ACL) Requirements

Diana Stram (NPFMC) reviewed the process required to bring crab, scallop, and groundfish Fishery Management Plans into compliance with new Annual Catch Limit (ACL) requirements in the revised Magnuson-Stevens Reauthorization Act (MSRA). Grant Thompson (NMFS, AFSC) and Jack Turnock (NMFS, AFSC) presented overviews of technical analyses of two approaches that could be used to provide a buffer between ABCs and OFLs, based on scientific uncertainty in the estimate of OFL. Public testimony was provided by Leonard Herzog (Alaska King Crab Harvesters Cooperative).

The SSC reviewed three approaches to providing buffers between ABC and OFL in June 2009, but had insufficient lead time to provide meaningful recommendations on the technical analyses presented. Further analyses were conducted over the summer on two possible approaches. The SSC reviewed written documents and received summary presentations on the probability only (P*) approach and the decision-theoretic (DT) approach.

The P* approach is relatively simple and could be applied to any stock for which a reasonable estimate of the uncertainty in OFL is available. The challenge with this approach is to determine which sources of uncertainty to include and how to properly quantify uncertainty. Once a probability distribution for OFL is constructed, ABC is simply selected such that the probability of overfishing (ABC > OFL) is less than some pre-specified probability P*, where P* must be less than 50%. The choice of an appropriate P* is a policy decision, but the SSC notes that several possible choices were explored in the analyses. First, analysts estimated the average value of P* that is implied by the current harvest control rules for groundfish. The estimated groundfish average (P* = 0.12) could provide a baseline for establishing an appropriate buffer between ABC and OFL in the crab and scallop FMPs, given that groundfish have been sustainably managed under these control rules. Second, the draft paper on *Setting Annual Catch Limits (ACLs) for BSAI and GOA Groundfish* presents a simple choice for P* that is based on past performance of the ABC-setting system (section 1.2.3 of the document). Third, the decision-theoretic approach (described below) could provide guidance on a suitable choice of P*, if a desired level of risk aversion can be specified.

The decision-theoretic approach is considerably more complex and much more challenging to implement. The approach finds the optimum fishing mortality F_{ABC} (and the corresponding buffer between F_{ABC} and F_{OFL}) given a pre-specified level of risk aversion. The required policy choice in this approach is the choice of a desired level of risk aversion. Similar to the P* approach, the choice of an appropriate level of risk aversion could be based on the level implied by our current groundfish harvest control rules (estimated average absolute risk aversion = 0.4). Alternatively, methods exist to identify the level of risk that managers or the public may be willing to take. The SSC appreciates the clear description of this approach and the examples provided by the analyst.

In addition, presentations were received on applications of both the P* approach and the DT approach to several data-rich crab stocks (paper by Punt, et al.), and an application of the P* approach to several Tier 4 crab stocks (i.e., stocks without an assessment). The application of the DT approach to Bristol Bay and Norton Sound red king crab and St. Matthew Island blue king crab resulted in an optimum fishing mortality that was very close to F_{OFL} ($0.95*F_{OFL}$ or larger, implying a very small buffer) under three very different levels of risk aversion. The small buffer size (in spite of considerably uncertainty in the assessments) and the fact that the same buffer size was chosen regardless of the level of risk aversion seems counterintuitive. Moreover, these results appear to be at odds with analytical results (using a simpler and less realistic model), which show much larger optimal buffer sizes, in spite of comparable levels of uncertainty. The small buffer sizes of the Punt, et al. analysis may be a result of using the sloping control rule within the model simulations, and the particular recruitment assumptions made in the model (Andre Punt, pers. comm.). Clearly, additional simulations would be needed to evaluate the use of the DT approach with "typical" assessment models.

A presentation was given on sources of uncertainty in Tier 4 crab stocks and an application using the P* approach to evaluate (1) buffer sizes implied by a pre-specified P* and (2) P* values implied by fixed buffer sizes. Results suggested considerable variability in the probabilities of exceeding OFL (P*) corresponding to a fixed buffer (ABC = 0.75*OFL), ranging from 0.3 to 0.7 under different assumptions about the levels of uncertainty in biomass estimates and M. The results for blue king crab imply a probability of exceeding OFL that is larger than 50%, even with ABC = 0.75*OFL. This implies a highly skewed distribution of OFL, with a specified OFL that is much higher than the median. The SSC suggested that, for these Tier 4 stocks, it may be most appropriate to set the OFL equal to the median of its distribution, to ensure that any ACL set below the OFL has less than a 50% chance of exceeding OFL (by definition).

The SSC concurs with the crab plan team (CPT) recommendation that analyses for the upcoming crab FMP amendments should focus on the P* approach. Our rationale for this recommendation is as follows:

- The P* approach is more readily understood than the DT approach by stock assessment scientists, managers, and the general public.

- The P* is easily implemented for both data-rich and data-poor stocks, while the DT approach may be impracticable for many of our stocks with complex, age-structured assessments.
- The DT approach may be inconsistent with NS1 guide lines as written, which seem to imply an approach similar to the P* approach: *"ABC should be based, when possible, on the probability that an actual catch equal to the stock's ABC would result in overfishing. This probability that overfishing will occur cannot exceed 50 percent and should be a lower value."*

The joint groundfish/crab plan team made a number of additional recommendations regarding ACL compliance. The SSC concurs with these recommendations, as reflected in the joint plan team minutes, and offers these additional recommendations and comments:

- For groundfish, the SSC recommends that the FMPs be modified to document how current buffers built into each Tier are adequate to meet the requirements of the NS1 guidelines. However, additional improvements that explicitly link uncertainty to the buffer between ABCs and OFLs should be explored in the future.
- As recommended by the teams, a range of P* values and buffer sizes should be considered in the crab ACL analysis (i.e., P* values corresponding to a fixed buffer size and buffer sizes corresponding to a given P*). The SSC notes that a constant buffer approach, while intuitively appealing and easier to implement, does not explicitly link the buffer to scientific uncertainty specific to a given stock assessment, and may not fully satisfy the requirements of the National Standard 1 guidelines.
- Where possible, for Tier 1-3 stocks, key sources of uncertainty should be considered. For example, uncertainty in natural mortality M, if it is estimated independently, could be included in the model by specifying a CV for M or using a set of alternative M values with pre-specified probabilities in the assessment.
- Uncertainty about model structure should be considered for Tier 1-3 stocks. While a model averaging or similar approach is beyond the scope of the SSC's review, a number of stocks exhibit consistent retrospective patterns, such as a consistent overestimation of current biomass in Bristol Bay red king crab and Norton Sound red king crab. This introduces additional uncertainty (and bias) in the model-generated estimates of B, which should be accounted for when determining an appropriate buffer. The PT minutes reported that the PFMC plans to estimate uncertainty in model structure by conducting a retrospective analysis of spawning stock biomass on a common date (5 years ago).
- The SSC recommends that the ACL uncertainty adjustment should be based on sources of uncertainty that the authors have a reasonable chance of quantifying. The NPFMC has always promoted the use of clear and transparent analytical approaches to management. Attempting to add unspecified adjustments, based on the Delphi method (a structured process for collecting and distilling knowledge from a group of experts, in this case the PT), could lead to confusion and debates about methodology and the size of the proposed adjustment. The SSC suggests development of a process for bringing forward proposals for initial or additional uncertainty adjustments that includes a repeatable, quantitative method to making the estimate. If an added buffer for unquantifiable sources of uncertainty is considered, then a method for estimating the buffer should be derived that does not only rely on the analyst's or PT's opinion.
- The SSC re-iterates our June 2009 recommendation to stock assessment authors that, if harvest strategies are modified to explicitly incorporate uncertainty in the buffer between OFL and ABC, then authors should strive to select the "best estimate" for parameterizing models and not precautionary estimates.

- With regard to Tier 4 crab stocks, the SSC notes that sources of uncertainty that affect the estimation of uncertainty in OFL may not be independent, for example, natural mortality estimates may be confounded with estimates of biomass and biomass reference points. In such cases, appropriate multivariate distributions should be specified for the joint distribution of these parameters.
- As a check on the Tier 4 approach for crab stocks, the SSC suggests comparing results from the P*-based approach to determining buffer sizes between a Tier 4 type analysis and a Tier-3 type analysis for at least one of the Tier 3 stocks.
- For Tier 5 crab stocks, only catch series are available. Uncertainty in the average catch (e.g., a function of the SE of mean), as well as uncertainty in the time period over which catches are averaged should be considered. For example, different periods in the time series could be weighted differently to arrive at an appropriate average of the stocks productive capacity as a proxy for OFL and the associated uncertainty.
- With respect to the scallop FMP, a Tier 5-type approach, as described above for crab, could be used to determine an appropriate level of uncertainty in OFL.
- For scallop and other species where an overall OFL is set with area-specific ABC apportionments, some clarification may be needed on the relationship between the area-specific ABCs and the overall buffer between total ABC and OFL.
- Regarding the analyses of different options to consider by the Council, the SSC suggests that a simplified management strategy evaluation (MSE) approach could be implemented. Simplified stock dynamics could be simulated as a basis for assessing different buffers and P* values. For example, stock dynamics could be simulated using a simple surplus production approach as described in Appendix 3 of the Pribilof Island Blue King Crab assessment.

June 2009

D-1 (b) ACL work plan

Jane DiCosimo (NPFMC), Grant Thompson (NMFS, AFSC), and Jack Turnock (NMFS, AFSC) presented information on the NPFMC's Annual Catch Limit Workshop, held May 21-22, 2009, at the Alaska Fisheries Science Center, Seattle, Washington.

Jane DiCosimo reviewed the actions needed to bring the Groundfish, Crab, and Scallop Fishery Management Plans into compliance with the revised Magnuson-Stevens Reauthorization Act (MSRA). The required actions outlined in these Action Plans differ by FMP and are detailed in D-1(b) (1-3). .

The SSC provides the following general comments regarding the timeline for revising FMPs to comply with the MSRA. Altering the analytical approach for setting harvest specifications for groundfish, crab, and scallops is an important activity that should be carefully analyzed, while the timeline for completion of these analyses is very short. **If the NPFMC elects to consider major modifications to the harvest strategy in the FMPs, then the scope of this analysis will be large because of the technical interactions between species and fishing sectors, and different stakeholders involved, making it difficult to meet the required timelines for compliance with ACL provisions of the MSRA.**

The technical guidelines for the MSRA recommend that scientific uncertainty and management uncertainty be taken into account when setting annual catch limits. A summary of three approaches to assessing scientific uncertainty in stock assessments that were discussed at the NPFMC ACL workshop were presented: 1) a qualitative approach, 2) a probability only (PO) approach, and 3) a decision theoretic (DT) approach. An example was presented that applied the PO approach, but limited the source of uncertainty to trawl survey data. Next presented were results from an application of the PO approach to Tanner crab, which assessed the size of the buffers relative to the probability of exceeding the FOFL (including the sloping control rule) under different levels of uncertainty in $F_{35\%}$, natural mortality, maturity, and handling mortality. Finally, the DT approach used a factorial analysis to assess the magnitude of the uncertainty buffer under various assumptions of absolute risk aversion and different levels of uncertainty in natural mortality, process error at all ages except age-0, recruitment (age-0), and relative spawning per recruit. The SSC noted that the PO and DT approaches were highly technical and the SSC did not have sufficient lead time to review the methodology. The SSC was, therefore, unable to make recommendations on a preferred analytical approach to assessing uncertainty**.**

The SSC notes that the qualitative approach would require several judgment calls on weights and buffers, and suggests that it would be useful to list the sources of uncertainty that have not been addressed. However, the SSC does not believe that authors should attempt to make judgment calls on the magnitude of the uncertainty and the weights or the buffers. The SSC was informed that assessing all sources of uncertainty in the assessment was not a requirement of the MSRA, so simplicity is desirable in the formulation of the amendment packages.

The SSC recommends to stock assessment authors that, if harvest strategies are modified to explicitly incorporate uncertainty in the buffer between OFL and ABC, then authors should strive to select the "best estimate" for parameterizing models and not the most precautionary estimate.
Groundfish FMPs:

Preliminary review of proposed Amendments to the GOA and BSAI Groundfish FMPs is scheduled for October or December 2009. Actions required to modify the FMPs are outlined in Agenda Item D-1(b)(1). In the case of groundfish management, a buffer currently exists between the OFL and the ABC (ACL). Thus, it is expected that the groundfish management strategy will be compliant with the provisions of the technical guidelines for the MSRA. The key activity will be to assess the level of precaution currently afforded by the management strategy for the groundfish stocks or stock complexes. It was reported that NMFS groundfish assessment authors plan to apply the PO and DT approaches to assess the performance of the current harvest strategy. These analyses should be completed by August 1, 2009. **The SSC supports this activity and will comment on the results at the October NPFMC meeting.**

It was reported that analyses of species currently listed in the Groundfish FMP's will be needed to determine which species or species groups should be included in the FMP and which of these species within the FMP should be managed as Ecosystem Components (EC) or as components "in the fishery." One strategy would be to remove non-specified species from the FMP, and consider forage fish and prohibited species as candidates for EC management. NMFS analysts presented a vulnerability assessment tool at the NPFMC workshop that considers the susceptibility of a species to fisheries and the productivity of the species. Workshop participants recommended that the vulnerability of forage species, target species, non-target species (members of the "other species" complex), and prohibited species should be assessed over the summer. **The SSC supports the recommendation to conduct the vulnerability analysis and will comment on management category assignments at the October Council meeting.**

Crab FMP
Preliminary review of the proposed amendments to the BSAI Crab FMP is scheduled for June 2010. Actions required to modify the BSAI crab FMP are outlined in Agenda Item D-1(b)(2).
It appears that the major change required is that ABCs (ACLs) will have to be determined, in addition to OFLs. **The SSC seeks clarification about ACL requirements, as well as the SSC role in ACL determinations in FMPs in which TAC-setting has been deferred to the State of Alaska.**
The SSC reiterates concern that the current timeline for review of OFL determinations for crab stocks does not allow an SSC review of the final OFL recommendations prior to the release of the TACs by the State of Alaska. It is the SSC's hope that this issue will be revisited by the Council and Board of Fisheries.

If the Crab FMP is modified to provide an ABC (ACL) control rule, it should explicitly consider uncertainty. Workshop participants suggested that the PO and DT approaches could be considered as a method for setting the buffer between ABC (ACL) and OFL. The workshop report suggested that groundfish could be used as a starting point: the analysis should include a table, by tier category, with the implied assumptions regarding P* or the level of risk aversion underlying each buffer. However, the SSC noted that crab assessment authors do not necessarily need to tie their selection of uncertainty buffers to the results from the retrospective analysis of the performance of the groundfish harvest strategy. The SSC recommended that crab stock analysts work over the summer on PO techniques like that presented for Tanner crab. This PO approach could be extended to Tier 3 crab stocks, using model estimates of OFL including uncertainty in current biomass, $F_{35\%}$ and $B_{35\%}$. There are several outstanding sources of uncertainty in crab assessments, including, biomass measure (male limited), vulnerability, and spatial differences in growth and reproductive processes.

Scallop FMP

Preliminary review of proposed Amendments to the Scallop FMP is scheduled for June 2010. Actions required to modify the BSAI scallop FMP are outlined in Agenda Item D-1(b)(3). The SSC notes that, like crab, major modification of the Scallop FMP will be needed for ACL specification. **As in the case of crab, the SSC had uncertainty about ACL requirements, and the SSC's role in ACL determinations in deferred management situations.**

The SSC reviewed alternative approaches for the scallop ACL analysis (item 38 in the workshop report). **The SSC concluded that the approaches identified by the workshop participants represented a reasonable suite of alternatives.**

APPENDIX 2: ADDITIONAL INFORMATION PROVIDED ON THE TAC-SETTTING PROCESS AT FINAL ACTION BY THE STATE OF ALASKA

Review of TACs for the 2009/10 Bering Sea king and Tanner crab season, presented by Doug Pengilly at the ADF&G–NMFS–Industry meeting, Seattle, WA, October 12, 2009.

Overfishing level (OFL) and total allowable catch (TAC) for Bering Sea king and Tanner crab fisheries, 2009/10.

Fishery	OFL (millions of pounds)	TAC (millions of pounds)
Bristol Bay red king crab	22.56 (total catch)	16.009
Saint Matthew Island blue king crab	1.72 (total male catch)	1.167
Pribilof red king crab	0.50 (total catch)	0 (closed
Pribilof blue king crab	0.004 (total catch)	0 (closed)
Bering Sea Tanner crab	5.57 (total catch)	1.350
Bering Sea snow crab	73.0 (total catch)	48.017

Federal Overfishing Definitions for 2009/10 (Amendment 24 process; 2009 Crab SAFE; 24 Sept 2009 NOAA stock status notification letter)

B_{MSY}: MSY biomass defined in terms of mature male biomass (MMB)
- Defined as the biomass at time of mating (assumed to be 15 February)
- MMB estimated as projection to time of mating for comparison with B_{MSY}

Minimum stock size threshold (MSST)
- Defines **overfished** status; stock is overfished if MMB < MSST
- Defined as 50% of B_{MSY}

Critical biomass threshold
- Directed fishery must be closed if MMB < critical biomass threshold
- Defined as 25% of B_{MSY}

Overfishing level (OFL)
- Defines when overfishing occurs
  - Biomass of fishing mortality > OFL → **overfishing** has occurred
- Established prior to season; Catch is compared to OFL after season (Sept '10)
- **OFL defined as "total catch" biomass** for most fisheries
  - Retained catch **+ bycatch mortality to males and females from all fisheries**
  - Exception:
    - St. Matthew blue king crab: OFL defined as biomass of total male catch
- **Retained-catch portion of OFL** is also estimated
  - This is NOT the TAC. Is NOT a legal/regulatory limit.
  - Provides guidance for State's setting of TAC to avoid reaching OFL
    - Generally, State sets TAC < estimated retained-catch portion of OFL

State regulatory harvest strategies
- Rules in state regulation for computing TAC from survey and stock assessment data
  - Stock threshold for opening fishery

    - Rules for setting exploitation rate on abundance/biomass of mature-sized males
        - Exploitation rate dependent on stock index estimated from survey data
    - Cap on exploitation rate on legal males
    - Minimum TAC for fishery opening
        - Exceptions: Tanner crab (*bairdi*) and, *now*, St. Matthew blue king crab
- No harvest strategy in regulation for Pribilof red king crab
- Harvest strategies reference stock biomass or abundance at time of survey (summer)
- Stock abundance or biomass estimates for computation of TACs are for time of survey
- Stock status estimates (MMB, B_{MSY}) for federal Amendment 24 process are relative to time of mating (assumed to be 15 February)
    - Values for 2009/10 are ***forecasts*** for 15 February 2010
        - Are finalized in Sept '10 after:
            - May '10 CPT review of stock assessment methods/models
            - Analysis of summer 2010 survey and 2009/10 fisheries data.
- Federal **"Overfished/Not-overfished"** status determination (MMB relative to MSST) for 2009/10 will be determined in Sept '10
    - For final 2008/09 "Overfished/Not-overfished" status determinations, see 2009 Crab SAFE or 24-Sept-09 NMFS stock status notification letter
- Federal **OFL** for 2009/10 is **NOT** a forecast
    - Determined in Sept '09 using the forecasts of MMB, B_{MSY}
    - Occurrence of overfishing in 2009/10 will be determined in Sept '10 by comparing the total catch estimated for 2009/10 with the OFL established in Sept '09
    - Determination that stock is below **"critical biomass threshold"** for directed fishery is **NOT** a forecast (is part of OFL determination)
        - Determined in Sept '09 using the 2009/10 forecasts of MMB, B_{MSY}
- Indices/estimates for state harvest strategies to determine 2009/10 TACs are for the time of the survey (i.e., Summer 2009)

Pribilof Blue King Crab

2009/10 Federal OFL Determination (Amendment 24 process)

Forecasts for 2009/10 (at time of mating, 15 February 2010)

- $\mathbf{B_{MSY}}$ = 9.28-million pounds MMB
- **MMB** = 1.13-million pounds = 12% of B_{MSY}

2009/10 overfishing level (OFL):

- 4-thousand pounds total catch, including bycatch mortality of males and females in all fisheries
- **Stock is below critical biomass threshold for opening directed fishery**
    - MMB < 25% of B_{MSY}

      → Directed fishery closed → Retained catch limit = 0 pounds.

State harvest strategy (5 AAC 34.918)

Stock threshold for opening fishery:

- 13.2-million pounds total (male and female) mature biomass for 2 consecutive years

Exploitation rate on mature-sized (≥120-mm CL) male abundance:

- 10%
- **Harvest capped at 20% of legal male abundance**

Minimum TAC:

- 0.556-million pounds (including portion allocated to CDQ fishery)
- **2008 estimate for total mature biomass:**
- 1.6-million pounds (NMFS area-swept estimate)

2009 estimate for total mature biomass:

- <2.91-million pounds (NMFS area-swept estimate of total stock biomass = 2.91-million pounds)
- **Stock is below threshold for a fishery opening**

<u>2009/10 TAC determination = 0 pounds (directed fishery closed)</u>

Federal OFL determination for 2009/10

- Stock < ½ of critical biomass threshold for directed fishery opening
- OFL = 4,000 pounds of bycatch mortality

Stock far below threshold for opening fishery in state harvest strategy

<u>Other state measures to protect stock from overfishing in 2009/10</u>

Closure of Pribilof red king crab fishery

Area closure for snow crab fishery

- West of 168° W long, east of 170° W long, north of 57° N lat, south of 58° N lat Statistical areas 685700, 685730, 695700, 695730

<u>Pribilof Red King Crab</u>

<u>2009/10 Federal OFL Determination (Amendment 24 process)</u>

Forecasts for 2009/10 (at time of mating, 15 February 2010)

- $\mathbf{B_{MSY}}$ = 8.78-million pounds MMB
- **MMB** = 4.46-million pounds = 51% of B_{MSY}

<u>2009/10 overfishing level (OFL)</u>:

- 0.50-million pounds <u>total</u> catch, including bycatch mortality of males and females in all fisheries
- Stock is above critical biomass threshold for opening directed fishery
  - MMB > 25% of B_{MSY}
- Estimated retained-catch portion of total-catch OFL = 0.34-million pounds

<u>State harvest strategy – none in regulation</u>

Stock threshold for opening fishery:

- None in regulation

Exploitation rate on mature-sized males abundance:

- None in regulation
- Historically during 1993/94–1998/99: high as 20%, low as 10% or less

Minimum TAC:

- None in regulation
- Fishery has been closed since 1999/00 season
- Poorer performance than expected from survey estimates in late 1990's
- Poor precision of abundance estimates
- Concerns for bycatch of blue king crabs

<u>2009 estimates</u>

- 0.944-million mature-sized males (≥120-mm CL; ADF&G CSA estimate)
- 0.761-million legal males (ADF&G CSA estimate)
- Legal male average weight = 6.9 pounds (ADF&G estimate from survey size)

<u>2009/10 TAC determination = 0 pounds (directed fishery closed)</u>

- Poor precision of abundance estimates

    - ±130%+ for NMFS area-swept estimates of legal males
  - Concerns for bycatch of blue king crabs remain <u>very</u> high
    - Pribilof blue king crab OFL = 0.004-million pounds (bycatch mortality only)

<u>Bristol Bay Red King Crab</u>

<u>2009/10 Federal OFL Determination (Amendment 24 process)</u>

Forecasts for 2009/10 (at time of mating, 15 February 2010)

  - **B_{MSY}** = 68.5-million pounds MMB
  - **MMB** = 95.2-million pounds = 139% of B_{MSY}

<u>2009/10 overfishing level (OFL)</u>:

  - 22.56-million pounds <u>total</u> catch, including bycatch mortality of males and females in all fisheries
  - Stock is above critical biomass threshold for opening directed fishery
    - MMB > 25% of B_{MSY}
  - Estimated retained-catch portion of total-catch OFL = 19.914-million pounds

<u>State harvest strategy (5 AAC 34.816)</u>

Stock threshold for opening fishery:

  - 8.4-million mature females, and
  - 14.5-million pounds of effective spawning biomass (ESB)

Exploitation rate on mature-sized (≥120-mm CL) male abundance:

  - 10%, when ESB <34.75-million pounds
  - 12.5%, when ESB is between 34.75-million pounds and 55.0-million pounds
  - 15%, when ESB ≥55.0-million pounds

Harvest capped at 50% of legal male abundance

Minimum TAC:

  - 4.444-million pounds (including portion allocated to CDQ fishery)
  - **2009 estimate for abundance of mature females:**
  - 31.827-million crabs (ADF&G LBA estimate)

2009 estimate for ESB:

  - 70.383-million pounds (ADF&G LBA estimate)
  - Stock is above threshold for a fishery opening
  - 15% exploitation rate on estimated mature male abundance applies

<u>2009/10 TAC computation according to state harvest strategy</u>

- 15% exploitation rate applied to estimated mature-sized male abundance
  - 17.708-million mature-sized males (ADF&G LBA estimate)
  - 0.15 X 17.708-million = 2.656-million crabs
- Check: 50% cap on harvest of legal males
  - 10.521-million legal males (ADF&G LBA estimate)
  - 0.5 X 10.521-million = 5.261-million crabs > 2.656-million crabs
  - Compute TAC on harvest of 2.656-million legal males
- TAC computed according to harvest strategy:
  - 16.009-million pounds (includes CDQ portion)
    - Assumed average weight = 6.03 pounds
    - 1.05 X estimated average weight from survey (5.74 pounds)
  - Computed TAC is above minimum 4.444-million pounds for fishery opening

<u>Comparison with federal OFL</u>

- A 16.009-million pound TAC is 71% of total-catch OFL
    - 22.56-million pounds, including male and female bycatch mortality in all fisheries
- A 16.009-million pound TAC is 80% of estimated retained-catch portion of OFL
    - 19.914-million pounds

2009/10 TAC determination = 16.009-million pounds (including CDQ)

- TAC of 16.009-million lbs represents 2.656-million crabs (avg. wt = 6.03 lbs)
    - 25% of legal males estimated at the time of survey (10.521-million crabs, LBA est.)
- ADFG confident that TAC can be achieved without reaching total-catch OFL (22.56-million pounds):

OFL - TAC = 22.56-million pounds - 16.009-million pounds = 6.55-million pounds

- Assumed bycatch mortality in crab fishery = 20%
- Assumed bycatch mortality in trawl fisheries = 80%
- Majority of estimated bycatch mortality due to crab fishery (>80% in recent years)
    - Max est. bycatch mortality due to crab fishery last 10 years = 3.8-million lbs
    - Max est. bycatch mortality due to groundfish fisheries last 10 years = 0.4-million lbs
- However, as usual, ADFG stresses:

Minimize bycatch/discards of red king crab during crab fishing

St. Matthew Blue King Crab

2009/10 Federal OFL Determination (Amendment 24 process)

Forecasts for 2009/10 (at time of mating, 15 February 2010)

- **B_{MSY}** = 7.99-million pounds MMB
- **MMB** = 12.47-million pounds = 156% of B_{MSY}

2009/10 overfishing level (OFL):

- 1.72-million pounds total **male** catch, including bycatch mortality of males (but not females) in all fisheries
- Stock is above critical biomass threshold for opening directed fishery
    - MMB > 25% of B_{MSY}

State harvest strategy (5 AAC 34.917)

Stock threshold for opening fishery:

- 2.9-million pounds of mature-sized males (≥105-mm CL)

Exploitation rate on mature-sized males abundance:

- 10%, when mature male biomass = 2.9-million pounds
- Increases linearly up to 20% with increasing mature male biomass up to 11.6-million pounds
- 20%, when mature male biomass > 11.6-million pounds

Harvest capped at 40% of legal male abundance

Minimum TAC:

- Not anymore
    - 2.778-million pound minimum TAC removed by BOF
        - 28 Sept 2009 emergency regulation (valid thru 1 Feb 2010)
            - Notification of “rebuilt” status by NMFS, 24 Sept 2009
            - Was declared “overfished” in Sept 1999, has not been fished since
            - Minimum TAC will be revisited at March 2010 BOF meeting
- **2009 estimate for mature male biomass:**
- 12.125-million pounds (ADF&G CSA estimate)

→ Stock is above threshold for a fishery opening

→ 20% exploitation rate on estimated mature male abundance would apply

<u>2009/10 TAC computation according to state harvest strategy</u>

- 20% exploitation rate applied to estimated mature-sized male abundance
  - 3.455-million mature-sized males (ADF&G CSA estimate)
  - 0.2 X 3.455-million = 0.691-million crabs
- Check: 40% cap on harvest of legal males
  - 1.898-million legal males (ADF&G CSA estimate)
  - 0.4 X 1.898-million =0.759-million crabs > 0.691-million crabs
    - → Compute TAC on harvest of 0.691-million legal males
- TAC computed according to harvest strategy:
  - 3.089-million pounds (includes CDQ portion)
    - Assumed average weight = 4.47 pounds

<u>Comparison with federal OFL</u>

- A 3.089-million pound TAC is 180% of <u>total-male-catch</u> OFL
  - 1.72-million pounds, including male bycatch mortality in all fisheries
- **Need to reduce TAC to level that minimizes risk of reaching OFL**

<u>Determination of 2009/10 TAC</u>

- Minimize risk of reaching total-male-catch OFL (1.72-million lbs)
  - Want: TAC + (lbs of ♂ discard/bycatch mortality in all fisheries) < 1.72-million lbs
    - TAC < 1.72-million lbs - (lbs of ♂ discard/bycatch mortality in all fisheries)
      - What will ♂ discard/bycatch mortality in all fisheries be?
      - How large can ♂ discard/bycatch mortality in all fisheries be?
  - Consider historic range of estimates of ♂ bycatch mortality in all fisheries
    - Directed St. Matthew blue king crab fishery bycatch
      - Assume amount of discards dependent on the TAC
        - Estimate lbs of ♂ discard mortality per pound retained catch
          - Discard mortality assumed = 20%
        - Heightened uncertainty: lack of directed fishery for previous 10 years
    - Other crab fisheries: snow and Tanner crab fisheries
      - Discard mortality assumed = 50%
    - Groundfish fishery bycatch
      - Discard mortality assumed = 50% for fixed gear, 80% for trawl gear

<u>Determination of 2009/10 TAC – Male Bycatch in Past Fisheries</u>

- **Estimates of lbs ♂ discard mortality per lb retained catch in <u>directed St. Matthew blue king crab fishery</u>**
  - Estimates from observer data; ADF&G crab observer database, 23 Sept '09.

Season	Observed Vessels	Observer Sampled Potlifts	Pounds per Potlift Legal	Pounds per Potlift Sublegal	Lbs Discarded Per Retained Lb.	Lbs Mortality[a] Per Retained Lb.
1990	1	10	*	*	*	*
1991	9	125	79.6	28.4	0.36	0.072
1992	8	71	55.4	36.7	0.66	0.132
1993	3	84	56.8	32.1	0.57	0.114
1994	6	203	49	39.3	0.80	0.160
1995	2	47	*	*	*	*
1996	3	96	26	11.5	0.44	0.088
1997	2	133	*	*	*	*
1998	3	135	29	17.3	0.60	0.120
					Minimum	0.072
					Average	0.121
					Median	0.120
					Maximum	**0.184**

a. Assumed handling mortality = 20%

• = Observer data confidential; observed number of vessels < 3.

→ **Assume up to 0.184 lbs of ♂ discard mortality per lb retained catch**

Determination of 2009/10 TAC – Male Bycatch in Past Fisheries

- **Estimates of millions of pounds of ♂ bycatch mortalities in other crab fisheries**
  - Bycatch of non-retained legals and sublegal males in snow and Tanner crab fisheries
    - Estimates (millions of pounds) from observer data supplied by ADF&G to CPT for 2008 and 2009 SAFEs
    - Discard mortality assumed = 50%

Fishery Year[a]	Total
1996-1997	0.0066
1997-1998	0.0000
1998-1999	0.0056
1999-2000	0.0042
2000-2001	**0.0202**
2001-2002	0.0000
2002-2003	0.0000
2003-2004	0.0000
2004-2005	0.0000
2005-2006	0.0038
2006-2007	0.0000
2007-2008	0.0000
2008-2009	0.0003
Minimum	0.0000
Average	0.0031
Median	0.0000
Maximum	**0.0202**

a. Fishery year is 1 July – 30 June

- **Assume up to 0.0202-million lbs ♂ bycatch mortality**

Determination of 2009/10 TAC – Male Bycatch in Past Fisheries

- **Estimates of millions of pounds of bycatch mortalities in groundfish fisheries**
  - Based on **total** bycatch (bycatch estimates by sex not available)
  - Federal reporting areas 521 and 524
  - NMFS estimates from observer data, 25 Sept '09.

Fishery Year[a]	Gear Type Fixed[b]	Trawl[b]	Total
1991-1992	0.000	0.025	0.025
1992-1993	0.010	0.014	0.024
1993-1994	0.000	0.011	0.011
1994-1995	0.000	0.002	0.003
1995-1996	0.001	0.005	0.005
1996-1997	0.000	0.000	0.000
1997-1998	0.001	0.000	0.001
1998-1999	0.004	0.000	0.004
1999-2000	0.006	0.000	0.006
2000-2001	0.000	0.000	0.000
2001-2002	0.004	0.000	0.004
2002-2003	0.002	0.005	0.007
2003-2004	0.005	0.007	0.012
2004-2005	0.003	0.001	0.004
2005-2006	0.003	0.000	0.003
2006-2007	0.006	0.020	0.026
2007-2008	**0.307**	**0.000**	**0.308**
2008-2009	0.029	0.002	0.031
		Minimum	0.000
		Average	0.026
		Median	0.006
		Maximum	**0.308**

a. Fishery year is 1 July – 30 June
b. Assumed bycatch mortality for fixed gear = 50%
c. Assumed bycatch mortality for trawl gear is 80%

- **Assume up to 0.308-million lbs ♂ bycatch mortality**

Determination of 2009/10 TAC

- Want: TAC < 1.72-million pounds - (lbs of ♂ discard/bycatch mortality in all fisheries)
    - Assumed 0.184-million lbs ♂ discard mortality per lb retained in directed fishery
        - Maximum estimate for 1990-1998
    - Assumed 0.0202-million lbs ♂ discard mortality in other crab fisheries
        - Maximum estimate for 1996/97-2008/09
    - Assumed 0.308-million lbs ♂ discard mortality in groundfish fisheries
        - Maximum estimate for 1991/92-2008/09 (unsexed data)

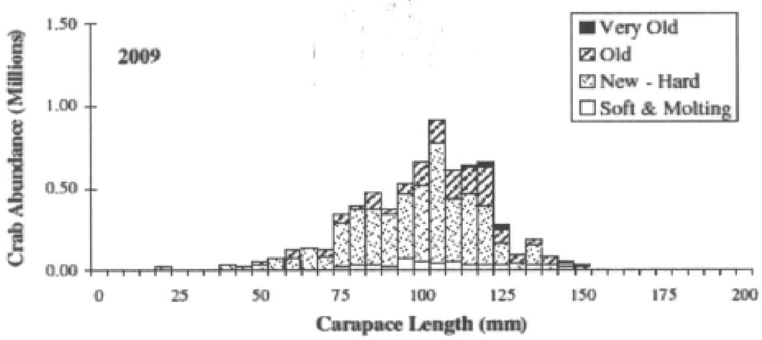
Use 1.71-million pounds as upper limit
Retained catch + discard mortalities in directed fishery =
= 1.71-million lbs – (lbs of ♂ discard/bycatch mortality in other fisheries)
= 1.71-million lbs - 0.0202-million lbs - 0.308-million lbs
= 1.382-million lbs
→TAC + (TAC)X(lbs ♂ discard mortality per lb retained catch) = 1.382-million lbs
TAC + (TAC)X(0.184) = 1.382-million lbs
(TAC)X(1+0.184) = 1.382-million lbs
(TAC)X(1.184) = 1.382-million lbs
TAC = (1.382-million lbs)/(1.184)
→TAC = 1.167-million lbs

2009/10 TAC determination = 1.167-million pounds (including CDQ)

- TAC of 1.167-million lbs represents 0.261-million crabs (ave wt = 4.47 lbs)
    - 14% of legal males estimated at time of survey (1.898-million crabs, CSA est)

ADFG confident that TAC can be achieved without reaching total-male catch OFL (1.72-million pounds).
However, as usual, ADFG stresses:
Minimize bycatch/discards during the crab fishery

1. High incidence of sublegal males during survey:



Size frequency of male St. Matthew blue king crab, 2009 NMFS survey (from: Chilton et al. 2009)

2. Although not counted towards OFL, **avoid bycatch of females**
    - Bycatch of females in directed fishery has been high historically
        - Up to 0.29 pounds discard mortality per retained pound
        - Females in fishery bycatch mainly mature
3. Fishery was closed for 10 years to rebuild from "overfished status"

Bering Sea Tanner Crab

2009/10 Federal OFL Determination (Amendment 24 process)

Forecasts for 2009/10 (at time of mating, 15 February 2010)

- **B_{MSY}** = 189.76-million pounds MMB
- **MMB** = 70.20-million pounds = 37% of B_{MSY}
    - Classified as "approaching overfished" by NMFS

2009/10 overfishing level (OFL):

- 5.57-million pounds total catch, including bycatch mortality of males and females in all fisheries
- Stock is above critical biomass threshold for opening directed fishery
    - MMB > 25% of B_{MSY}
- Estimated retained-catch portion of OFL = 1.55-million pounds
    - Note: One OFL for entire Bering Sea
        - Not separated for TACs east and west of 166° W longitude

State harvest strategy (5 AAC 35.508)

Stock threshold for opening fishery:

- 21-million pounds mature female biomass in Eastern Subdistrict

Exploitation rate on "molting mature male abundance":

- Applied separately to areas east and west of 166° W long for separate TACs
- "Molting mature males" = all new-shell and 15% of old-shell males >112-mm CW
- If mature female biomass is above threshold for second consecutive year
    - 10%, when Eastern Subdistrict mature female biomass < 45-million pounds
    - 20%, when Eastern Subdistrict mature female biomass ≥ 45-million pounds
    - **Harvest capped at 50% of "exploitable legal males"**
        - All new-shell and 32% of old-shell legal males (≥5.5-inches CW)
- If mature female biomass is above threshold this year, below last year

- 5%, when Eastern Subdistrict mature female biomass < 45-million pounds
- 10%, when Eastern Subdistrict mature female biomass ≥ 45-million pounds
- **Harvest capped at 25% of "exploitable legal male abundance"**

Minimum TAC:

- None

<u>Estimates for application of state harvest strategy (5 AAC 35.508)</u>

2008, 2009 estimates for mature female biomass in Eastern Subdistrict:

- 2008: 36.420-million pounds (ADF&G area-swept estimate)
- 2009: 22.108-million pounds (ADF&G area-swept estimate)
  - → Stock is above threshold for a fishery opening
  - → 10% exploitation rate on estimated molting mature male abundance applies
  - → 50% harvest cap on exploitable legal male abundance

2009 estimates for area east of 166° W longitude

- Molting mature male abundance = 7.872-million crabs (ADF&G area-swept est.)
- Exploitable legal male abundance = 2.186-million crabs (ADF&G area-swept est.)
  - → Legal male abundance = 3.716-million crabs (ADF&G area-swept est.)

2009 estimates for area west of 166° W longitude

- Molting mature male abundance = 19.014-million crabs (ADF&G area-swept est.)
- Exploitable legal male abundance = 2.246-million crabs (ADF&G area-swept est.)
  - → Legal male abundance = 3.125-million crabs (ADF&G area-swept est.)

<u>2009/10 TAC computations according to state harvest strategy</u>

Area east of 166° W longitude

- 10% exploitation rate on estimated molting mature male abundance
  - 0.10 X 7.872-million crabs = 0.787-million crabs
- Check: 50% cap on harvest of exploitable legal male abundance
  - 0.50 X 2.186-million crabs = 1.093-million crabs > 0.787-million pounds
    - → Compute TAC on harvest of 0.787-million crabs
- TAC computed according to harvest strategy:
  - 1.850-million pounds (includes CDQ portion)
  - Average weight estimate = 2.351 pounds (ADFG estimate, from survey)

Area west of 166° W longitude

- 10% exploitation rate on estimate molting mature male abundance
  - 0.10 X 19.014-million crabs = 1.901-million crabs
- Check: 50% cap on harvest of exploitable legal male abundance
  - **0.50 X 2.246-million crabs = 1.123-million crabs < 1.901-million crabs**
    - → Compute TAC on harvest of 1.123-million crabs
- TAC computed according to harvest strategy:
  - 2.457-million pounds
  - Average weight estimate = 2.188 pounds (ADFG estimate, from survey)

<u>Comparison with federal OFL</u>

- Combined computed TACs east and west of 166° W longitude:
  - 1.850-million pounds + 2.457-millon pounds = 4.307-million pounds
- A 4.307-million pound TAC is 77% of <u>total-catch</u> OFL
  - 5.57-million pounds, including male and female bycatch mortality in all fisheries
- A 4.307-million pound TAC is 278% of estimated <u>retained-catch portion of OFL</u>

- 1.55-million pounds

→**Need to reduce TAC to level that minimizes risk of reaching OFL**

Determination of 2009/10 TAC

- Minimize risk of reaching total-catch OFL (5.57-million lbs)
  - Want: TAC + (lbs of discard/bycatch mortality in all fisheries) < 5.57-million lbs
    - TAC < 5.57-million lbs - (lbs of discard/bycatch mortality in all fisheries)
      - What will ♂ and ♀ discard/bycatch mortality in all fisheries be?
        - How large can bycatch mortality in all fisheries be?
  - Consider estimates of ♂ and ♀ discard/bycatch mortality in all fisheries
    - Range of estimates for directed Bering Sea Tanner crab fishery bycatch, 2006/07-2008/09 seasons
    - Use bycatch estimates from observer data supplied by ADF&G for the 2009 Crab SAFE
    - Separately for areas east and west of 166 degrees W longitude
    - Assume amount of discards dependent on the TACs
      - Estimate lbs of ♂ + ♀ discard mortality per lb of retained catch
        - Discard mortality assumed = 50%
  - Other fisheries: Use projections from Rugolo and Turnock (2009 Crab SAFE, Tables 7 and 8)
    - Other crab fisheries (mainly snow crab):
      - Projected lbs of discard mortality = 1.754-million lbs, ♂ + ♀
    - Groundfish fisheries:

Projected lbs of bycatch mortality = 1.105-million lbs, ♂ + ♀

Determination of 2009/10 TAC – Bycatch in past Tanner seasons

Estimates of lbs ♂ + ♀ discard mortality per lb retained catch in directed Tanner crab fisheries, 2006/07-2008/09, W and E of 166° W longitude.

Area	Season	Retained Catch[a]	♂ + ♀ Tanner Discards[a]	Discard Mortalities[a, b]	Lbs Discard Mortality per Retained Lb.
W of 166	2006/07	0.721	2.190	1.095	1.52
W of 166	2007/08	0.524	1.920	0.960	1.83
W of 166	2008/09	0.110	0.181	0.091	0.83
				Minimum	0.83
				Average	1.39
				Median	1.52
				Maximum	1.83
E of 166	2006/07	1.402	1.267	0.634	0.45
E of 166	2007/08	1.583	2.922	1.461	0.92
E of 166	2008/09	1.830	0.800	0.400	0.22
				Minimum	0.22
				Average	0.53
				Median	0.45
				Maximum	0.92

a. Millions of pounds

b. Assumed 50% discard mortality

- Lbs ♂ + ♀ discard mortality per lb retained catch far higher in area west of 166 than east of 166

  → **Close area west of 166, limit fishery opening to area east of 166**
- Uncertainty due to only 3 years of data for estimates
  - **Assume 1 lb ♂ + ♀ discard mortality per lb retained catch for computing TAC east of 166**
  - Higher than maximum observed (0.92 lbs discard mortality per lb retained)

Determination of 2009/10 TAC

1. Close area west of 166° W longitude

2. For area east of 166° W longitude, want:
   - TAC < 5.57-million lbs – (lbs of ♂ + ♀ discard/bycatch mortality in all fisheries)
     - Assumed 1 lb ♂ + ♀ discard mortality per lb retained in directed fishery
       - Maximum estimate for 2006/07-2008/09 = 0.92
     - Assumed 1.754-million lbs ♂ +♀ discard mortality in other crab fisheries
       - Projection from Rugolo and Turnock (2009 Crab SAFE, Tables 7 & 8)
     - Assumed 1.105-million lbs ♂+ ♀ bycatch mortality in groundfish fisheries
       - Projection from Rugolo and Turnock (2009 Crab SAFE, Tables 7 & 8)
     - Use 5.56-million lbs as upper limit

Retained catch + discard mortalities in directed fishery =

= 5.56-million lbs – (lbs of ♂ + ♀ discard/bycatch mortalities in other fisheries)

= 5.56-million lbs - 1.754-million lbs - 1.105-million lbs

= 2.70-million lbs

→TAC +(TAC)X(lbs ♂ + ♀ discard mortality per lb retained catch) = 2.70-million lbs

TAC + (TAC)X(1) = 2.70-million lbs

(TAC)X(1+1) = 2.70-million lbs

(TAC)X(2) = 2.70-million lbs

TAC = (2.70-million lbs)/(2)

→TAC for area east of 166° W longitude = 1.350-million lbs

<u>2009/10 TAC Determination:</u>

1.350-million pounds, east of 166° W longitude (including CDQ)

Closed, west of 166° W longitude

TAC of 1.350-million lbs represents 0.574-million crabs (ave wt = 2.351 lbs)

- 15% of legal males estimated at time of survey east of 166° W long
  - 3.716-million legal males (ADF&G area-swept estimate)
    - 61% old-shell or older (ADF&G area-swept estimate)

ADF&G confident that TAC can be achieved without reaching the total-catch OFL (5.57-million pounds). However, as usual, ADFG stresses:

Minimize bycatch/discards during the directed fishery and other crab fisheries

- Estimated 61% legal males are old-shell or older in area east of 166° W longitude
- Note, especially: bycatch mortalities in the 2009/10 snow crab fishery will be counted towards the OFL
- Stock has been classed by NMFS as “approaching overfished” in 2009

<u>Bering Sea Snow Crab</u>

<u>2009/10 Federal OFL Determination (Amendment 24 process)</u>

Forecasts for 2009/10 (at time of mating, 15 February 2010)

- $\mathbf{B_{MSY}}$ = 326.7-million pounds MMB
- **MMB** = 251.0-million pounds = 77% of B_{MSY}

<u>2009/10 overfishing level (OFL)</u>:

- 73.0-million pounds <u>total</u> catch, including bycatch mortality of males and females in all fisheries
- Stock is above critical biomass threshold for opening directed fishery
  - MMB > 25% of B_{MSY}
- Estimated retained-catch portion of OFL = 61.6-million pounds

<u>Status Determination Relative to Rebuilding</u>:

- **Sept 1999: Declared overfished by NMFS**

- **Dec 2000: Amendment 14 to FMP (rebuilding plan) approved by NMFS**
  - Adopted harvest strategy in State regulation (5 AAC 35.517) as rebuilding harvest strategy
  - Defines "rebuilt" as stock above B_{MSY} for <u>two consecutive</u> years
  - Stipulates maximum 10-year rebuilding period ("T_{max}")
    - Needs to be rebuilt by end of 2009/10 fishery year
- **Sept 2009: <u>NMFS determined stock failed to rebuild by end of T_{max}</u>**
  - Stock has not been estimated above B_{MSY} since rebuilding plan enacted
  - 2008/09 MMB = 74% of B_{MSY}
    - **Stock cannot be rebuilt by end of 2009/10 fishery year**
- **<u>Implications of rebuilding failure to 2009/10 TAC determination*</u>**
- National Standard 1 Guidelines, 50 CFR § 600.310(j)(3)(ii):

"If the stock or stock complex has not rebuilt by T_{max}, then the fishing mortality rate should be maintained at $F_{rebuild}$ or 75 percent of the MFMT, **whichever is less**."

- "$F_{rebuild}$" determined by harvest strategy in State regulation (adopted by FMP Amendment 14 – rebuilding plan for Bering Sea snow crab)
- "MFMT" = overfishing rate (F_{OFL}) determined in the FMP Amendment 24 process
  - → Need to compute and compare total catch under
    - Application of the harvest strategy in State regulation ("$F_{rebuild}$")
    - Application of 75% of F_{OFL} ("75 percent of the MFMT")

*Future: NPFMC needs to revise/amend the rebuilding plan and implement in two years

- In that regard, 74 Federal Register at 3200 says:

  "NMFS believes that requiring that F does not exceed $F_{rebuild}$ or 75 percent MFMT, whichever is lower, is an appropriate limit, **but Councils should consider a lower mortality rate to meet the requirement to rebuild stocks in as short a time as possible, pursuant to the provisions in MSA section 304(e)(4)(a)(i).**"

<u>State harvest strategy (5 AAC 35.517)</u>

Stock threshold for opening fishery:
- 230.4-million pounds total mature (male and female) biomass (TMB)

Exploitation rate on mature male biomass:
- 10%, when TMB = 230.4-million pounds
- Increases linearly up to 22.5% with increasing TMB up to 921.6-million pounds
- 22.5%, when TMB ≥921.6-million pounds

Harvest capped at 58% of "exploited legal male abundance"
- Males ≥ 4-inches CW with old-shell males counted as percentage corresponding with expected fishery selectivity (25% has been used since 2001)

Minimum TAC:
- 16.667-million pounds (including portion allocated to CDQ fishery)

2009 estimate for TMB:
- 553.1-million pounds (NMFS 2009 snow crab assessment model estimate)
  - → Stock is above threshold for a fishery opening
  - → 15.84% exploitation rate on estimated mature male biomass applies

2009 estimate for mature male biomass
- 363.3-million pounds (NMFS 2009 snow crab assessment model estimate)

2009 estimate for exploited legal male abundance
- 91.50-million crabs
  - 147.3-million males ≥ 4-in CW, 50.5% old-shell (NMFS 2009 assessment model estimate)

<u>2009/10 TAC computation according to state harvest strategy</u>

- 15.84% exploitation rate applied to estimated mature male biomass
  - 0.1584 X 363.3-million pounds = 57.52-million pounds
- Check: 58% cap on harvest of exploited legal male abundance
  - 0.58 X 91.50-million X 1.32 pounds = 70.05-million pounds > 57.52-million pounds
- TAC computed according to harvest strategy:
  - **57.52-million pounds** (includes CDQ portion)
    - → Computed TAC is above minimum 16.667-million pounds for fishery opening

<u>Total-catch limit at 75% of F_{OFL}(Turnock and Rugolo, 2009 SAFE)</u>

- F_{OFL} = F35% = 0.70
- Total catch limit for 75% of F_{OFL}= **59.9-million pounds**
  - Estimated retained-catch portion = **50.5-million pounds**

<u>Comparison of $F_{rebuild}$ (harvest strategy) to 75% of MFMT (75% of F_{OFL})</u>

- A 57.52-million pound TAC is 96% of <u>total catch</u> at 75% of F_{OFL}
  - 59.9-million pounds, including ♂ and ♀ discard/bycatch mortality in all fisheries
- A 57.52-million pound TAC is 114% of estimated <u>retained-catch portion of OFL</u>
  - 50.5-million pounds
- NMFS estimates total catch > 69-million pounds if TAC set according to harvest strategy

→ **2009/10 total catch is limited to total catch at 75% of F_{OFL}**
59.9-million pounds, including ♂ and ♀ discard/bycatch mortality in all fisheries

<u>Determination of 2009/10 TAC</u>

- Minimize risk of reaching total-catch limit of 59.9-million lbs (75% of F_{OFL} limit)
  - Want: TAC + (lbs of discard/bycatch mortality in all fisheries) < 59.9-million lbs
    - → TAC < 59.9-million pounds - (lbs of discard/bycatch mortality in all fisheries)
    - What will ♂ + ♀ discard/bycatch mortality in all fisheries be?
    - How large can ♂ + ♀ discard/bycatch mortality in all fisheries be?
  - Consider estimates of ♂ + ♀ bycatch mortality in all fisheries
    - Range of estimates for directed Bering Sea snow crab fishery bycatch for previous 10 seasons (1999/00-2008/09)
      - → Use discard estimates in Table 1 of Turnock and Rugolo (2009 SAFE)
      - → Assume amount of discards dependent on the TAC
        - Estimate lbs of ♂ + ♀ discard mortality per lb retained catch
          - Discard mortality assumed = 50%
  - Other fisheries:
    - Range of estimates for groundfish fisheries for previous 10 seasons (1999/00-2008/09)
    - Use bycatch estimates in Table 1 of Turnock and Rugolo (2009 SAFE)
      - → Bycatch mortality assumed = 80%

<u>Determination of 2009/10 TAC – Discards/bycatch in previous 10 seasons</u>

- Estimates of lbs ♂ + ♀ mortalities per lb retained catch in snow crab fishery
- Estimates of lbs of bycatch mortality in groundfish fisheries

	Snow crab fishery						Groundfish fishery	
Season	Retained Catch[a]	Male Discards[a, b]	Female Discards[a, b]	Total ♂ and ♀ Discards[a]	Discard Mortality[a, c]	Lbs Discard Mortality per Retained Lb.	Total ♂ and ♀ Bycatch[a, b]	Bycatch Mortality[a, d]
1999/00	33.500	3.790	0.002	3.792	1.896	0.06	1.345	1.076
2000/01	25.256	4.537	0.002	4.539	2.270	0.09	1.174	0.939
2001/02	32.722	13.824	0.017	13.841	6.921	**0.21**	0.865	0.692
2002/03	28.307	9.938	0.003	9.941	4.971	0.18	0.511	0.409
2003/04	23.942	4.196	0.006	4.202	2.101	0.09	1.683	1.346
2004/05	24.892	3.716	0.003	3.719	1.860	0.07	2.124	**1.699**
2005/06	36.974	9.965	0.012	9.977	4.989	0.13	0.810	0.648
2006/07	36.356	12.995	0.005	13.000	6.500	0.18	1.858	1.486
2007/08	63.034	18.560	0.066	18.626	9.313	0.15	0.966	0.773
2008/09	58.548	15.115	0.052	15.167	7.584	0.13	0.664	0.531
					Minimum	0.06		0.409
					Average	0.13		0.960
					Median	0.13		0.856
					Maximum	**0.21**		**1.699**

a. Millions of pounds.
b. From Turnock and Rugolo (2009 Crab SAFE), Table 1.
c. Assumed 50% discard mortality.
d. Assumed 80% bycatch mortality.

→ Assume up to 0.21 lbs of ♂ + ♀ discard mortality per lb of retained catch in directed fishery

→ Assume up to 1.699-million lbs of ♂ + ♀ bycatch mortality in groundfish fisheries

Determination of 2009/10 TAC

- Want: TAC < 59.9-million lbs – (lbs of ♂ + ♀ discard/bycatch mortality in all fisheries)
    - Assumed 0.21 lbs discard ♂ + ♀ mortality per lb retained in directed fishery
        - Maximum estimate for 10 previous seasons
    - Assumed 1.699-million lbs ♂ + ♀ bycatch mortality in groundfish fisheries
        - Maximum estimate for 10 previous seasons
    - Use 59.8-million lbs as upper limit

Retained catch + discard mortalities in directed fishery =

= 59.8-million lbs – (lbs of ♂ + ♀ discard/bycatch mortalities in other fisheries)
= 59.8-million lbs – 1.699-million lbs
= 58.1-million lbs

→TAC +(TAC)X(lbs ♂ + ♀ discard mortality per lb retained catch) = 58.1-million lbs

TAC + (TAC)X(0.21) = 58.1-million lbs
(TAC)X(1+0.21) = 58.1-million lbs
(TAC)X(1.21) = 58.1-million lbs
TAC = (58.1-million lbs)/(1.21)

→TAC = 48.017-million lbs

2009/10 TAC Determination:

- **48.017-million pounds (including CDQ)**
- TAC of 48.017-million lbs represents 36.377-million crabs (ave wt = 1.32 lbs)
    - 25% of males ≥ 4-inches CW at time of survey
        - 147.3-million crabs (NMFS 2009 stock assessment model)
            - 50.5% old-shell or older (NMFS 2009 stock assessment model)
- ADF&G confident that TAC can be achieved without reaching the total-catch limit (59.9-million pounds). However, as usual, ADFG stresses:

Minimize bycatch/discards during the directed fishery

- Higher estimated incidence of old-shell and older males ≥ 4-inches
- Note, also: bycatch mortalities of Tanner crabs in the 2009/10 snow crab fishery will be counted towards the Tanner crab OFL
    - Tanner crab stock has been classed by NMFS as "approaching overfished" in 2009

ALASKA DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

MEMORANDUM

TO: Forrest R. Bowers
Fishery Biologist III
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DATE: July 15, 2010

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FROM: Jeanette Alas
Fishery Biologist II
Region IV - Dutch Harbor

Subject: 2010/11 Aleutian Islands Golden King Crab TACs

INTRODUCTION

This memo summarizes recent and historic fishery performance information prior to announcing the 2010/2011 total allowable catch (TAC) for golden king crab in the eastern and western Aleutian Islands. TACs are apportioned 90% to individual fishing quota (IFQ) harvests; the remaining 10% is allocated to Community Development Quota (CDQ) in the eastern Aleutian Islands and to the Adak Community Allocation in the western Aleutian Islands.

Prior to the 1996/97 season, the Aleutian Islands king crab fisheries were managed as two distinct areas: the Dutch Harbor Area (east of 171o W long.) and the Adak Area (west of 171o W long.). In 1996, the Alaska Board of Fisheries (BOF) noted that the management boundary at 171o W long. appeared to bisect a single stock of golden king crab. The BOF combined the Dutch Harbor and Adak Areas into a single management area and directed the department to conservatively manage golden king crab, east and west of 174o W long., 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.

Fishery, observer-collected, and survey data, as well as tag recovery information were used in reviewing stock status, previously established guideline harvest levels (GHLs), and TACs. Fishery data were examined for catch per unit of effort (CPUE) and geographic harvest trends. Observer-collected data were examined for size composition of retained and discarded crabs, shell-condition of male and female crabs, stock composition, and reproductive condition of female crabs.

During the 1996/97 – 2004/05 seasons all fishing vessels carried observers at all times while fishing. With the implementation of crab rationalization beginning with the 2005/06 season, observer coverage was reduced as follows: catcher-only vessels carry an observer for 50% of the total golden king crab harvest during each trimester (August 15 to November 15, November 16 to February 15, and February 16 to May 15). Catcher-processor vessels carry an observer for 100% of the harvest. Observer coverage fees in this fishery are pay-as-you-go.

EAST OF 174º W LONGITUDE

For the eastern Aleutian Islands the 1996/97 season GHL was 3.2 million pounds. The 3.2 million pound GHL was arrived at by doubling the previous 5-year (1991/92 to 1995/96) average harvest of 1.6 million pounds from the former Dutch Harbor Area (east of 171° W long.), to account for additional crab habitat added to the registration area in 1996 when the registration area boundary was moved westward. The news release in 1996 indicated that the 1996/97 GHL was based on doubling the average harvest from 1991/92 to 1995/96; however a fish ticket search in 2001, of the 1991/92 to 1995/96 seasons, indicated an average annual harvest of only 1.5 million pounds rather than 1.6 million pounds.

The 1996/97 GHL of 3.2 million pounds for all waters east of 174º W long. represents a reduction from the previous 5-year (1991/92 to 1995/96) average harvest of 4.36 million pounds for the waters east of 174º W long. The GHL established in 1996 was intended to meet the BOF's directive to manage waters between 171° and 174º W long. more conservatively and in alignment with historical management practices for the area east of 171o W long. (Dutch Harbor Area).

A trend of declining CPUE during the 1997/98 season, coupled with information from tag returns during that season, indicated that fishery mortality in this area was near the maximum rate allowed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. To prevent exceeding federal overfishing definitions, the 1998/99 GHL, was reduced to 3.0 million pounds and the GHL remained at that level until the 2008/09 season.

In March 2008, the BOF adopted a regulation increasing TAC to 3.15 million pounds until a stock assessment model is developed for Aleutian Islands golden king crab. This regulation went into effect prior to the 2008/09 season.

From the 1996/97 to the 2004/05 season, duration of the eastern fishery decreased from 115 to 14 total fishing days, while harvest ranged from 2.8 to 3.5 million pounds. Commensurately, seasonal legal-male CPUE and weekly number of pot pulls increased during this time period.

A Leslie estimator of stock size for the 1996/97 and 1997/98 seasons was performed prior to the 1998/99 season. The Leslie estimator indicated that the population of legal males decreased slightly between the two years and that the fleet was harvesting between 34% and 43.5% of the legal male population annually. The Leslie estimator assumes that fishery CPUE decreases linearly as the season progresses. During the 1998/99 and 1999/00 fisheries, fishery CPUE increased near the end of the season, thus no estimates were performed for those years. While the Leslie estimator indicates that a large portion of the legal males were removed in the 1996/97 and 1997/98 seasons, fishery CPUEs in the shorter 1998/99 – 2001/02 seasons increased from the 1997/98 level, suggesting that the legal male population may have increased. The Leslie calculations were not performed using 2000/01 – 2009/10 data.

Since the 1996/97 season, legal-male CPUE increased nearly five-fold to 28 crabs per pot lift in the 2007/08 season and then decreased slightly to 26 crabs per pot lift in 2009/10 (Table 1). Current legal-male CPUE is high relative to the years immediately prior to the start of the crab rationalization (CR) program.

The 2009/10 season was open August 15 through May 15, and participants exceeded the TAC by 474 pounds. Since the implementation of CR, fleet size has decreased by approximately 75%, and the number of pots used by the rationalized fleet has decreased by more than 50%, but the average number of pots deployed by each vessel has increased. The fleet used nearly 10% more pots in 2009/10 than during the 2008/09 season and the number of pot lifts increased by 7%.

During the 2000/01 to 2009/10 seasons, the fleet operated in roughly the same geographic areas of the eastern Aleutian Islands (Table 2), however harvest has become concentrated within that area as harvest locales have shifted away from the western and eastern bounds of the area. The fishery may take place between 166° W long.

and 174° W long., however greater than 90% of the post-CR harvest has occurred between 170° and 173° W long.

In the three years prior to the start of CR approximately 80% of the annual harvest was taken from 170° - 173° W long. Post-CR, no harvest has occurred east of 169° W long. During the 2009/10 season approximately 41% of the catch was taken between 171° W long. and 172° W long. with 24% of the harvest taken from ADF&G statistical area 715202.

Average CPUE during the first five CR seasons (2005/06 – 2009/10) was high relative to the pre-CR period. Pre-CR, gear competition and the number of fishery participants likely forced some fishermen to deploy gear in less than ideal fishing locales with low abundance of legal males. Recent fleet consolidation and reduced gear competition has allowed fishermen to set pots in only the most productive areas. High CPUEs in recent seasons may be explained by reduced on the grounds competition, deployment of gear in areas with highest legal male abundance, a possible increase in legal male abundance, and greatly increased pot soak times.

A portion of the golden king crab stock east of 174° W long. is subject to a triennial survey, however the survey only covers waters between 170° 21' and 171° 33' W long. Comparing survey CPUE over the four surveys (1997, 2000, 2003, and 2006) indicates that legal male catch rates fluctuate from one survey to the next, and have ranged from 2.9 to 4.7 legal male crabs per pot (Table 3). A survey was not conducted in 2009 because the sole bid for the vessel exceeded project budget constraints. Sublegal male survey CPUE declined from a high of 50 in 1997 to 12 in the 2003 and 2006 surveys. Female survey CPUE declined from 59 in 1997 to 17 in 2006. Crabs tagged during the survey are recaptured in the commercial fishery to estimate minimum harvest rate. In the 1997/98 season, 20.3% of legal males tagged in 1997 were recaptured; 20.1% of legal males tagged in 2000 were recovered during the 2000/01 season; 10.5% of the legal males tagged in 2003 were recovered during the 2003/04 season; and 7.6% of the legal males tagged in 2006 were recovered during the 2006/07 season. The number of legal males tagged was 2,943 in 1997, 2,011 in 2000, 2,213 in 2003, and 2,799 in 2006 for a total of 9,966. Most of the tags recovered during the fishery are recovered by observers. However, after the 2004/05 season, observer coverage decreased from 100% coverage and has ranged from 56.1% of the harvest during the 2009/10 season to 68.5% of the harvest during the 2006/07 season. That reduction in observer coverage may have influenced tag recovery rate during the 2006/07 season; adjusting for the reduction in observer coverage, the 7.6% recovery rate in 2006/07 would be comparable to a recovery rate of 10–11% in a season with 100% coverage. More crabs were harvested in the area east of 174º W long. during the 1997/98 and 2000/01 seasons than during the 2003/04 and 2006/07 seasons and that fact, along with other factors influencing tag recovery rates (including distribution of fishing effort) could account for some of the reduction in recovery rates from the 1997/98 and 2000/01 seasons to the 2003/04 and 2006/07 seasons. The decreasing trend in recovery rates may also suggest some increase in legal male abundance. Of the legal males tagged during the four survey years, overall tag recapture percentage through the 2009/10 season were 29.0% of those tagged in 1997, 23.9% of those tagged in 2000, 22.3% of those tagged in 2003, and 11.8% of legal males tagged in 2006.

Observer-collected data from both measure and count pots, indicate that legal males constituted 23% to 25% of the catch during the 1996/97 through 1998/99 seasons and 49% in 2004/05 (Table 4). Post-CR, the percentage of legal males increased to a high of 70% of the catch in 2008/09 and decreased to 61% in 2009/10. Sublegal males accounted for 43% of the total catch in 1998/99, declined to a low of 19% in 2008/09 and increased to 23% in 2009/10. Females comprised 40% of the catch in 1997/98, declined to a low of 12% in 2008/09 and increased to 16% in 2009/10. Estimated average total crab per pot has ranged from a high of 46 in the 2007/08 season to a low of 24 during the 1996/97 season (Table 4). Pre-CR the average total number of crabs per pot was highest in 200/01 when the CPUE of sublegal males and females was greatest. The 2009/10 season CPUE averaged 44 total crabs per pot, and is dominated by legal males. Increased soak time during the CR fishery likely contributes to the relatively high legal male catch rate and reduced catch rate of both sublegal and female crabs by allowing some females and sublegal males to escape the pots as legal males accumulate.

Although the estimated CPUE of sublegal males during the fishery has shown a declining trend since the late 1990s (Figure 1, top panel), the CPUE of pre-recruit-1 males (sublegal males ≥121 mm CL) has remained stable over the years (Figure 1, bottom panel); the decrease in CPUE of sublegal males is due to decreases in the CPUE of sublegal males <121 mm CL (Figure 1, bottom panel). The sharp increase in CPUE of legal males in recent seasons would not be expected given stability of the CPUE of pre-recruit-1 males. Much of the increase in legal CPUE is likely due to changes in fishing practices rather than recruitment trends. Similarly, stability in the pre-recruit-1 male CPUE would not be expected from a decreasing trend in the CPUE of smaller sublegals, suggesting that the decrease in CPUE of smaller sublegals may also be due to post-CR changes in fishing practices.

The percent of legal males that are "recruit-sized" (<151 mm CL) has been declining in both the fishery and pot survey (Table 5, Figure 2); that trend helps explain the recent increase in average weight. The trend in percent of legal males that are "recruit-sized" provides no indication of a recruitment event that could explain the sharp increases in legal CPUE that occurred between the 2003/04 and 2004/05 seasons or between the 2004/05 and 2005/06 seasons.

Female and male size-composition data from observer sampling are presented in Figures 3 and 4. Average carapace length of female crabs ranged from 115 mm to 119 mm during the three seasons immediately prior to the start of the CR program. During the 2005/06 season average carapace length of female crab increased to 120 mm, and increased to 127 mm during the 2006/07 season. Average female size continued to increase during the 2007/08 season to 133 mm CL, decreased to 132 mm CL during the 2008/09 season, and again to 131 mm CL during the 2009/10 season.

Since the 2002/03 season, average carapace length of legal male crabs has generally increased, ranging from 148 mm in the 2002/03 season to 153 mm in the 2007/08 season. Average size during the 2008/09 and 2009/10 seasons was similar at 152 mm CL.

Average size of sublegal males from the 2002/03 to 2004/05 seasons ranged from 121 to 123 mm CL. During the 2005/06 and 2006/07 seasons, the average increased to 125 mm CL and 130 mm CL during the 2007/08 season. Sublegal golden king crabs captured during the 2008/09 fishery averaged 127 mm CL and increased to 129 mm CL during the 2009/10 fishery.

During the 2009/10 fishery 4.1% of the legal males captured were discarded at sea, a 5% decrease from the 2008/09 season and a 46% increase from 2007/08.

Soak time decreased from an average of 4.5 days during the 1997/98 to 2001/02 seasons, to 4 days in 2002/03 and 3.7 days in 2004/05. As anticipated, CR resulted in increased soak times; post-CR average soak times have ranged from a low of 11.6 days during the 2006/07 season to a high of 17.2 days during the 2007/08 season. Average soak time was 16.3 days during the 2009/10 season.

Reproductive condition of females can be an indicator of stock status in king crab populations and reduced female fecundity has been associated with stock crashes in other crab fisheries. Assessment of trends in reproductive condition of golden king crabs is difficult due to asynchronous mating and a prolonged period of barren condition between hatching and extrusion of the next clutch. Additionally, reproductive maturity status of female king crabs cannot be determined by external inspection. However, since 1997/98, observer-collected data indicate between 63 and 90% of all bycatch females were mature as evidenced by the presence of eggs or matted setae and between 39 and 72% were carrying eggs. During the 2008/09 season 82% of females were mature as evidenced by the presence of eggs or matted setae and 67% were carrying eggs. During the 2009/10 season nearly 82% of females were mature as evidenced by the presence of eggs or matted setae and 72% were carrying eggs. The available data do not indicate a negative trend in female reproductive condition.

WEST OF 174º W LONGITUDE

The Aleutian Islands golden king crab fishery west of 174º W long. was managed with a GHL of 2.7 million pounds from 1996/97 through the 2007/08 season. The 2.7 million pound GHL was determined on the basis of the preceding 5-year (1990/91 through 1994/95 seasons) average harvest in the waters west of 174º W long. (note: fish ticket search in 2001 indicates a 5-year, 1990/91 through 1994/95, average of 2.67 million pounds). The fishery was open year-round (GHL was not achieved) from 1996/97 through the 1999/00 seasons. From the 2000/01 through the 2004/05 seasons, the fishery closed by emergency order when the GHL was achieved. Season length decreased from a 286-day fishery in 2000/01 to a 141-day fishery in 2004/05. Under the CR program, the 2005/06 – 2009/10 seasons were open from August 15 until May 15. Participants harvested 98% of the 2005/06 Western Aleutian Islands golden king crab TAC, but only 84% of the 2006/07 TAC and 83% of the 2007/08 TAC. The Alaska Board of Fisheries increased the TAC to 2.835 million pounds beginning with the 2008/09 season. Harvest increased to 89% of the TAC during the 2008/09 season and increased further to 97% of the TAC in 2009/10. A federal regulation requires that 25% of western Aleutian Islands A share IFQ be delivered west of 174° W long. This regulation may be contributing to the fleet's inability to harvest the entire TAC in recent years. For the 2009/10 season National Marine Fisheries Service issued an emergency order exempting this regulation effective February 18, 2010 through August 17, 2010 due to the lack of a processing facility open in the West region.

Golden king crabs are not surveyed in the western Aleutian Islands; rather the stock is assessed through analysis of fishery data and relative abundance information collected by observers in the fishery. Legal-male CPUE in 1998/99 was 11 and declined to six in the 1999/00 fishing season (Table 1). However, total harvest was approximately 50% lower during the 1998/99 season than the 1999/00 season. CPUE of legal males from 1999/00 to 2002/03 was seven to eight crabs per pot and increased to 12 crabs per pot during the 2004/05 season. Post-CR CPUE of legal males increased and has ranged from 19 in 2006/07 to 24 in 2009/10.

Soak time recently increased in the western Aleutian Islands from an average of 10.2 days during the 1997/98 to 2002/03 seasons to 13.4 days in 2003/04 and 11.6 days in 2004/05. Under CR average soak time has more than doubled and was 26.8 days during the 2009/10 season.

Recent harvest by longitude is provided in Table 6. Similar to the trend in the eastern Aleutian Islands golden king crab fishery, the area of harvest in the western Aleutian Islands has contracted since CR began. The fishing area extends from 174° W long. to 170° E long., however since CR 70% of the annual harvest has occurred from 177° W long. to 178° E long. In the three years prior to CR approximately 55% of the annual harvest was taken from this area. During the 2009/10 season 29% of the catch occurred between 180° long. and 179° E long.

Female and male size composition data is presented in Figures 5 and 6. Average carapace length of female crab ranged from 124-128 mm during the 2002/03 to 2004/05 seasons. The average carapace length of female crab ranged from 130-132 mm in 2005/06 through 2007/08, increased to 134 mm CL during the 2008/09 season, and then to 138 mm CL during the 2009/10 season.

Average carapace length of legal-male crabs was between 144 and 145 mm from 2002/03 to 2004/05 seasons. The average carapace length of legal-male crabs ranged from 147 to 149 mm in 2005/06 through 2008/09 seasons, and increased to 151 mm CL during the 2009/10 season.

Sublegal males under 93 mm carapace length comprised 2.7% of the sublegal males measured during the 2004/05 season, but beginning with the 2006/07 season have comprised less than 1% of the catch. The lower retention rate of small sublegal males could be due to increased pot soak times allowing increased escapement. Sublegal males from 2002/03 to 2004/05 seasons ranged from 123-126 mm average carapace length. The average size of sublegal males ranged from 127 to 129 mm CL in 2005/06 through 2008/09. During the 2009/10 season the average carapace length for sublegal males was 130 mm.

During the 2009/10 fishery 1.4% of the legal males captured were discarded at sea, an increase from <1% in the 2007/08 and 2008/09 seasons.

Average weight of legal males for the 2009/10 season was 4.4 pounds, an increase from the 2008/09 season of 4.3 pounds which is at the high end of range seen during recent seasons, when legal males have averaged 3.9 to 4.3 pounds each.

Observer-collected data, from both measure and count pots, indicate that legal males accounted for 22% of the total catch in 1996/97 and increased to a high of 63% during the 2009/10 season (Table 7). Sublegal males comprised 37% of the total catch in 1998/99 and declined to a low of 17% during the 2009/10 season. Females comprised 44% of the total catch in 1996/97 and declined to a low of 20% during the 2009/10 season. Estimated average total crab per pot ranged from 23 during the 2001/02 season to 50 during the 2008/09 season. Average total CPUE for the 2009/10 season was 41. Both sublegal male and female CPUE have remained fairly constant during the 1999/00 season through the 2008/09 season, and both decreased in the 2009/10 season (Figure 7, top panel).

A moderate increasing trend since the 1999/00 season in the estimated CPUE of sublegal males (Figure 7, top panel), may have been due mainly to moderate increases in the CPUE of pre-recruit-1 males (sublegal males ≥121 mm CL; Figure 7, bottom panel). Sublegal male CPUE ranged from 10 to 13 during the 2004/05 through 2008/09 seasons and then decreased to 7 in the 2009/10 fishery. CPUE of smaller sublegals (<121 mm CL) has decreased since 2004/05 and continues to trend downward. The increase in CPUE of pre-recruit-1 males from 2006/07 to 2008/09 seasons is minor in comparison with the increase in CPUE of legal males that occurred between the 2004/05 and 2005/06 seasons, suggesting that much of the increase in legal-male CPUE has been due to changes in fishing practices rather than increases in abundance. CPUE of pre-recruit-1 males decreased in 2009/10 to almost half of the previous season.

The percent of legal males that are 'recruit-sized' has decreased since 2004/05 (Table 5, Figure 8); that trend is consistent with the increase in average weight in recent years. The trend in percent of legal males that are "recruit-sized" provides no indication of a recruitment event that could explain the sharp increase in legal CPUE that occurred between the 2004/05 and 2005/06 seasons.

Since 1997/98, between 66 and 94% of all bycatch females have been mature as evidenced by the presence of eggs or matted setae and between 49 and 69% have been carrying eggs. In 2008/09 nearly 85% of the females were mature as evidenced by the presence of eggs or matted setae and 62% were carrying eggs. During the 2009/10 fishery 94% of the females were mature as evidenced by the presence of eggs or matted setae and nearly 65% were carrying eggs.

SUMMARY

The Aleutian Islands golden king crab seasons legal-male CPUE increased substantially while CPUE of sublegal and female crabs experienced an increasing trend pre-CR, but has declined post-CR (Tables 4 and 7). Legal-male CPUE, based on fish ticket data, was 26 crabs per pot for the 2009/10 fishery. The high CPUE is likely due to many factors including, but not limited to, long pot soak time, less gear saturation on the grounds, reduced fleet size, and perhaps an increase in legal male abundance. Sublegal male and female golden king crab occur over a wider depth range than legal crab and may not be as vulnerable to capture as legal males, nor are they targeted by the fishery. Observer data on CPUE of pre-recruit-1 sublegal males and data on the percentage of legal males that are recruit-sized provides no evidence for a large recruitment of legal males in recent years. A declining trend in tag-recovery rates from the 1997–2006 tag releases is consistent with an increasing trend in legal male abundance. However, it is very unlikely that the increase in legal male abundance has been proportional to the increase in legal-male CPUE in recent fisheries. The abundance of legal males may be growing steadily with stable recruitment and survival of legal males.

A review of observer-collected size frequency data and CPUE data are used in a qualitative manner to ensure there are no adverse effects from the current constant-catch harvest strategy. Sublegal male CPUE has generally decreased since the 1999/00 season while the average size of sublegal male crab has increased. However, CPUE of pre-recruit-1 sublegals has been relatively steady. The declining trend in CPUE of the smaller sublegals is most likely attributable to the same changes in fishing practices that have resulted in the high CPUE of legal males in recent fisheries. Hence there do not seem to be conservation concerns arising from the constant-catch harvest strategy.

The constant-catch harvest strategy assumes that fishing mortality rate changes annually, however those changes in fishing mortality are not currently estimated for the golden king crab stocks. The constant-catch harvest strategy has provided for a stable fishery and in setting TAC for recent seasons the department has not annually adjusted the TAC based on increases or decreases in CPUE. Attempting to extract the maximum sustained yield from these stocks is inherently risky when it is known that stock size varies annually but those changes are not estimated. Under the current constant-catch harvest strategy biomass will fluctuate between high and low levels.

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.

In March 2008 the BOF adopted a regulation increasing the Aleutian Islands golden king crab TAC by 5% until a stock assessment model is developed (5 AAC 34.612 Harvest Levels for Golden King Crab). Despite the apparent effect of this regulation, obviating the need for annual stock assessment, ADF&G intends to continue using fishery data and relative abundance information to assess the status of golden king crabs in the Aleutian Islands.

The North Pacific Fishery Management Council's (NPFMC) Crab Plan Team (CPT) annually recommends overfishing levels (OFL) for Bering Sea/Aleutian Islands crab. The CPT recommended that Aleutian Islands golden king crab be classified as a Tier 5 stock meaning that the OFL should be set based on average catch from a period of years representing the production potential of the stock; the CPT also recommended that the OFL be based on total catch rather than retained catch, but could not agree on a methodology to determine that total catch OFL. The NPFMC Science and Statistical Committee (SSC) agreed with CPT rationale for a total catch OFL and recommended that the OFL be based on the mean annual rate of crab bycatch mortality over the period 1996/97 to 2008/09, the mean annual retained catch over the period 1985/86 to 1995/96 and the mean annual bycatch mortality in groundfish fisheries over the period 1996/97 to 2008/09. Application of this method results in a total catch OFL of 11.0 million pounds for 2010/11. TACs must be set below the OFL and the OFL established by the SSC would not constrain the 2010/11 TACs set by the BOF.

Based on 5 AAC 34.612, the eastern Aleutian Islands TAC is 3.15 million pounds. The 2010/11 TAC is apportioned as follows:

Individual Fishing Quota (IFQ)	2,835,000
Community Development Quota (CDQ)	315,000
Total eastern Aleutian Islands TAC	3,150,000

In the Aleutian Islands west of 174o W long., fishery and observer data do not demonstrate a compelling reason to change the TAC from 2.7 million pounds. CPUE of legal males increased during the rationalized seasons while areas targeted by the fleet decreased. Based on observer-collected data the legal-male CPUE in 2009/10 was similar to prior CR seasons while the sublegal male and female CPUE decreased. CPUE of pre-recruit and female crabs has been relatively stable in the commercial catch, although both declined in 2009/10 (Table 7). Most commercial fishing effort occurs at depths less than 200 fathoms. Recent fishery data from the western Aleutian Islands implies that the stock in that area is healthy. There are no indications of recent strong recruitment. The 2010/11 western Aleutian Islands 2.835 million pound TAC is apportioned as follows:

Individual Fishing Quota (IFQ)	2,551,500
Adak Community Allocation (ACA)	283,500
Total western Aleutian Islands TAC	2,835,000

Relative abundance indicators (CPUE) may fluctuate from one year to the next. However, what those fluctuations mean in terms of true stock abundance cannot be determined for these unsurveyed stocks without an assessment model or a more comprehensive survey. CPUE is a function of abundance and gear efficiency; interpreting changes in CPUE has become more difficult because of post-CR changes in fishing practices. In the eastern and western Aleutian Islands soak time has increased allowing additional opportunity for escape mechanisms to work. Longer soak time may be contributing to lower CPUE of both female and sublegal male crabs, and the higher CPUE of legal male crab.

The department's policy for managing unsurveyed stocks under a catch share program is to set TACs conservatively because inseason closures may be difficult to implement. TACs should be attainable without impacting the reproductive potential of the stock.

Lacking population abundance estimates and a population assessment model, the 1996/97 season GHL was established by using the average annual harvest for the previous five seasons as an estimate of a sustainable annual harvest. These harvest levels, after a minor adjustment to the GHL for the area east of 174º W long. prior to the 1998/99 season, were sustainable and provided a stable fishery through the 2007/08 season. It is not clear, however, if the new harvest levels, established by the BOF will do the same. Until an assessment model capable of providing reliable abundance estimates is developed and an abundance based harvest strategy relying on those estimates is implemented, staff recommends that the department continue to annually assess the sustainability of TACs using the current, fishery-dependent data approach. Staff recommends that any further consideration of raising the TAC above the 2009/10 levels await development and adoption of an assessment model and of a formal harvest strategy that can be applied to abundance estimates. Additionally, TACs should be set so that they do not constitute overfishing as defined annually by the NPFMC.

cc: Alinsunurin, Barnard, Barnhart, Donaldson, Gaeuman, Gish, Honnold, Pengilly, Schwenzfeier, Siddeek, Woodby.

Table 1. Aleutian Islands golden king crab harvest, catch per unit effort (CPUE), and average weight of landed crabs based on fish ticket data, 1996/97 through 2009/10 season.

Fishery Season	East of 174° W longitude				West of 174° W longitude			
	GHL/TAC[a]	Harvest[b]	CPUE[c]	Avg. Wt.[d]	GHL/TAC[a]	Harvest[b]	CPUE[c]	Avg. Wt.[d]
1996/97	3.20	3,262,516	6	4.5	2.700	2,591,720	6	4.2
1997/98	3.20	3,501,054	7	4.5	2.700	2,444,628	7	4.3
1998/99	3.00	3,247,863	9	4.4	2.700	1,691,385	11	4.1
1999/00	3.00	3,069,886	9	4.3	2.700	2,768,902	6	4.1
2000/01	3.00	3,134,079	10	4.5	2.700	2,884,682	7	4.1
2001/02	3.00	3,178,652	12	4.4	2.700	2,740,054	7	4.0
2002/03	3.00	2,821,851	12	4.4	2.700	2,640,604	8	4.0
2003/04	3.00	2,977,055	11	4.6	2.700	2,688,773	10	4.0
2004/05	3.00	2,886,817	18	4.5	2.700	2,684,842	12	3.9
2005/06	3.00	2,866,602	25	4.6	2.700	2,653,716	21	4.2
2006/07	3.00	2,992,010	25	4.6	2.700	2,270,334	19	4.3
2007/08	3.00	2,989,997	28	4.7	2.700	2,518,103	20	4.2
2008/09	3.15	3,144,423	27	4.7	2.835	2,535,661	22	4.3
2009/10	3.15	3,150,474	26	4.6	2.835	2,761,813	24	4.4
Average	**3.05**	**3,087,377**	**12**	**4.6**	**2.719**	**2,562,516**	**10**	**4.2**

Note: Crab rationalization (CR) began 2005/06, harvest includes individual fishing quota (IFQ) and Community Development Quota (CDQ).
[a]Guideline harvest level, total allowable catch after 2004/05, in millions of pounds.
[b]Harvest in pounds, deadloss included.
[c]Average number of legal male crabs per pot lift.
[d]In pounds.

Table 2. Eastern Aleutian Islands golden king crab harvest in pounds by one degree longitude intervals, 2000/01 to 2009/10 season.

This data is confidential.

Table 3. Catch per unit effort (CPUE; number of crabs per pot lift) of legal males, sublegal males, and females in the 1997–2006 ADF&G Aleutian Islands golden king crab triennial pot survey for 61 stations fished in common over all four surveys (62 stations were fished in common over all four surveys, but data from one of those stations is not included due to excessive soak time and inability to sample entire catch in 2006 survey). A survey was not conducted in 2009.

Survey Year	Legal Males	Sublegal Males	Females
1997	4.7	49.7	58.6
2000	3.1	30.7	32.7
2003	2.9	11.9	10.5
2006	4.3	11.9	17.2

Table 4. Percent catch composition and average catch per unit effort (CPUE) of legal males, sublegal males, and females in pots randomly sampled by observers during the Aleutian Islands golden king crab CDQ and IFQ fishery east of 174° W longitude, 1996/97 to 2009/10 season.

Fishery Season	% Catch Composition			Average CPUE			
	Legal Males	Sublegal Males	Females	Legal Males	Sublegal Males	Females	Total
1996/97	25%	38%	38%	6	9	9	24
1997/98	23%	37%	40%	7	11	12	30
1998/99	24%	43%	32%	9	16	12	37
1999/00	30%	37%	33%	9	11	10	30
2000/01	26%	41%	33%	10	16	13	39
2001/02	35%	35%	29%	11	11	9	31
2002/03	36%	33%	30%	12	11	10	33
2003/04	41%	30%	30%	11	8	8	27
2004/05	49%	30%	22%	18	11	8	37
2005/06	68%	20%	13%	27	8	5	40
2006/07	61%	20%	20%	25	8	8	41
2007/08	67%	20%	13%	31	9	6	46
2008/09	70%	19%	12%	30	8	5	43
2009/10	61%	23%	16%	27	10	7	44

Note: CR began 2005/06, harvest includes individual fishing quota (IFQ) and Community Development Quota (CDQ).

Table 5. Percent of legal males that were recruit-sized (<151 mm CL) in pots randomly sampled by observers and in samples of retained legal males during the Aleutian Islands golden king crab fishery east and west of 174º W longitude, 1996/97–2009/10, and in pots fished during the triennial ADF&G Aleutian Islands golden king crab pot survey, 1997–2006.

	East			West	
Fishery Season	Fishery Pot Samples	Fishery Retained Catch	Survey	Fishery Pot Samples	Fishery Retained Catch
1996/97	67%	65%	–	74%	71%
1997/98	71%	69%	76%	72%	69%
1998/99	71%	66%	–	79%	75%
1999/00	71%	72%	–	76%	71%
2000/01	69%	69%	82%	76%	64%
2001/02	71%	63%	–	79%	72%
2002/03	67%	66%	–	81%	76%
2003/04	64%	64%	72%	77%	74%
2004/05	63%	63%	–	80%	74%
2005/06	54%	52%	–	73%	66%
2006/07	51%	52%	57%	64%	58%
2007/08	47%	49%	–	65%	53%
2008/09	51%	50%	–	62%	53%
2009/10	51%	48%	–	57%	49%
Average	**65%**	**64%**	**72%**	**73%**	**68%**

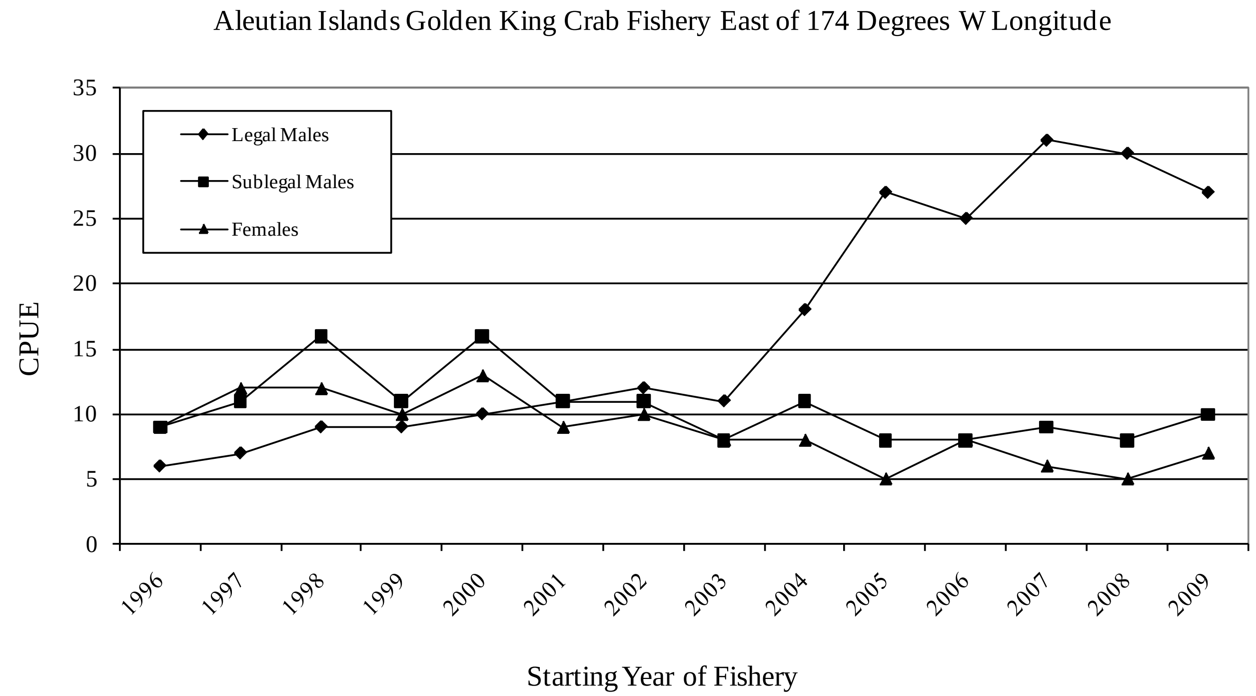
Table 6. Western Aleutian Islands golden king crab harvest in pounds by one degree longitude intervals, 2000/01 to 2009/10 season.

This data is confidential.

Table 7. Percent catch composition and average catch per unit effort (CPUE) of legal males, sublegal males, and females in pots randomly sampled by observers during the Aleutian Islands golden king crab ACA and IFQ fishery west of 174° W longitude, 1996/97 to 2009/10 season.

Fishery	% Catch Composition			Average CPUE			
Season	Legal Males	Sublegal Males	Females	Legal Males	Sublegal Males	Females	Total
1996/97	22%	33%	44%	6	9	12	27
1997/98	27%	31%	42%	7	8	11	26
1998/99	26%	37%	37%	11	16	16	43
1999/00	25%	33%	42%	6	8	10	24
2000/01	24%	34%	41%	7	10	12	29
2001/02	26%	35%	39%	6	8	9	23
2002/03	31%	35%	35%	8	9	9	26
2003/04	33%	33%	33%	9	9	9	27
2004/05	34%	34%	31%	11	11	10	32
2005/06	51%	28%	21%	22	12	9	43
2006/07	50%	24%	26%	21	10	11	42
2007/08	44%	24%	31%	20	11	14	45
2008/09	48%	26%	26%	24	13	13	50
2009/10	63%	17%	20%	26	7	8	41

Note: CR began 2005/06, harvest includes individual fishing quota (IFQ) and Community Development Quota (CDQ).



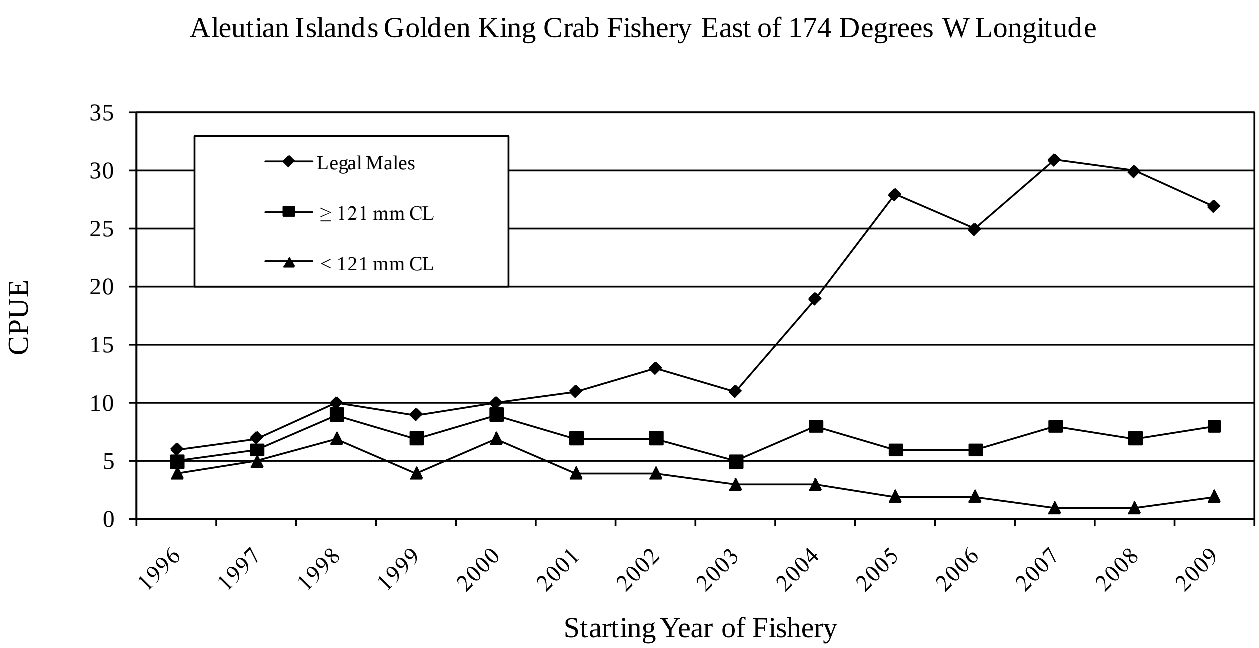


Figure 1. Catch per unit effort of legal males, sublegal males, and females (top panel) and of legal males, sublegal males ≥121 mm CL, and sublegal males <121 mm CL (bottom panel) in the Aleutian Islands golden king crab fishery east of 174º W longitude, 1996/97–2009/10 season, as estimated from contents of pots randomly sampled by observers.

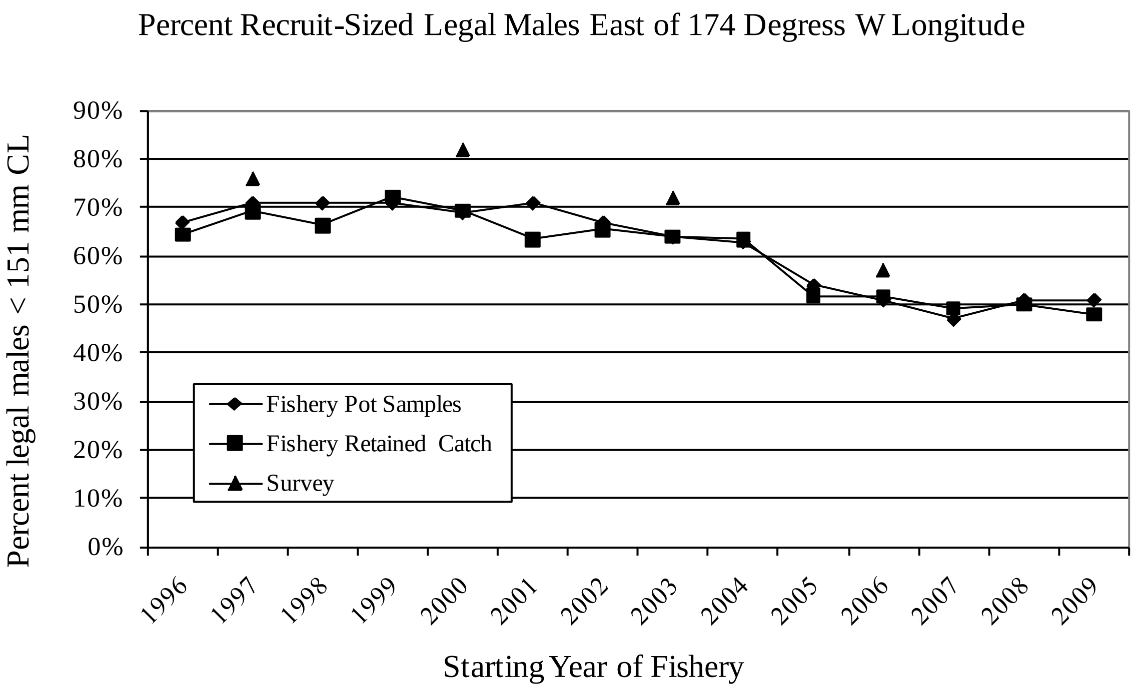


Figure 2. Percent of legal males that were recruit-sized (<151 mm CL) in pots randomly sampled by observers and in samples of retained legal males during the Aleutian Islands golden king crab fishery east of 174º W longitude, 1996/97–2009/10, and in pots fished during the triennial ADF&G Aleutian Islands golden king crab pot survey, 1997–2006.

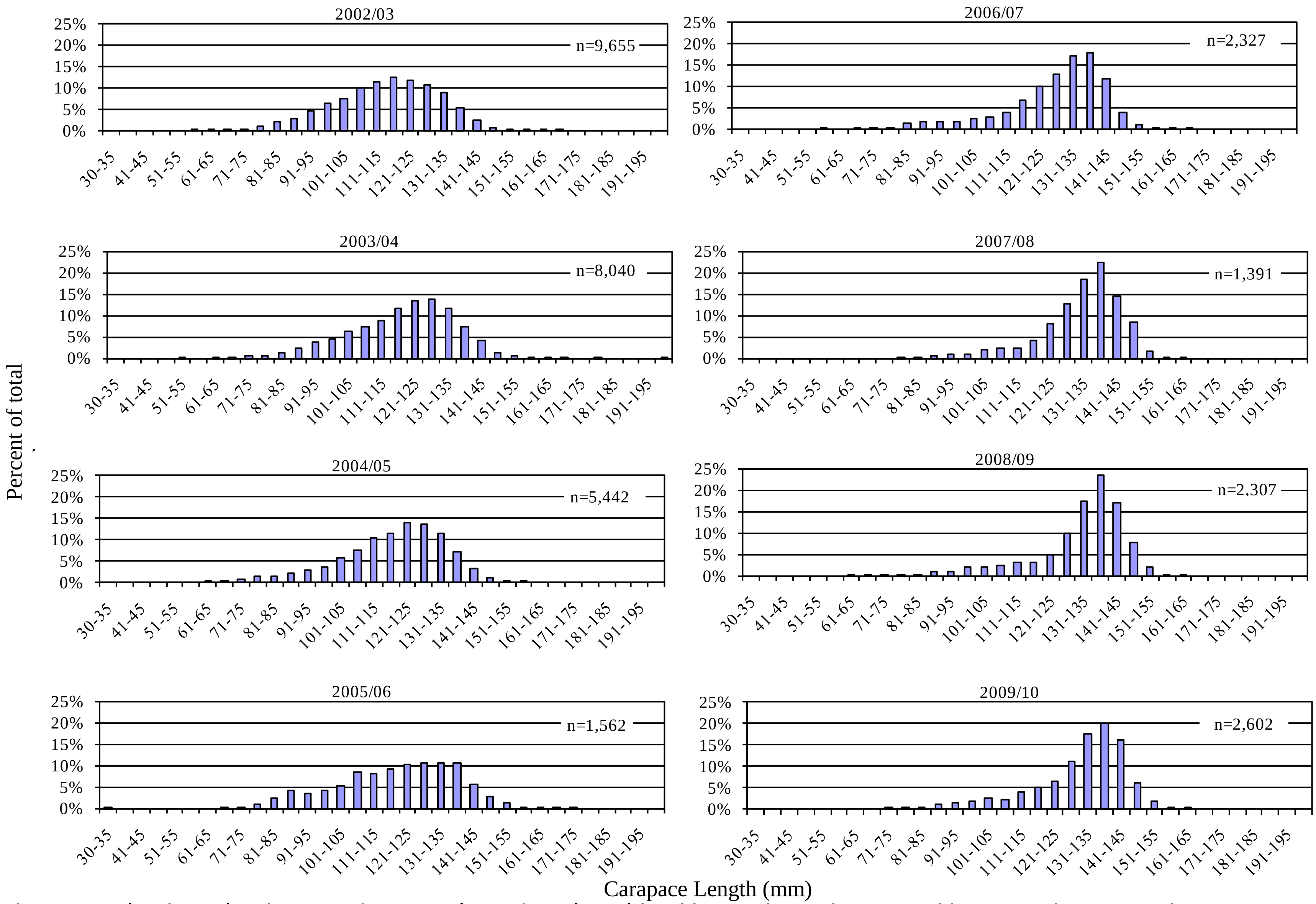


Figure 3. Aleutian Islands east of 174° W long. female golden king crab catch composition, 2002/03 – 2009/10.

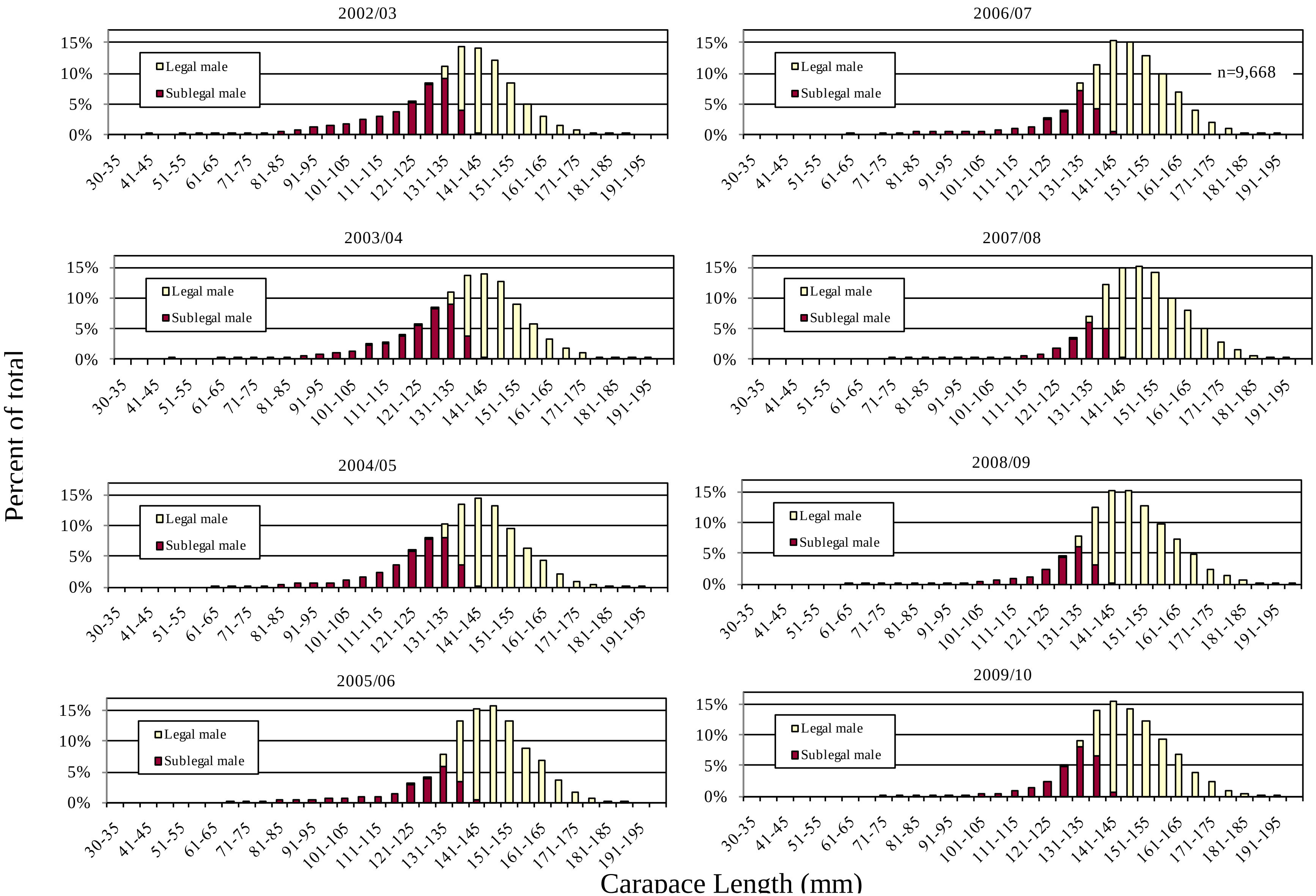


Figure 4. Aleutian Islands east of 174° W long. male golden king crab catch composition, 2002/03-2009/10.

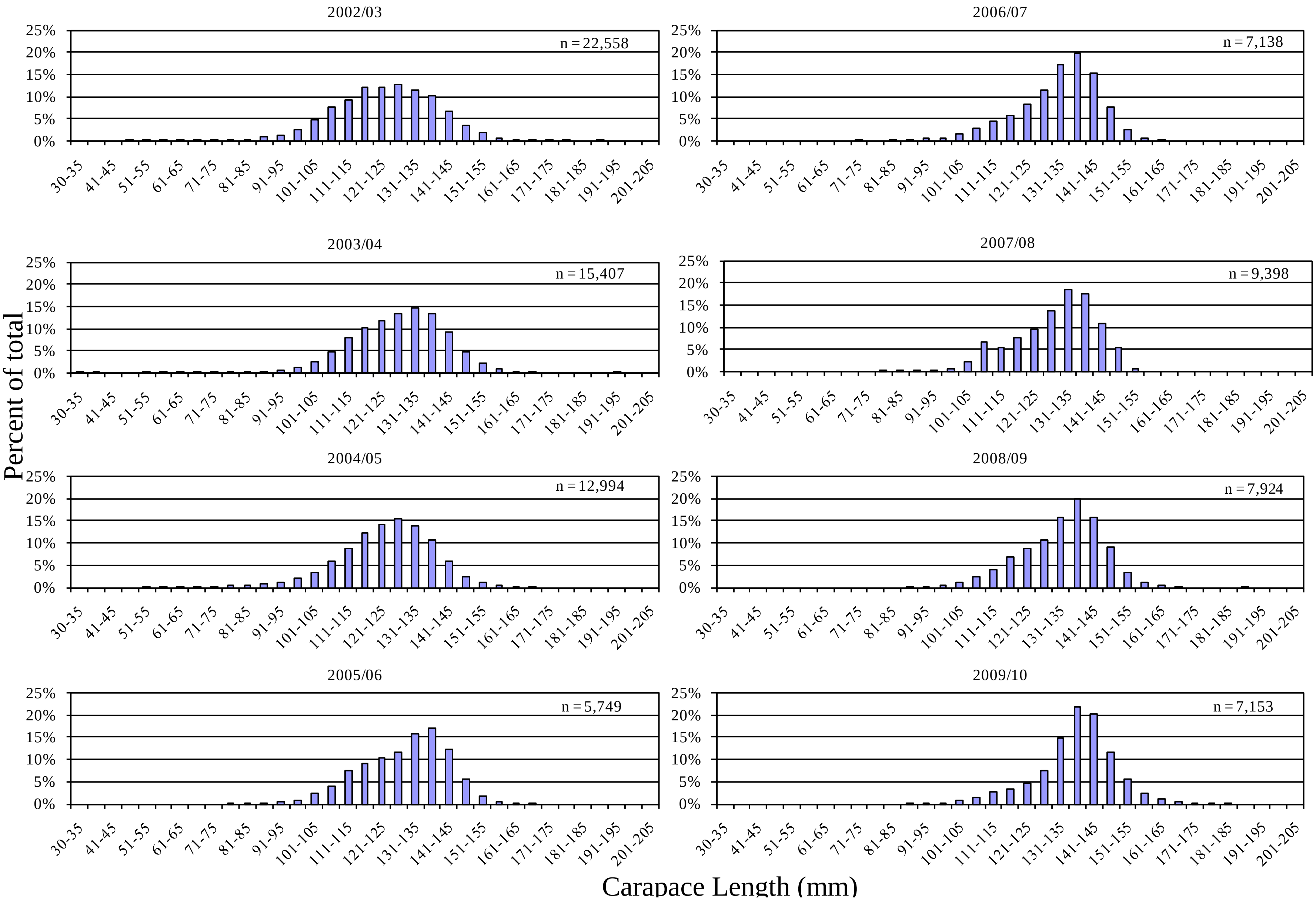


Figure 5. Aleutian Islands west of 174° W long. female golden king crab catch composition, 2002/03 – 2009/10.

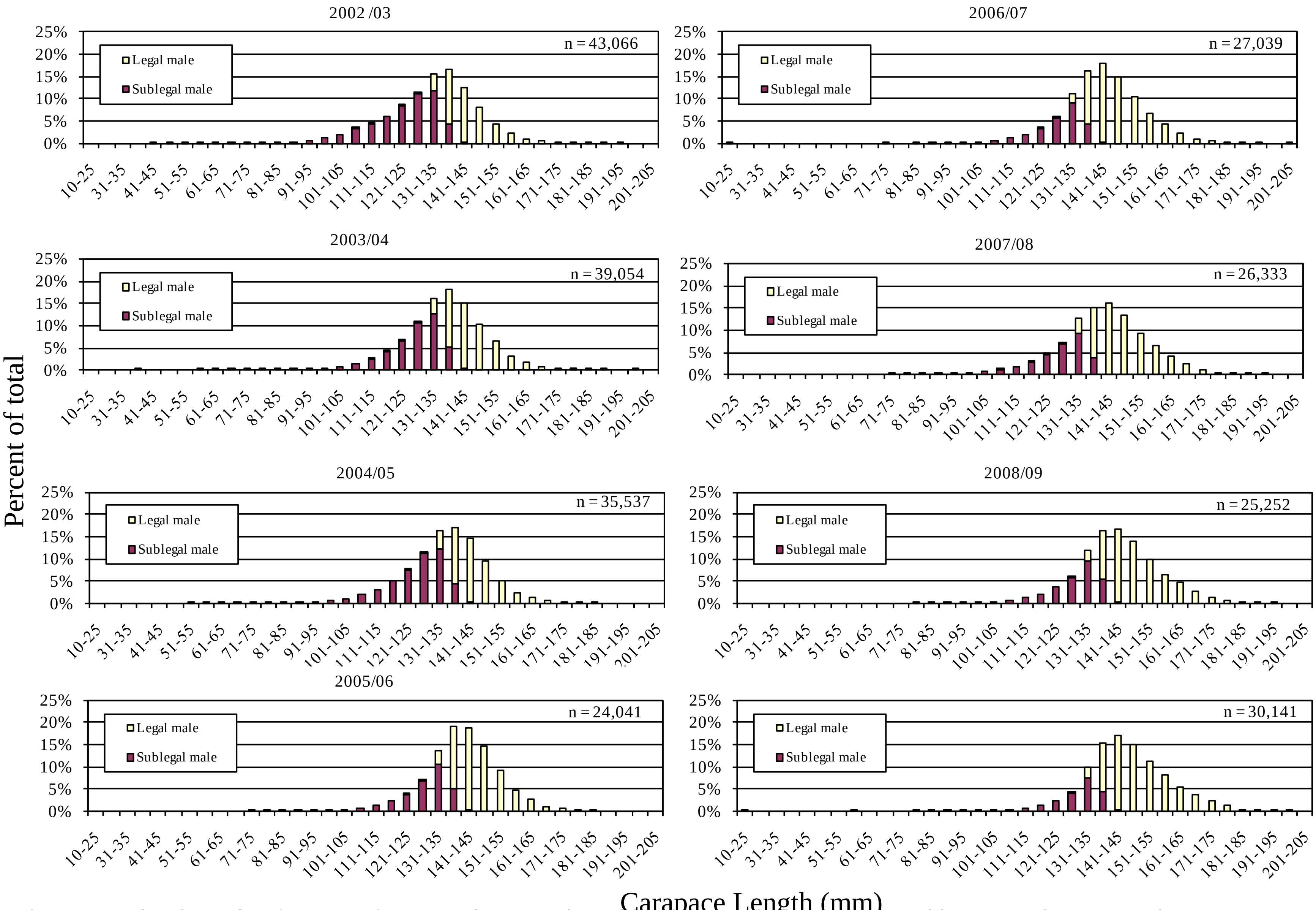
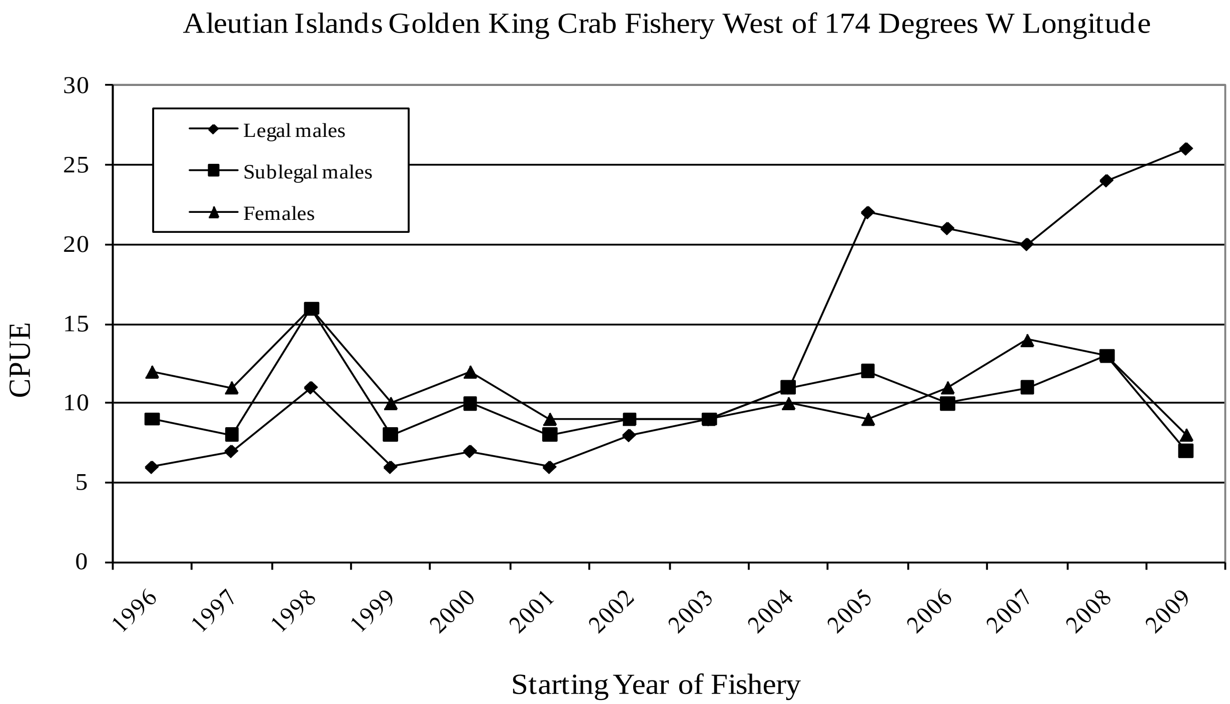


Figure 6. Aleutian Islands west of 174° W long. male golden king crab catch composition, 2002/03 – 2009/10.



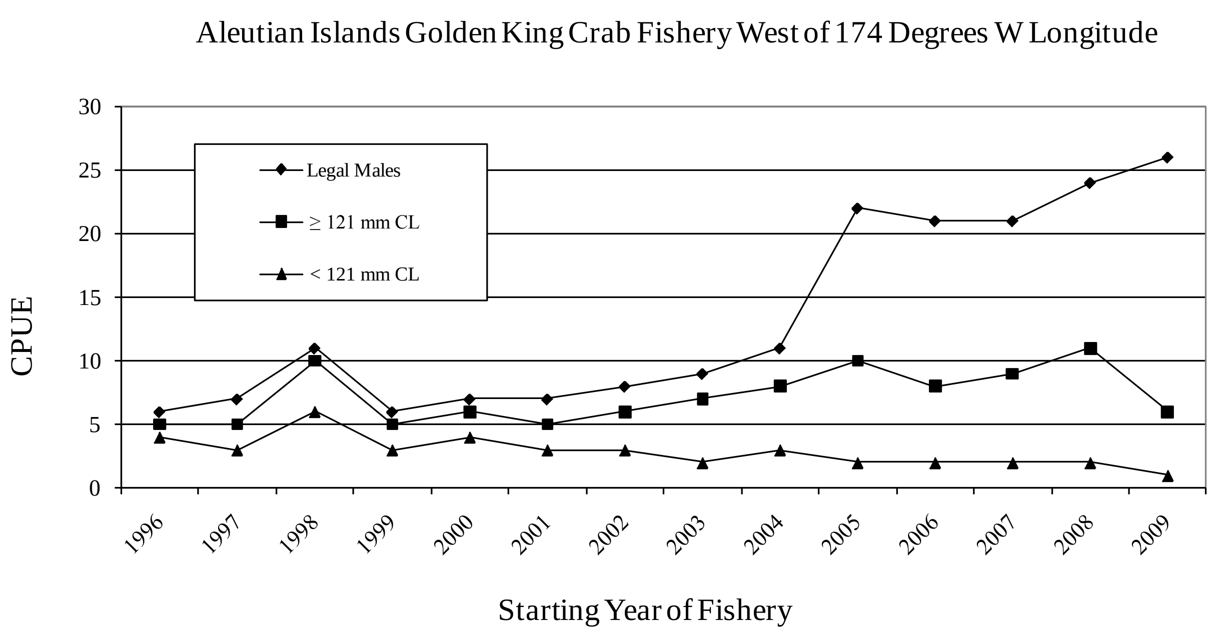


Figure 7. Catch per unit effort of legal males, sublegal males and females (top panel) and of legal males, sublegal males ≥121 mm CL, and sublegal males <121 mm CL (bottom panel) in the Aleutian Islands golden king crab fishery west of 174º W longitude, 1996/97–2009/10 seasons, as estimated from contents of pots randomly sampled by observers.

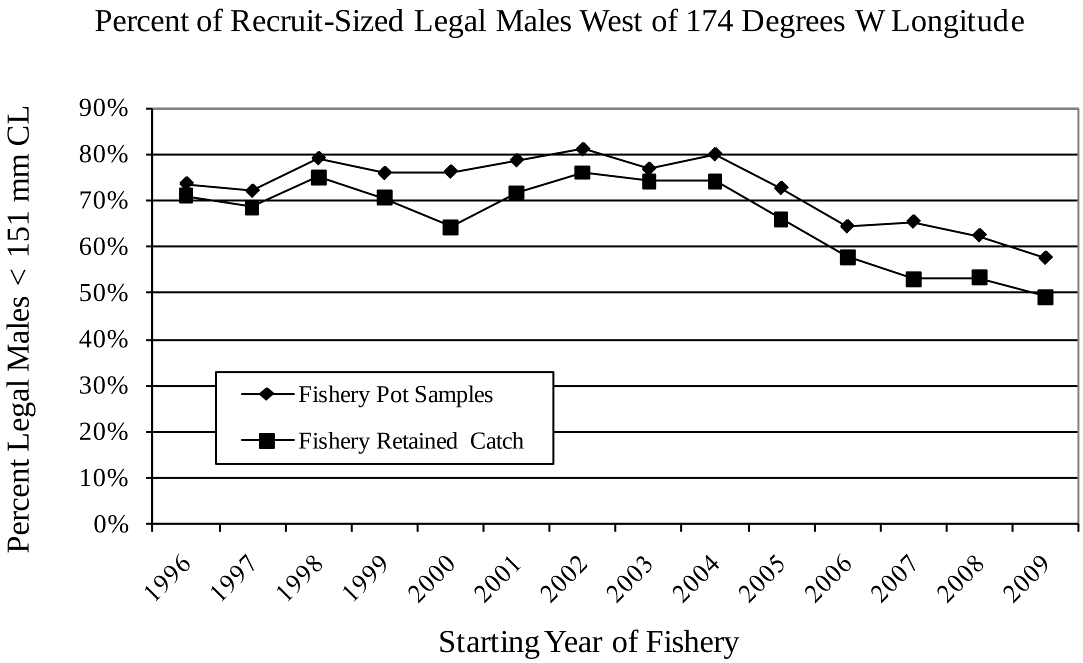


Figure 8. Percent of legal males that were recruit-sized (<151 mm CL) in pots randomly sampled by observers and in samples of retained legal males during the Aleutian Islands golden king crab fishery west of 174º W longitude, 1996/97–2009/10.

ALASKA DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

MEMORANDUM

TO:	Wayne Donaldson Fishery Biologist IV Division of Commercial Fisheries Region IV - Kodiak	**DATE:** **PHONE:** **FAX:**	June 21, 2006 (907) 581-1239 (907) 581-1572
FROM:	Forrest R. Bowers Fishery Biologist III Division of Commercial Fisheries Region IV - Dutch Harbor	**SUBJECT:**	Pribilof District golden king crab stock status

The Pribilof District golden king crab stock is not surveyed for abundance. The fishery is managed under terms of a commissioner's permit and harvest has been set at 150,000 pounds since the 2000 season. The guideline harvest level (GHL) was set at 50% of the Maximum Sustained Yield (MSY) of mature biomass for this stock in the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. The fishery opens on January 1 and is closed by emergency order when the GHL is reached or other biological factors warrant a closure, or by regulation on December 31. Pot limits, established at the March 1993 Board of Fisheries meeting, are set at 40 pots for vessels 125 feet or less in overall length and 50 pots for vessels greater than 125 feet in length. Since 2001, observers have been required on each vessel registered for this fishery.

In 2001, a total of six vessels fished between February 21 and April 15, harvesting 145,876 pounds of golden king crab (Table 1). Catch per unit of effort (CPUE) averaged eight crabs per pot during the 2001 fishery, an increase from an average of five crabs per pot the previous year. Fishing effort in 2002 began in mid-January directly after the snow crab season closed when one vessel registered to fish. A total of eight vessels participated in the fishery and the season was closed by emergency order on May 14. Harvest totaled 150,434 pounds of golden king crab and the CPUE decreased to six legal crabs per pot during the 2002 fishery. In 2003, three vessels harvested 148,741 pounds of golden king crab in five weeks between February 24 and May 1. Average CPUE increased to 13 legal crabs per pot during the 2003 fishery. The 2004 fishery was the shortest on record. Five vessels harvested 140,583 pounds of golden king crab in three weeks between February 6 and March 12. Average CPUE increased to 15 legal crabs per pot during the 2004 fishery, a level not seen since the 1999 fishery when over 177,000 pounds were harvested. During the 2005 fishery, five vessels fished from January 27 to April 15. A total of 61,738 pounds were harvested and the GHL was not achieved. Average CPUE dropped to six legal crabs per pot during the 2005 fishery.

	2001	2002	2003	2004	2005
Legal CPUE	8	6	13	15	6

Average number of legal males per pot, fish ticket data.

Shell-age composition data indicate the stock is healthy. Since the 2001 season, more than 93% of crabs sampled during the fishery have had new shells. No negative trends are readily apparent in the shell age data.

Observer data, consisting of both measure and count pots, indicate that legal males constituted 47% of the catch in 2003 and over 60% in 2001, 2002, 2004 and 2005. Sublegal males accounted for 19% in 2001 and increased to 36% in 2003. Since 2003, the percentage of sublegal males captured in the fishery has declined to 15% in 2005. Females have constituted 10 – 23% of the catch in the past five years.

Percent catch composition, based on observer data, of legal, sublegal and female golden king crab, by season for the Pribilof District.

	2001	2002	2003	2004	2005
Legal males	61	60	47	68	62
Sublegal males	19	25	36	22	15
Females	20	15	17	10	23

Average total crab per pot has ranged from 10 crabs/pot in the 2005 season to 23 crabs/pot during the 2003 and 2004 seasons. Sublegal male CPUE has declined since the 2003 season from eight crabs per pot to just one in 2005. Female CPUE has remained fairly constant at two to four crabs per pot.

Average CPUE, based on observer data, by size and sex class of golden king crab, by season.

	2001	2002	2003	2004	2005
Legal males	8	7	11	16	6
Sublegal males	3	4	8	5	1
Females	3	2	4	2	3
Total	14	13	23	23	10

Soak times in the Pribilof District averaged 44 and 45 hours in 2001 and 2002, and then decreased to 27 and 26 hours in 2003 and 2004. Average soak time during the 2005 fishery was 39 hours.

Reproductive condition of females can be an indicator of stock status in king crab populations, and dramatically reduced female fecundity has been associated with stock crashes in other crab fisheries. Assessment of trends in reproductive condition of golden king crabs is difficult due to asynchronous mating and a prolonged period of barren condition between hatching and extrusion of the next clutch. Since 2001, observer data indicate between 33 and 81% of all bycatch females have been mated and between 27 and 68% have been carrying eggs. During the 2005 fishery 81% of the females had been mated and 68% were carrying eggs.

Over the last 5-years the golden king crab harvest has averaged 130,000 pounds. Compared to the guideline harvest level of 150,000 pounds established in 2000, harvests appear stable although legal-male catch rates have been variable. Harvest in 2005 was the second lowest in the last 10 years due to increased vessel operating costs, a 27% decrease in exvessel price from 2004 and relatively low CPUE of six legal crabs per pot. Legal male CPUE was 15 crabs per pot for the 1999 and 2004 fisheries, which is the highest on record.

It is difficult to predict recruitment in the golden king crab stock using commercial fisheries data, because the commercial fishery may not sample all depths where Pribilof golden king crab inhabit. In addition, 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. Nonetheless, observer data indicates that sublegal male CPUE decreased from eight crabs per pot in 2003 to one crab per pot in 2005; this drop in CPUE is likely due to a large year class which recruited to legal size in 2003 and 2004 (Figures 1 and 2). The observer-collected data from the last 5-years does provide annual trend in sublegal abundance. Based on observer-collected data in sublegal male catch, few prerecruit males appear to have followed the 2003/04 recruitment event and few recruits are expected in 2006.

Increases in operating costs combined with the need for 100% observer coverage and low pot limits make the Pribilof District golden king crab fishery an expensive venture. It is likely that few vessels will participate in this fishery when catch rates and exvessel value are relatively low and operating expenses are relatively high. Based on a review of fishery performance information, staff recommends no change to the Pribilof District golden king crab GHL of 150,000 pounds. Despite the recommendation of status quo GHL for 2006, low sublegal male and overall golden king crab CPUE is an indicator that this stock may be decreasing in abundance. If this stock is commercially exploited in 2006, staff will closely monitor CPUE inseason.

The geographic distribution of the fishery is limited. Most golden king crab harvest in the Pribilof District occurs in Pribilof Canyon, a relatively small and well defined area. Often the majority of harvest in any given year occurs in one or two ADF&G statistical areas. Since the fishery occurs in a relatively small and well defined area, the stock in Pribilof Canyon is vulnerable to overfishing in years when recruitment to the legal-size class is poor. Staff will continue to monitor harvest by statistical area and encourage fishers to explore other areas of known golden king crab distribution within the District.

cc: McCullough, Schwenzfeier, Failor, Burt, Pengilly, Barnard, Gish

Table 1. Harvest table containing confidential data.

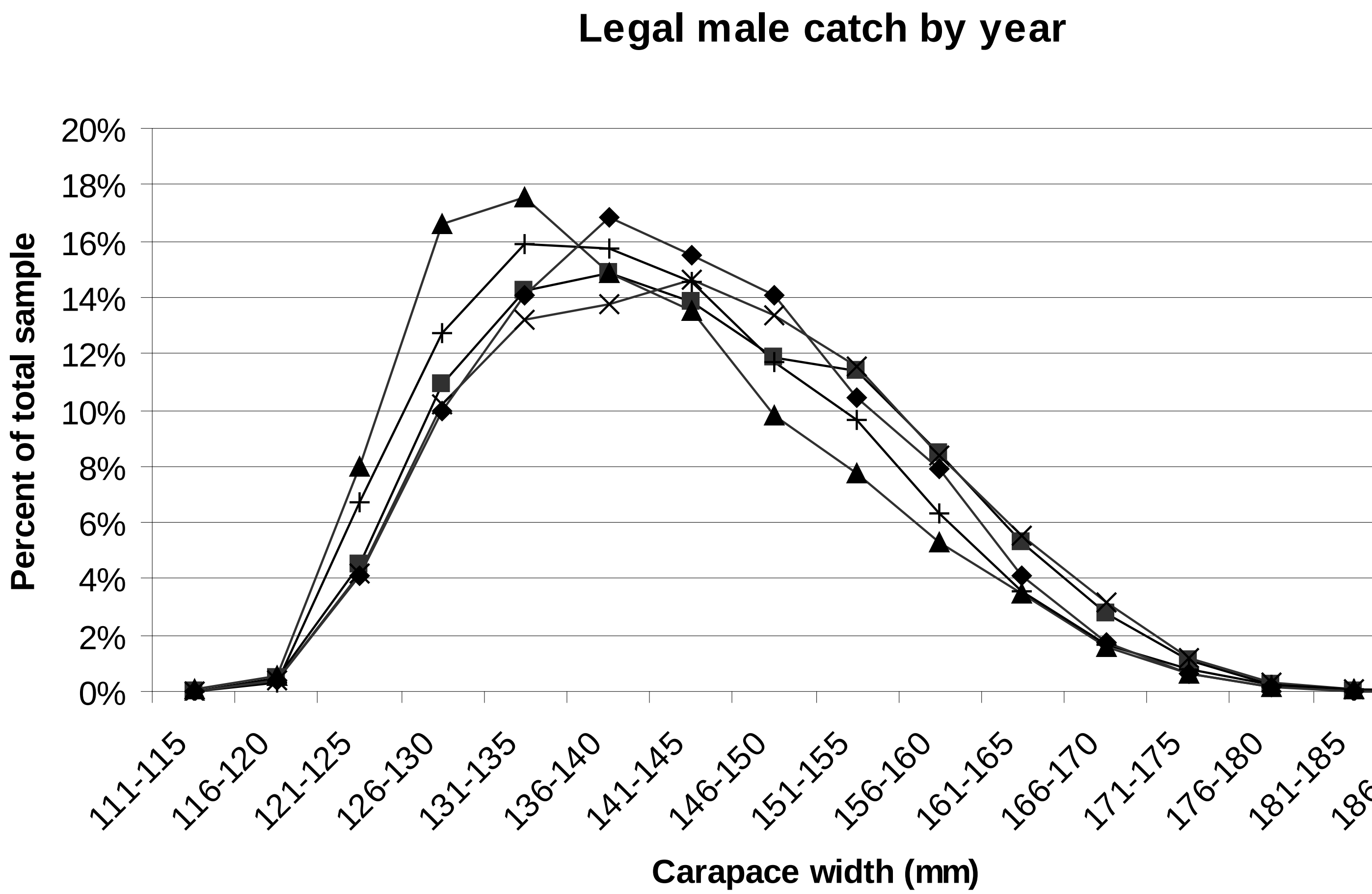


Figure 1. Pribilof District golden king crab legal male catch from observer bycatch samples 2001 – 2005.

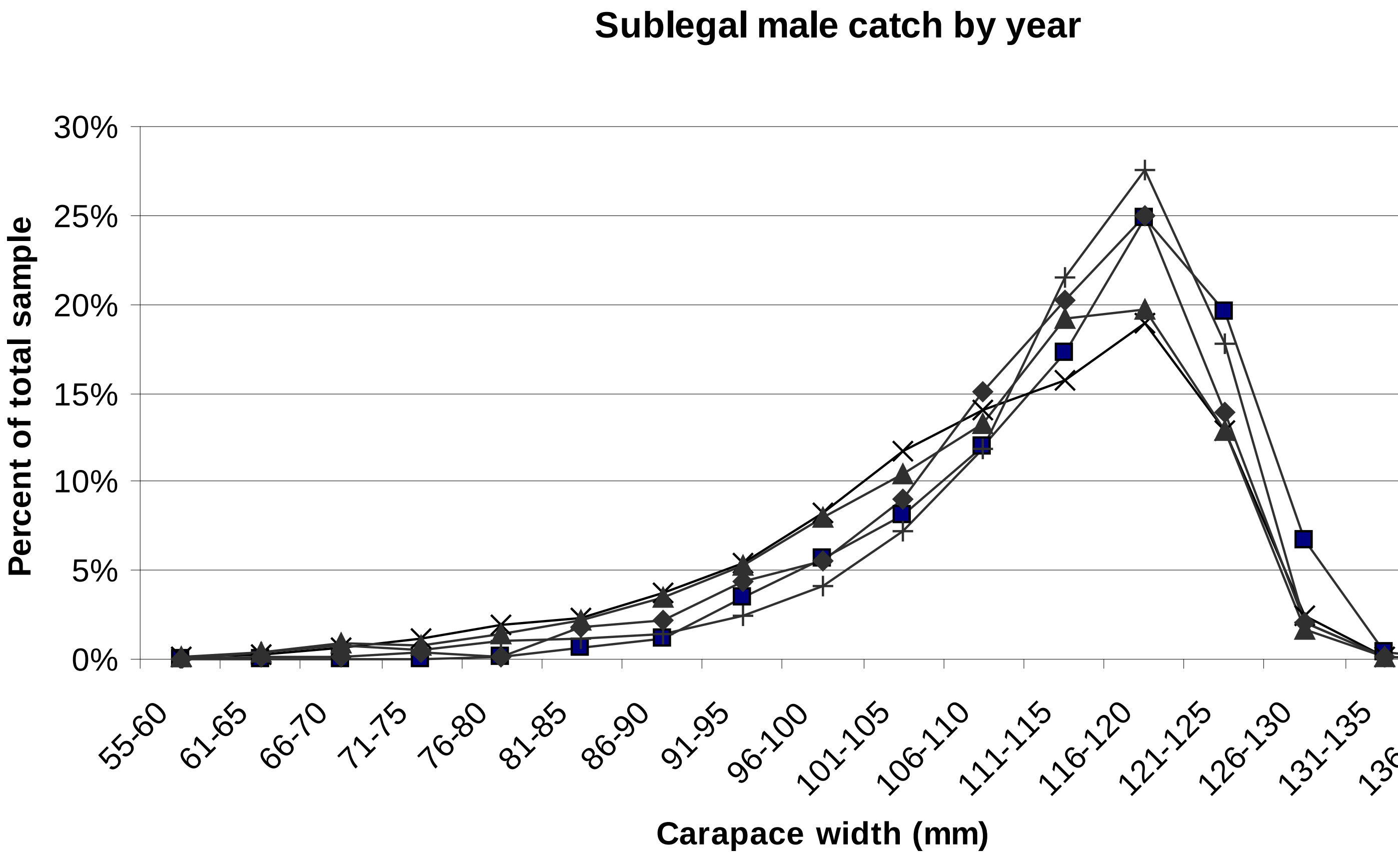


Figure 2. Pribilof District golden king crab sublegal male catch from observer bycatch samples 2001 – 2005.

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES
NEWS RELEASE

Denby S. Lloyd, Commissioner
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Date Issued: July 23, 2007

PETREL BANK RED KING CRAB
COMMERCIAL FISHERY TO REMAIN CLOSED FOR 2007/08 SEASON

The Alaska Department of Fish and Game has completed a review of data collected during the November 2006 Petrel Bank red king crab survey. Data from the 2006 survey was compared to information from the 2001 industry survey and the 2002 and 2003 commercial fisheries to evaluate current stock status. The Petrel Bank red king crab fishery was closed from 2004 to 2006 to protect the reproductive potential of the stock.

Because of differences in fishing practices between the 2001 survey, the 2002 and 2003 commercial fisheries, and the 2006 survey, a direct catch per unit effort (CPUE) comparison cannot be made. However, legal male red king crab catch rate during the 2006 survey was lower than during the 2001 survey and recent commercial fisheries. The 2006 survey CPUE of legal males was 1.2 crabs per pot from 170 stations fished. Red king crabs captured during the survey were predominately larger, mature-sized crabs, and the size distribution of surveyed crabs provides no expectation for significant recruitment of legal males in the immediate future. Although males that were estimated to be new recruits to legal size accounted for 36% of the 2006 survey catch of legal crabs, recruitment occurring since the 2001 survey has been insufficient to rebuild legal male abundance to levels of the early 2000s.

Spatial distribution of legal males during the 2006 survey decreased from the 2001 survey distribution and was limited to the northwestern portion of Petrel Bank. Overall, red king crabs in 2006 appeared to be absent or at very low densities in areas where they were captured during the November 2001 industry survey. Distribution of red king crabs was also restricted relative to harvest location during the last two commercial fisheries.

Given the limited distribution and low relative abundance of legal male red king crab on Petrel Bank and the lack of projected recruitment to the legal size class in the near future, a harvestable surplus of red king crab is not available and the commercial fishery will remain closed for the 2007/08 season. In order to build upon the relative abundance survey data collected in 2006, the department intends to conduct another red king crab survey of Petrel Bank in November 2007.

For further information please contact the Alaska Department of Fish and Game in Dutch Harbor at (907) 581-1239.

-end-

APPENDIX 3: APPENDICES TO CHAPTER 3

Appendix A to Chapter 3: Implement of the SOA Control Rules

A. EBS Snow Crab

This exploitation rate on survey mature male biomass is based on total survey mature biomass (TMB) which decreases below maximum E when TMB < average 1983-97 TMB calculated from the survey.

$$E = \begin{cases} Bycatch\,only, Directed\ E=0, & if\ \dfrac{TMB}{averageTMB} < 0.25 \\[2em] \dfrac{0.225 * \left[\dfrac{TMB}{averageTMB} - \alpha\right]}{(1-\alpha)} & if\ 0.25 < \dfrac{TMB}{averageTMB} < 1 \\[2em] 0.225 & if\ TMB \geq averageTMB \end{cases} \qquad (13)$$

Where, α = -0.35 and average TMB = 921.6 million lbs.

The maximum target for the retained catch is determined by using E as a multiplier on survey mature male biomass (SMMB),

Retained Catch = E * SMMB.

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 may be changed yearly, however, in this analysis it is set at 25%, which is the value that has been used in recent years.

B. BB Red King Crab

Let M_t be the number (abundance) of survey-selected mature males at the time of the survey during year *t*, $\tilde{M}_t$ be the number of females which could be mated by survey-selected mature males at the time of the survey during year *t*, F_t be the number of survey-selected mature females at the time of the survey during year *t*, F_t^B be the biomass of survey-selected mature females at the time of the survey (in thousand lbs), L_t be biomass of legal males at the time of the survey during year *t*, and $\overline{W}_t$ be the mean weight of legal males at the time of the survey during year *t*. The effective spawning biomass, ESB_t, is F_t^B multiplied by the minimum of 1 and $\tilde{M}_t / F_t$. The control rule is for the HG during year *t* is as follows:

1. If ESB_t < 14,500,000 lb or F_t is less than 8400000 then $HG_t = 0$. Stop
2. If ESB_t <34,750,000 lb, then $HG_t = 0.1 M_t \overline{W}_t$
3. If 34,750,000 < ESB_t < 55,000,000 lb then $HG_t = 0.125 M_t \overline{W}_t$
4. If ESB_t > 55,000,000 lb then $HG_t = 0.5 M_t \overline{W}_t$
5. If HG_t > 0.5 L_t then $HG_t = 0.5 L_t$
6. If HG_t < 4,444,000 lb then $HG_t = 0$.

C. EBS Tanner crab

Let MFB_t be the estimate of mature female biomass in the Eastern Subdistrict (i.e., the waters of the Bering Sea District east of 173º W longitude) at the time of the survey in year *t* defined as the estimated biomass of females > 79 mm carapace width (cw), MFB_{t-1} be the estimate of mature female biomass in the Eastern Subdistrict at the time of the survey in the previous year (*t-1*), $MMMA_t$ be the molting mature male abundance in each area east and west of 166° W longitude within the Eastern Subdistrict at the time of the survey in year *t* defined as the estimated abundance of all new-shell males > 112-mm cw plus 15% of the estimated abundance of old-shell males > 112-mm cw, $ELMA_t$ be the exploitable legal male abundance in each area east and west of 166° W longitude within the Eastern Subdistrict at the time of the survey in year *t* defined as the estimated abundance of all new-shell legal males ≥ 138 mm cw plus 32% of the estimated abundance of old-shell legal males ≥ 138 mm cw, W_t be the average weight of legal males in the Eastern Subdistrict east or west of 166° W longitude in year *t* estimated by applying a weight-length relationship to the survey size-frequency data for legal (≥ 138 mm cw) males, HG_{COMP} be the total allowable catch computed for each area east and west of 166° W longitude in the Eastern Subdistrict, HG_{CAP} be the capped total allowable catch derived for each area east and west of 166° W longitude in the Eastern Subdistrict. In applying the control rule, [i] a separate *HG* is determined as the minimum of the HG_{COMP} and the HG_{CAP} for each area east and west of 166º W longitude, and [ii] the *HG* of legal males in each area east or west of 166° W longitude in the Eastern Subdistrict is capped at 50% of the exploitable legal male abundance.

The control rule for the HG during year *t* in each area east and west of 166° W longitude in the Eastern Subdistrict is as follows: (mp=million pounds).

1. If MFB_{t-1} < 21.0 mp and MFB_t < 21.0 mp, then HG_{COMP}=0 and HG_{CAP}=0.
2. If MFB_{t-1} < 21.0 mp and 21.0 mp ≤ MFB_t < 45.0 mp, then $HG_{COMP}=0.05 MMMA_t W_t$ and $HG_{CAP}=0.25 ELMA_t W_t$.

3. If MFB_{t-1} < 21.0 mp and $MFB_t \geq$ 45.0 mp, then HG_{COMP}=0.1$MMMA_tW_t$ and HG_{CAP}=0.25$ELMA_tW_t$.
4. If $MFB_{t-1} \geq$ 21.0 mp and MFB_t < 21.0 mp, then HG_{COMP}=0 and HG_{CAP}=0.
5. If $MFB_{t-1} \geq$ 21.0 mp and 21.0 mp ≤ MFB_t < 45.0 mp, then HG_{COMP}=0.1$MMMA_tW_t$ and HG_{CAP}=0.5$ELMA_tW_t$.
6. If MFB_{t-1} < 21.0 mp and $MFB_t \geq$ 45.0 mp, then HG_{COMP}=0.2$MMMA_tW_t$ and HG_{CAP}=0.5$ELMA_tW_t$.

D. Pribilof Island Blue king crab

Let M_t be the number (abundance) of survey-selected mature males at the time of the survey during year *t*, L_t be biomass of legal males at the time of the survey during year *t*. The control rule is for the HG during year *t* is as follows:

1. If M_t<6,000,000lb or M_{t-1}<6,000,000lb then $HG_t = 0$. Stop
2. $HG_t = 0.1M_t$
3. If HG_t > 0.2 L_t then $HG_t = 0.2L_t$
7. If HG_t < 556,000 lb then $HG_t = 0$.

E. St Mathews Blue King crab

Let M_t be the number (abundance) of survey-selected mature males at the time of the survey during year *t*, L_t be biomass of legal males at the time of the survey during year *t*. The control rule is for the HG during year *t* is as follows:

1. if M_t < 2,900,000lb then $HG_t = 0$. Stop
2. Set the harvest rate h to $\max(0, 0.1 + \min(0.1, 0.1(M_t - 2900)/8700))$
3. If HG_t > 0.4 L_t then $HG_t = 0.4L_t$

F. Norton Sound red king crab

Let L_t be biomass of legal males at the time of the survey during year *t*. The control rule is for the HG during year *t* is as follows:

1. If L_t < 1,500,000lb then $HG_t = 0$. Stop
2. If 1,500,000 < L_t < 2,500,000lb then $HG_t = 0.05L_t$
3. If L_t > 2,500,000lb then $HG_t = 0.1L_t$

G. Adak and Dutch Golden king crab

The HG is 105% of the average catch from 1989 (Adak) and 1990 (Dutch) to 2008.

Appendix B to Chapter 3: BACKTESTING PROBABILITY FORECASTS FOR ALASKA KING CRAB AND SNOW CRAB WHOLESALE PRICES: VAR(3) ANALYSIS

INTRODUCTION

This document briefly summarizes model development and data updates and extensions to a report submitted by the author for SSC review in September 2008 as part of the 3-year review of the crab rationalization program. That report described a time series model that was used to test hypotheses about the effects of rationalization and global trade on the wholesale prices for Alaska king crab that were reported by Alaska processors in the period 1991-2006, the most recent year of data available at the time of writing.

This appendix updates the VAR(3) model documentation from March 1, 2009. Specifically, it replaces the model for all king crab with two separate models, one for gold king crab and another for red king crab. The model for snow crab is the same the one in the March 1, 2009 report and the relevant figures and tables are reproduced here to integrate this document with the previous report. There are now 3 separate models: gold king crab, red king crab, and snow crab. Each model is a VAR(3) with 3 time series. The series included in each model are identified below.

DATA

Time series data for the period 1991-2008 were derived from COAR reports and U.S. Census Bureau Merchandise Trade Statistics, the latter were accessed via the U.S. Trade Policy Information System (TPIS). The COAR time series represent the i) physical quantity of production in each year and ii) an index of real first-wholesale prices (i.e., economic value per physical unit) for (all) types of frozen crab products. Separate series were derived from COAR for gold king crab, red king crab, snow crab, and an aggregate series that combines blue, gold, and red king crab. The latter is used in the snow crab model. Similarly, quantities and price indices for exports and imports were retrieved from the TPIS. However, the trade data do not distinguish among the three king crab species, and thus, are most comparable to the aggregate COAR series. In forming the real price indices, all nominal economic values were converted into real economic values using a price deflator based on a producer price index (PPI)available from the U.S. Bureau of Labor Statistics (BLS), WPU0223= Processed and unprocessed fish, a general category that includes frozen shellfish commodities.

MODEL

Vector autoregression (VAR) models with (alternatively) lags of 1-2-3 years were considered. Model specification tests based on the Akaike Information Criterion (AIC) and the Bayesian-Schwarz Information Criterion (BIC) were conducted using the 1991-2008 dataset. These, and a battery of bivariate, trivariate, quadravariate Granger causality tests, had the strongest support for the VAR(3) model specification. The number of parameters to estimate grows with each lag and the VAR(4) model exhausted the time series. Likewise, the number of parameters grows for each series that is added to the system, and the statistical software (S+Finmetrics) had severe problems with bad results, for example, with a VAR(3) and 4 series. In terms of the backtesting results, the VAR(2) model with 4 series was outperformed by the best VAR(3) with 3 series. Therefore, model selection here is limited to the VAR(3) specification, each with three time series for prices. The software that was used is S+8 with the module Finmetrics 3. All tests, estimation, and forecasting procedures are described in Chapter 11 ("Vector autoregressive models for multivariate time series") of Zivot and Wang (2003).

The final set of models that were used to forecast prices are each represented by three time series (x1, x2, x3):

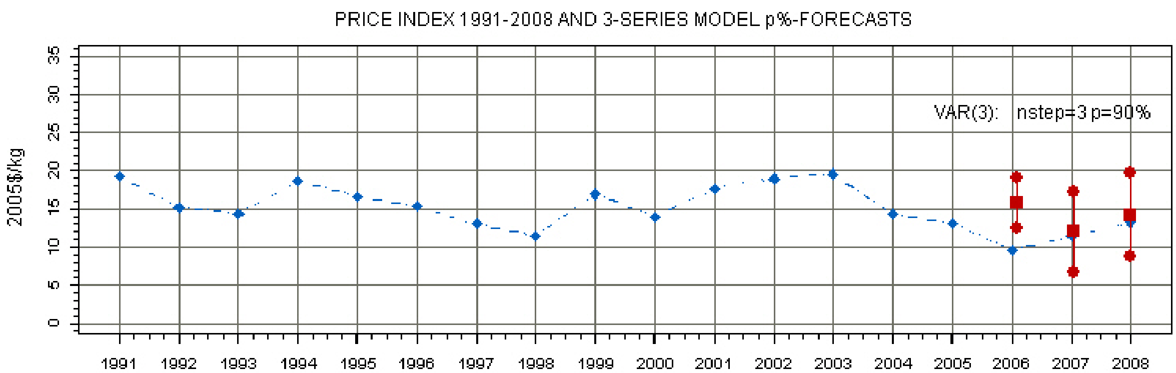
1. Gold king crab: COAR gold king crab price index (x1), COAR snow crab price index (x2), TPIS king crab import price index (x3);

2. Red king crab: COAR red king crab price index (x1), COAR snow crab price index (x2), TPIS king crab import price index (x3);

3. Snow crab: COAR aggregate ('all') king crab price index (x1); COAR snow crab price index (x2), TPIS king crab import price index (x3).

BACKTESTING RESULTS

Fig. 1a: Gold king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (upper plot), COAR wholesale values for snow crab (lower plot), and TPIS king crab imports (not shown). The regression runs through 2005 with 90% 3-step forecasts for 2006-2008. The expected values of each forecast are represented by squares in the forecast intervals for each year. All values are in 2005 dollars per kilogram.



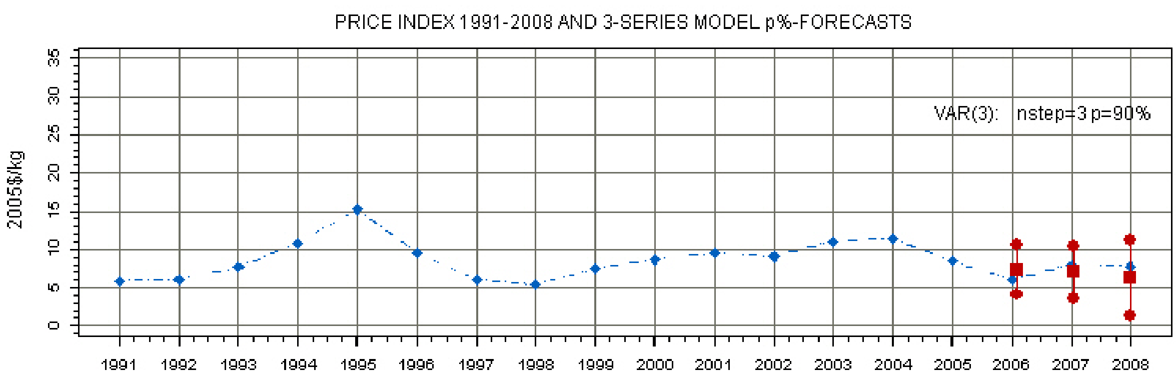
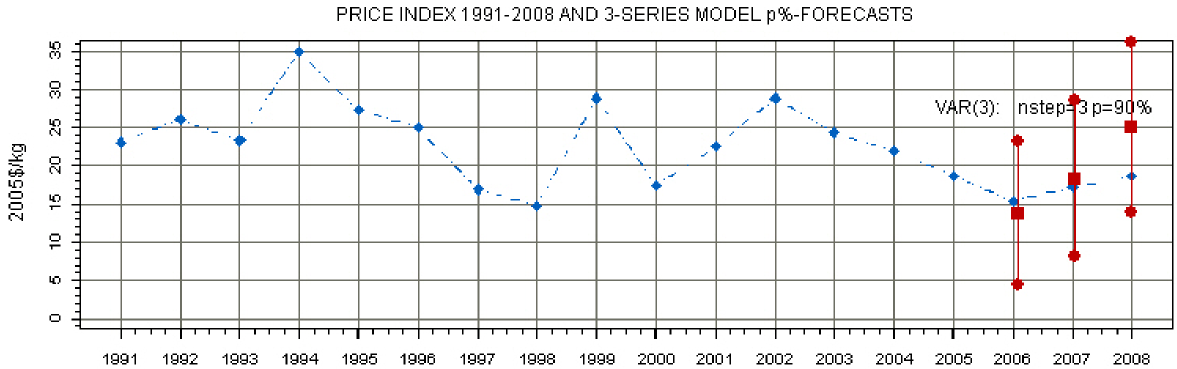


Fig. 1b: Red king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (upper plot), COAR wholesale values for snow crab (lower plot), and TPIS king crab imports (not shown). The regression runs through 2005 with 90% 3-step forecasts for 2006-2008. The expected values of each forecast are represented by squares in the forecast intervals for each year. All values are in 2005 dollars per kilogram.



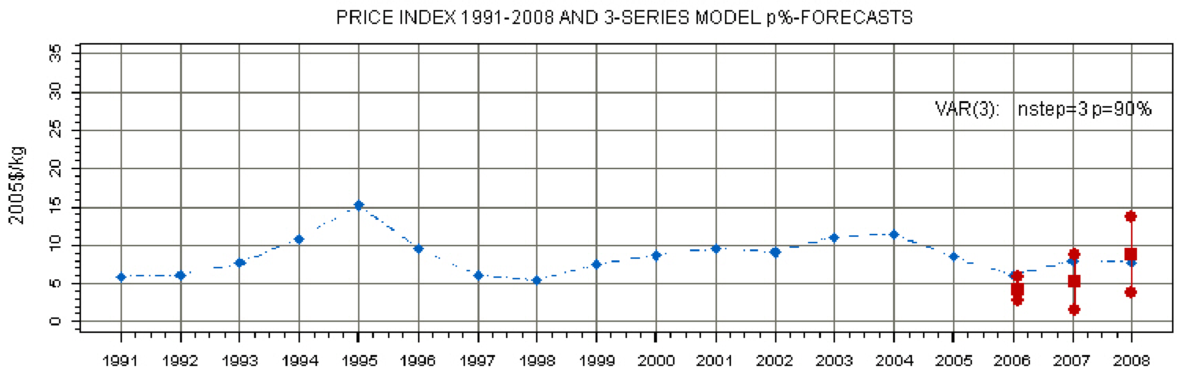
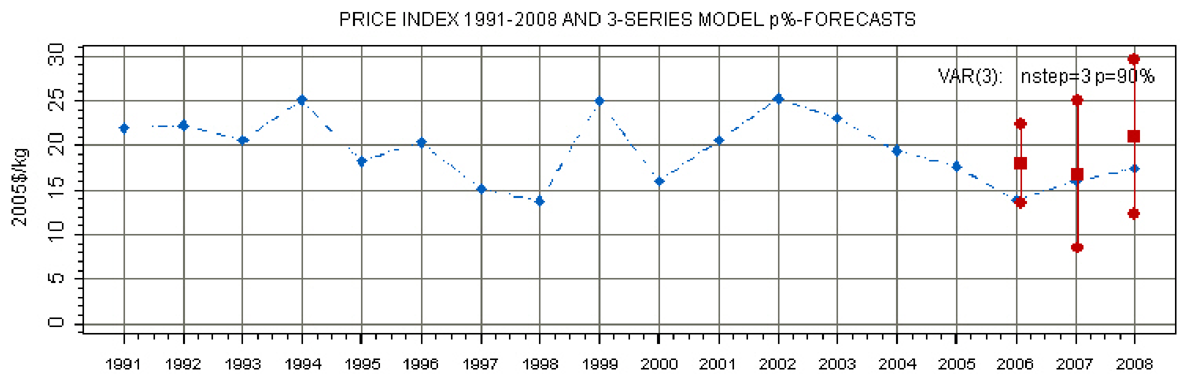
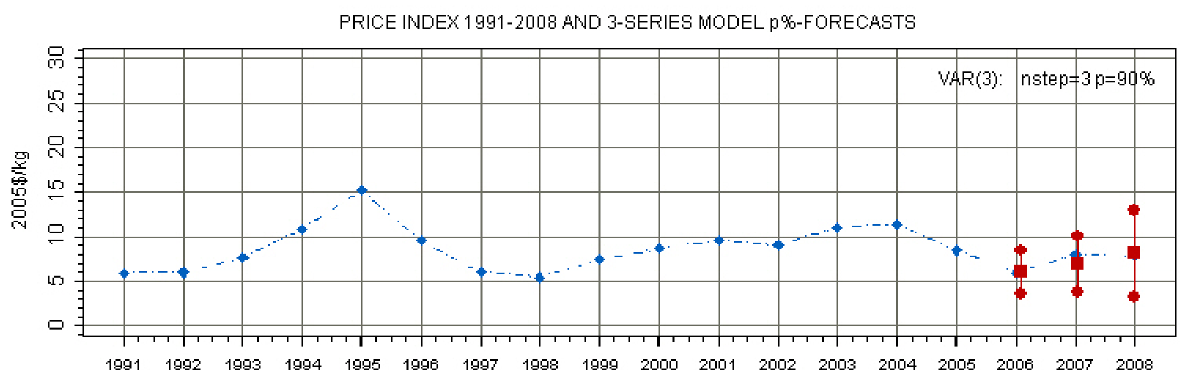


Fig. 1c: Snow crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for king crab (upper plot), COAR wholesale values for snow crab (lower plot), and TPIS king crab imports (not shown). The regression runs through 2005 with 90% 3-step forecasts for 2006-2008. The expected values of each forecast are represented by squares in the forecast intervals for each year. All values are in 2005 dollars per kilogram.





FORECASTING RESULTS

Fig. 2a: Gold king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 30-step 90%-forecasts for 2009-2038. All values are in real 2005 dollars per kilogram.

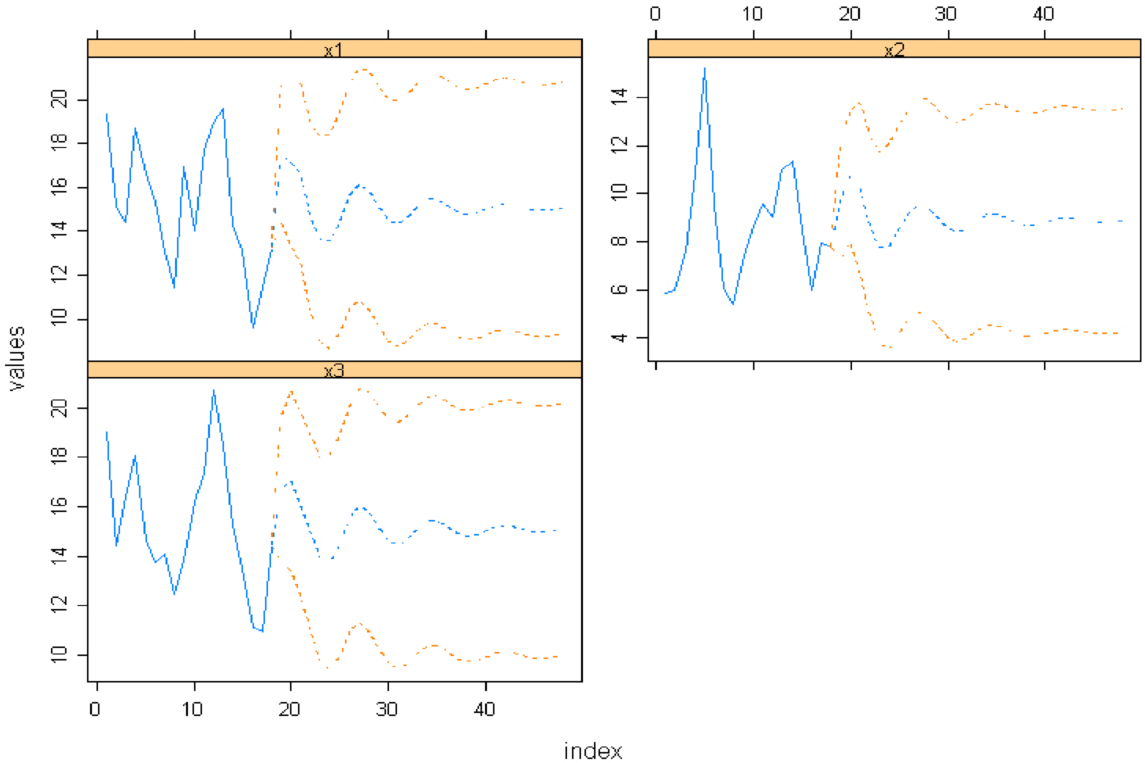


Fig. 2b: Red king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for red king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 30-step 90%-forecasts for 2009-2038. All values are in real 2005 dollars per kilogram.

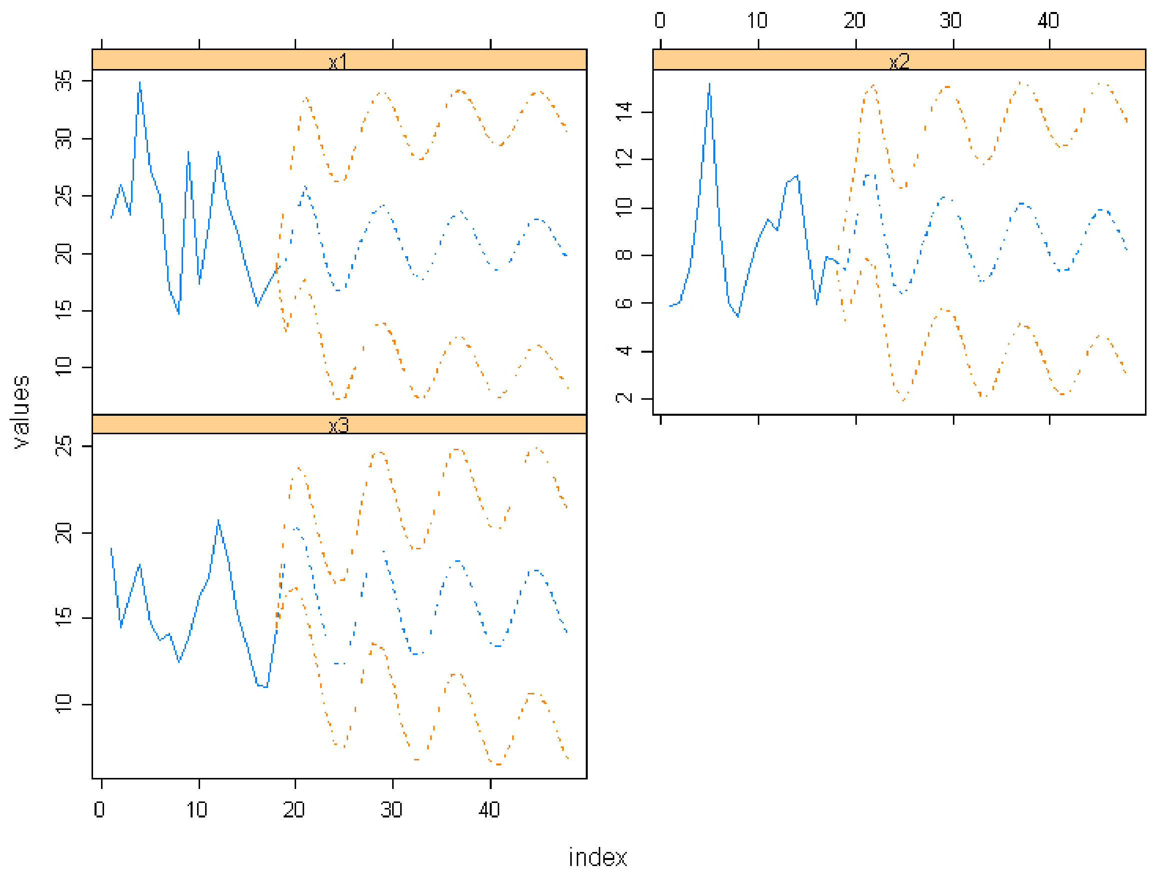
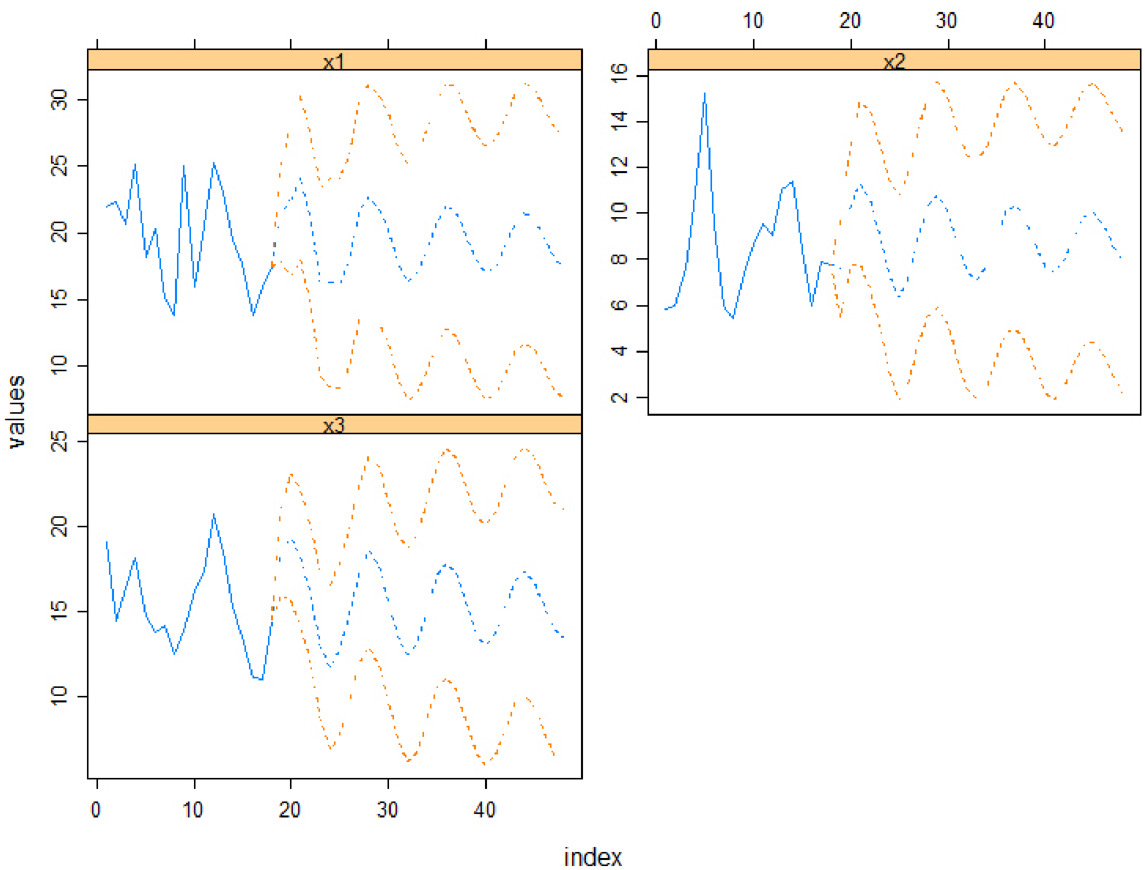


Fig. 2c: Snow crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 30-step 90%-forecasts for 2009-2238. All values are in real 2005 dollars per kilogram.



MODEL DIAGNOSTICS

Fig. 3a: Gold king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 200-step 90%-forecasts for 2009-2208. All values are in 2005 dollars per kilogram.

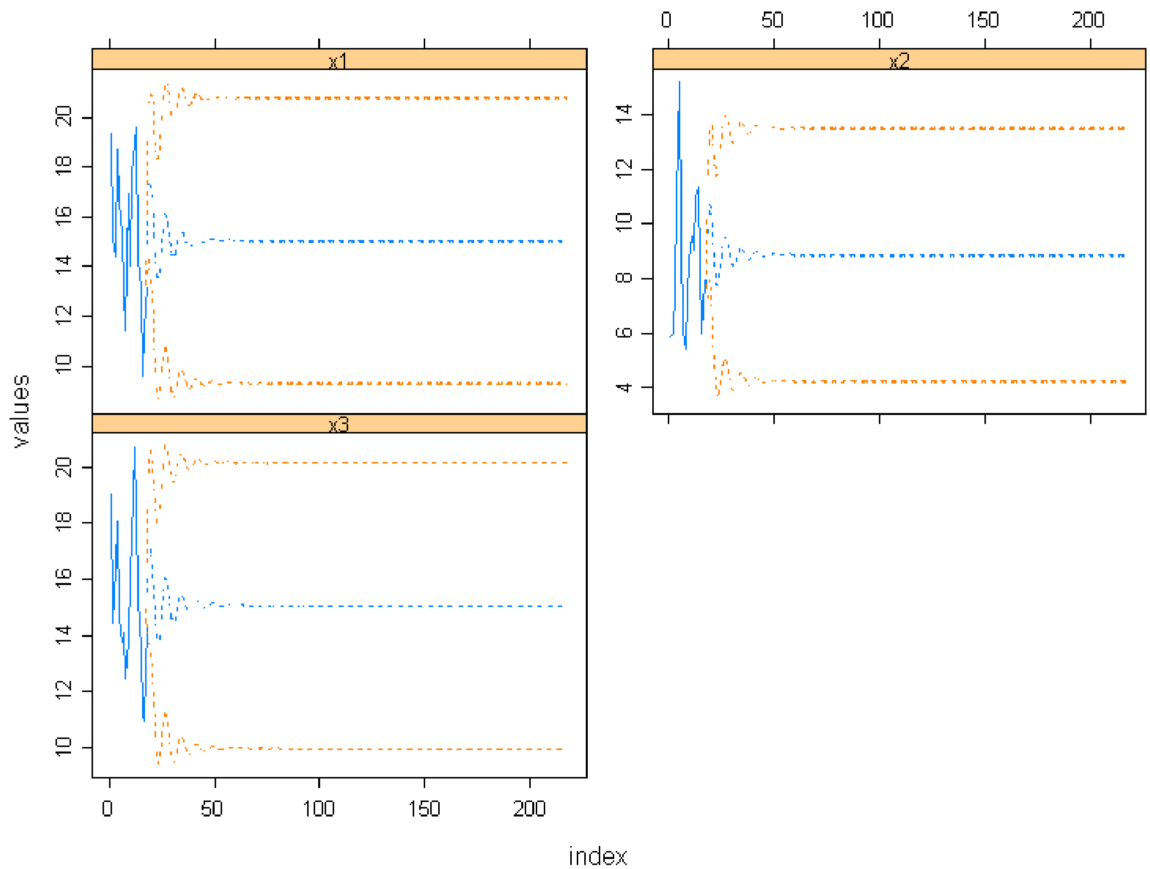


Fig. 3b: Red king crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for red king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 200-step 90%-forecasts for 2009-2208. All values are in 2005 dollars per kilogram.

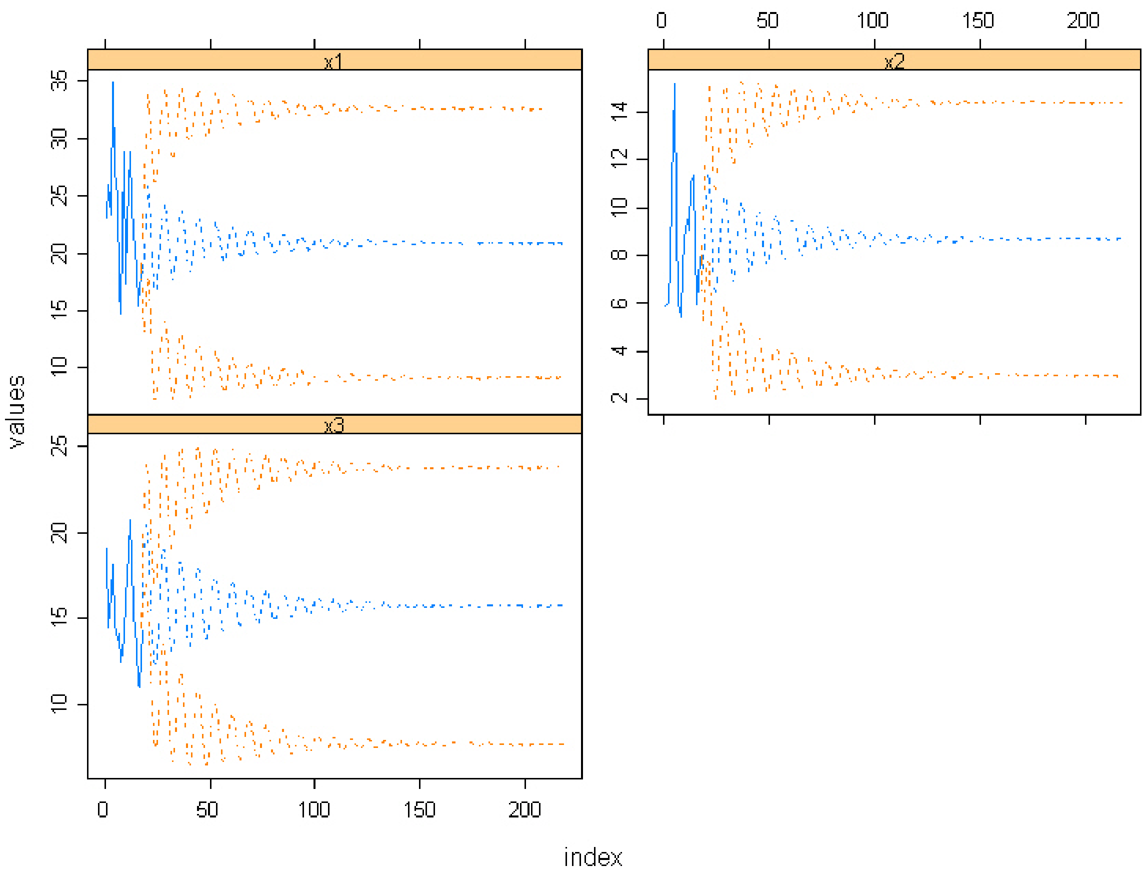


Fig. 3c: Snow crab VAR(3) model and data 1991-2008 with three price series based on COAR wholesale values for king crab (x1, upper-left plot), COAR wholesale values for snow crab (x2, upper-right plot), and TPIS king crab imports (x3, lower-left plot). The regression runs through 2008 with 200-step 90%-forecasts for 2009-2208. All values are in 2005 dollars per kilogram.

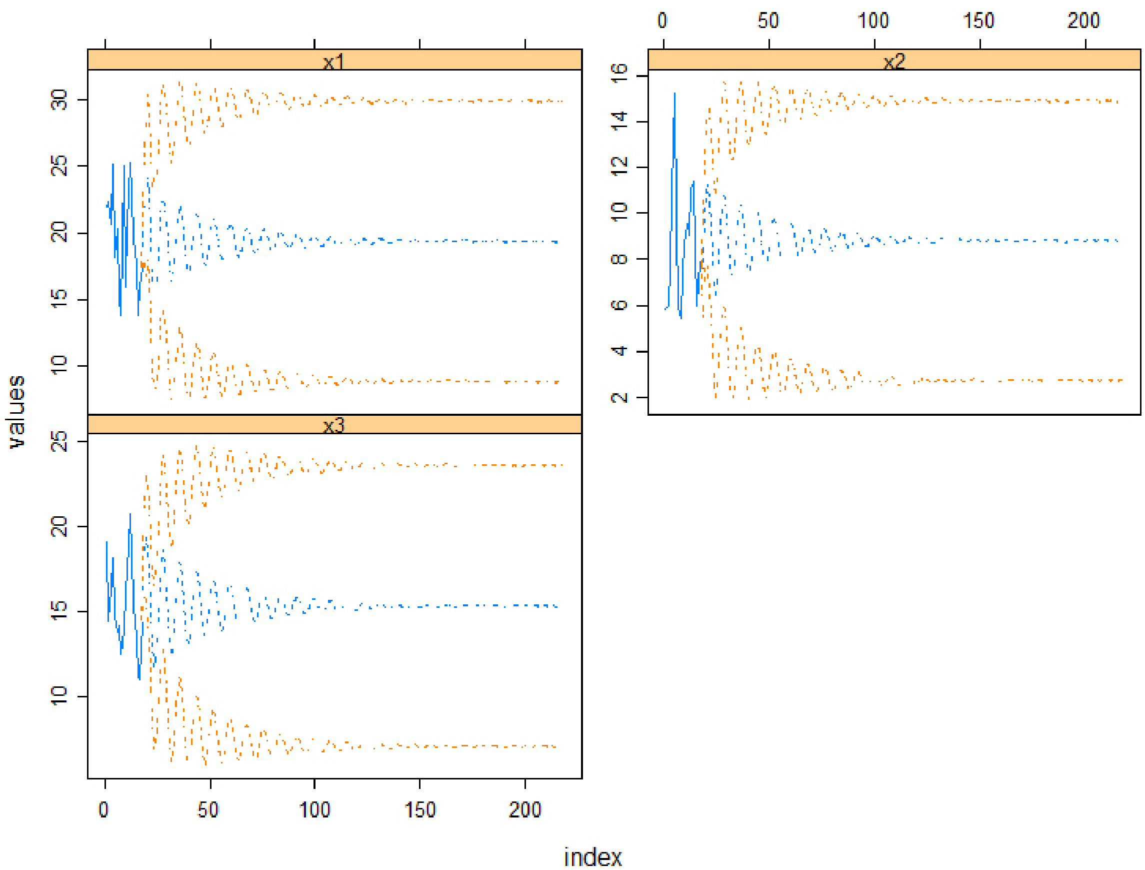


Fig. 4a: Gold king crab VAR(3) model fit and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (series 1, upper-left plot), COAR wholesale values for snow crab (series 2, upper-right plot), and TPIS king crab imports (series 3, lower-left plot). The regression runs through 2008. All values are in 2005 dollars per kilogram.

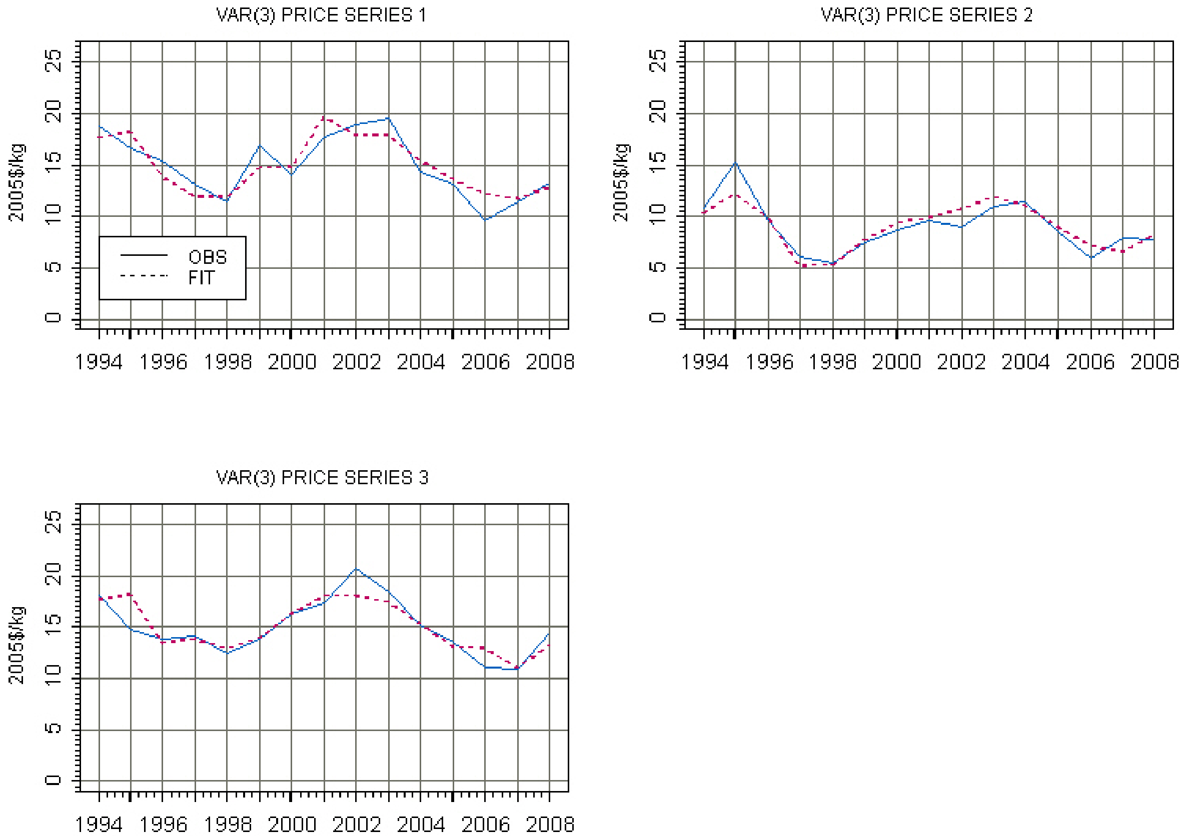


Fig. 4b: Red king crab VAR(3) model fit and data 1991-2008 with three price series based on COAR wholesale values for red king crab (series 1, upper-left plot), COAR wholesale values for snow crab (series 2, upper-right plot), and TPIS king crab imports (series 3, lower-left plot). The regression runs through 2008. All values are in 2005 dollars per kilogram.

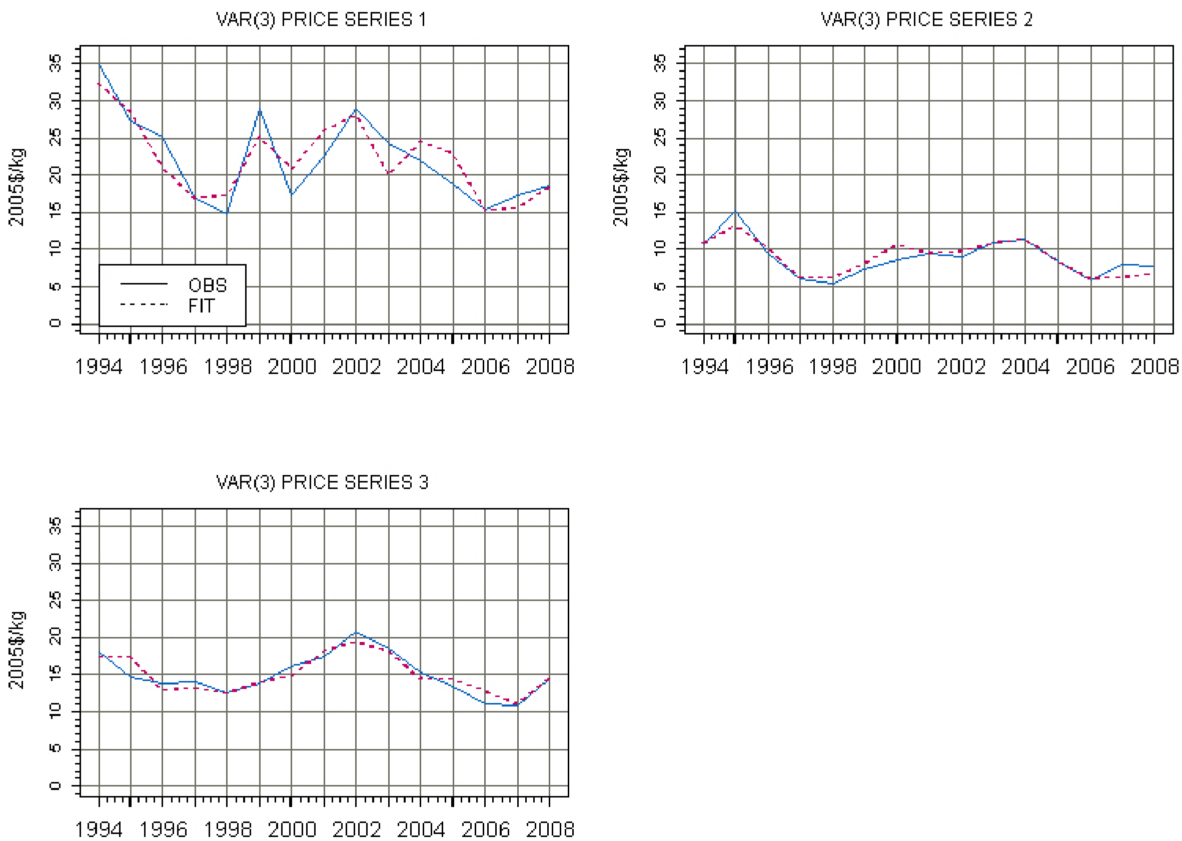


Fig. 4c: Snow crab VAR(3) model fit and data 1991-2008 with three price series based on COAR wholesale values for king crab (series 1, upper-left plot), COAR wholesale values for snow crab (series 2, upper-right plot), and TPIS king crab imports (series 3, lower-left plot). The regression runs through 2008. All values are in 2005 dollars per kilogram.

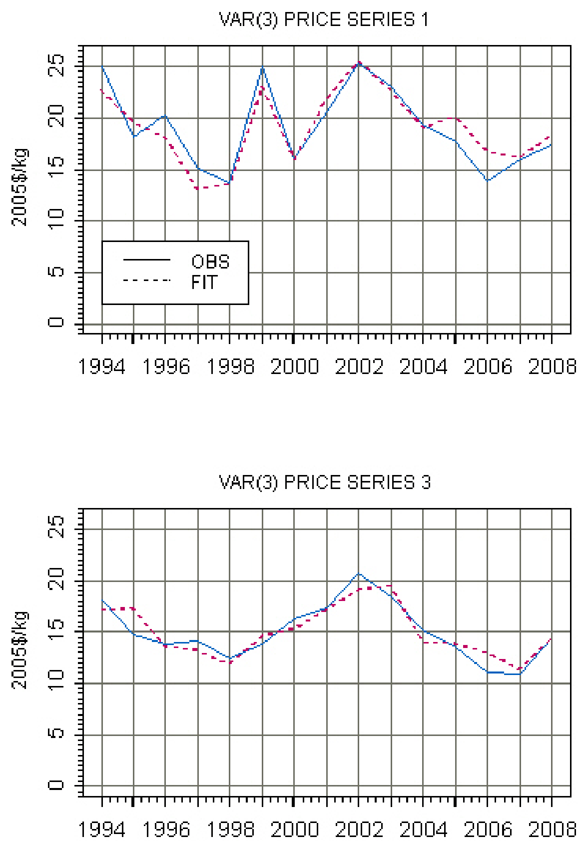


Fig. 5a: Gold king crab VAR(3) model residual time series (upper row plots), residual histograms (upper-middle row plots), autocorrelation functions (lower-middle row plots), and normal quantile-quantile plots (lower row plots) for three price series based on COAR wholesale values for gold king crab (series 1, left-column plots), COAR wholesale values for snow crab (series 2, middle-column plot), and TPIS king crab imports (series 3, right-column plots). The regression runs through 2008. All values are standardized.

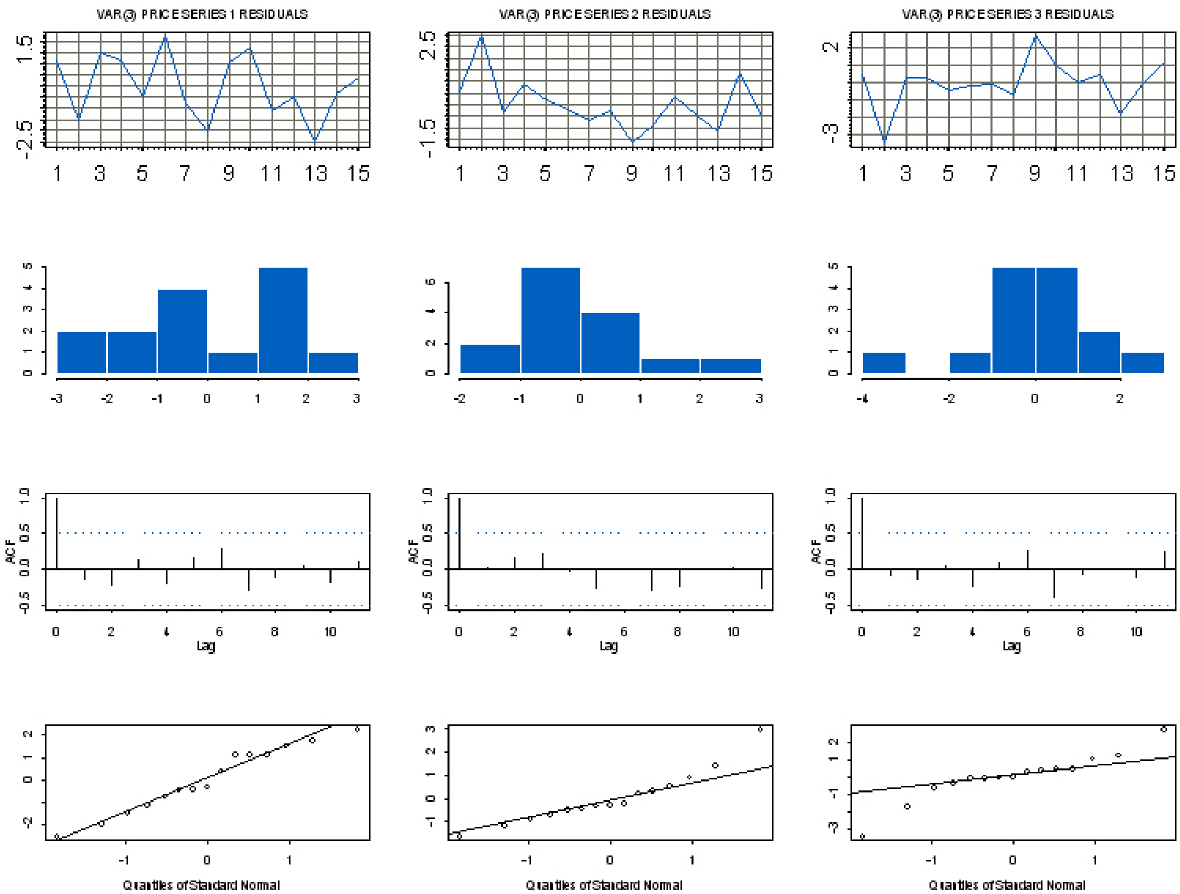


Fig. 5b: Red king crab VAR(3) model residual time series (upper row plots), residual histograms (upper-middle row plots), autocorrelation functions (lower-middle row plots), and normal quantile-quantile plots (lower row plots) for three price series based on COAR wholesale values for red king crab (series 1, left-column plots), COAR wholesale values for snow crab (series 2, middle-column plot), and TPIS king crab imports (series 3, right-column plots). The regression runs through 2008. All values are standardized.

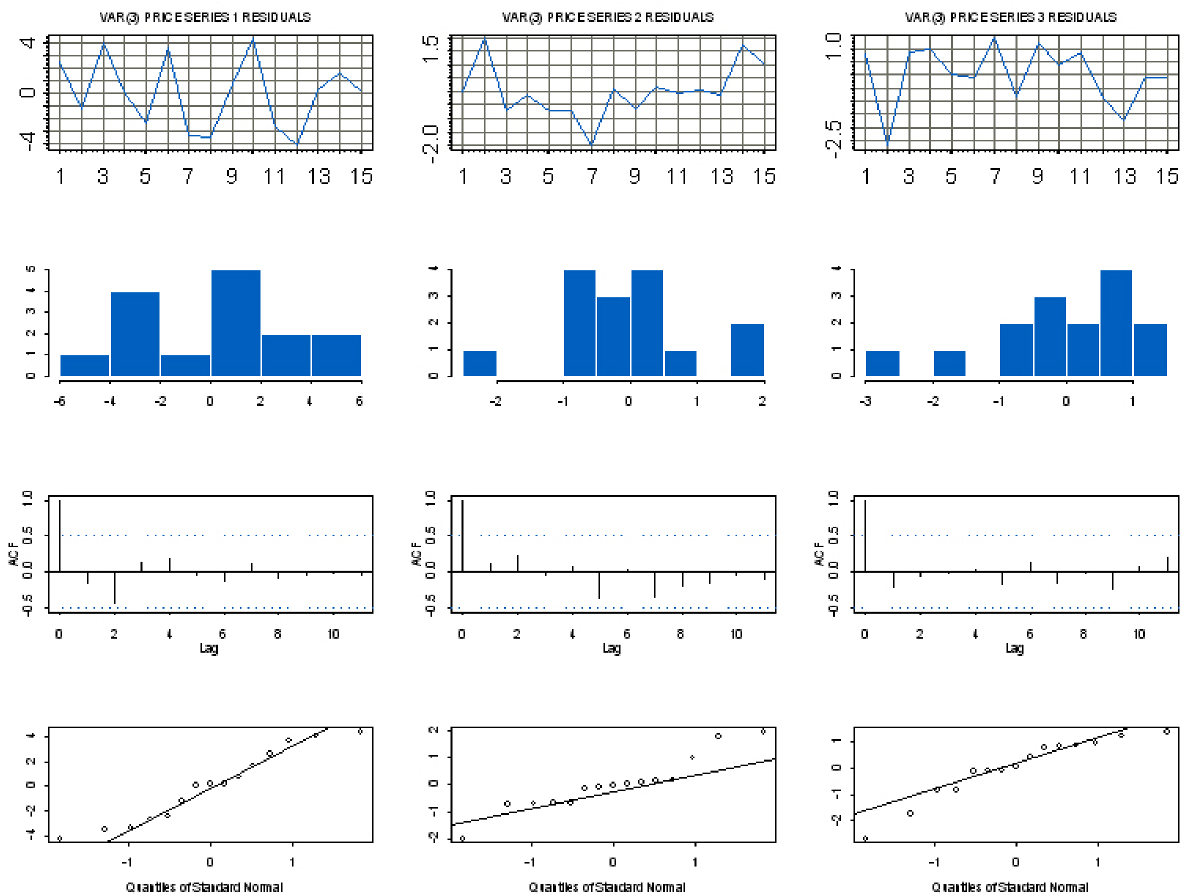
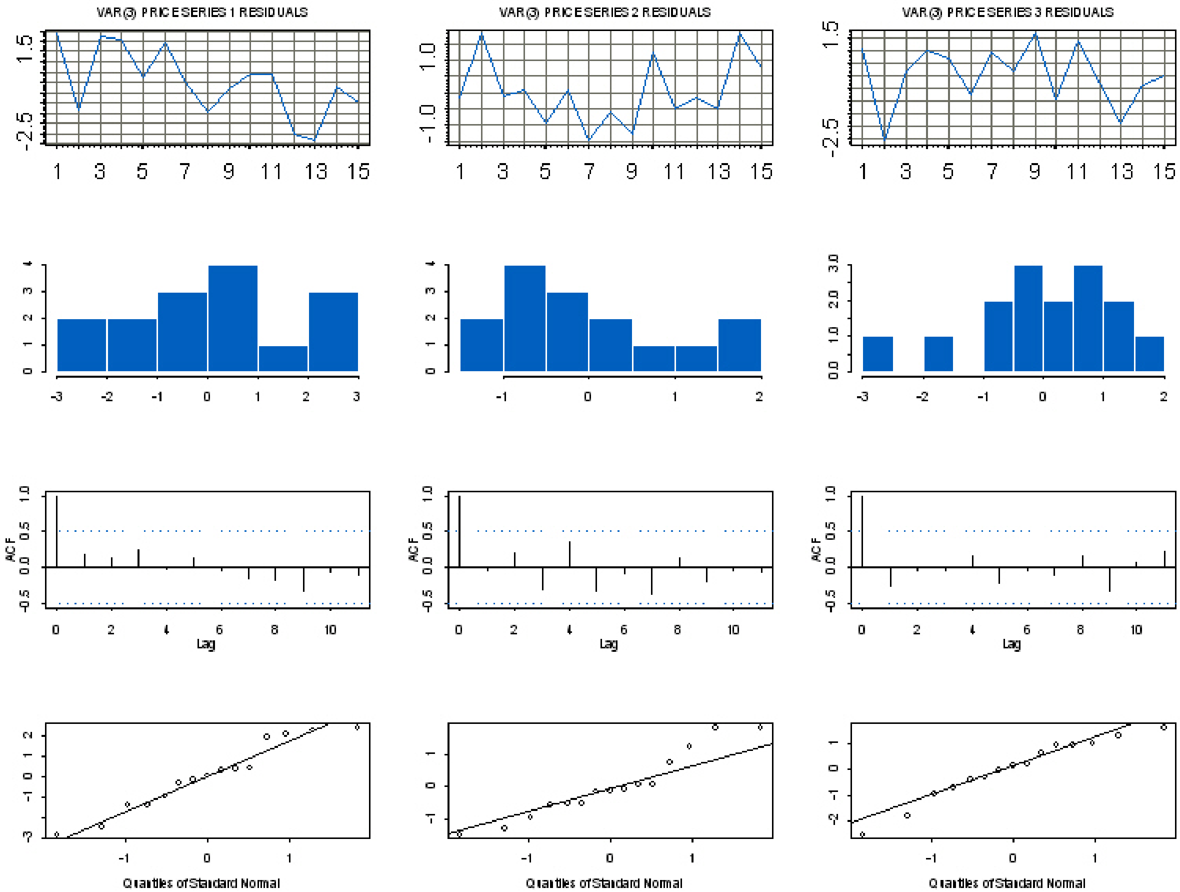


Fig. 5c: Snow crab VAR(3) model residual time series (upper row plots), residual histograms (upper-middle row plots), autocorrelation functions (lower-middle row plots), and normal quantile-quantile plots (lower row plots) for three price series based on COAR wholesale values for king crab (series 1, left-column plots), COAR wholesale values for snow crab (series 2, middle-column plot), and TPIS king crab imports (series 3, right-column plots). The regression runs through 2008. All values are standardized.



Tab. 1a: Regression results produced by the S+finmetrics software for the gold king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

Coefficients:

	x1	x2	x3
(Intercept)	17.2555	4.3915	14.5803
(std.err)	7.2167	5.6676	6.8481
(t.stat)	2.3910	0.7748	2.1291
x1.lag1	-0.3846	-0.2259	0.1332
(std.err)	0.5958	0.4679	0.5654
(t.stat)	-0.6456	-0.4828	0.2356
x2.lag1	-0.0953	0.2775	-0.1098
(std.err)	0.6520	0.5120	0.6187
(t.stat)	-0.1461	0.5421	-0.1775
x3.lag1	0.8544	0.6704	0.5765
(std.err)	0.6984	0.5485	0.6627
(t.stat)	1.2234	1.2223	0.8699
x1.lag2	0.2088	-0.4387	0.2104
(std.err)	0.6288	0.4939	0.5967
(t.stat)	0.3321	-0.8884	0.3525
x2.lag2	-0.0277	-0.2205	-0.0155
(std.err)	0.5165	0.4056	0.4901
(t.stat)	-0.0536	-0.5436	-0.0316
x3.lag2	-0.0679	0.4256	-0.4713
(std.err)	0.7564	0.5940	0.7178
(t.stat)	-0.0898	0.7164	-0.6566
x1.lag3	0.3014	-0.2087	0.4156
(std.err)	0.5397	0.4239	0.5122
(t.stat)	0.5584	-0.4923	0.8114
x2.lag3	-0.6685	-0.2233	-0.4990
(std.err)	0.4790	0.3762	0.4545
(t.stat)	-1.3957	-0.5936	-1.0979
x3.lag3	-0.5942	0.1700	-0.4642
(std.err)	0.5999	0.4711	0.5692
(t.stat)	-0.9906	0.3609	-0.8155

Regression Diagnostics:

	x1	x2	x3
R-squared	0.7755	0.7949	0.7485
Adj. R-squared	0.3715	0.4257	0.2957
Resid. Scale	2.4271	1.9061	2.3031

Information Criteria:

logL	AIC	BIC	HQ
-65.6903	191.3807	212.6222	191.1544

	total	residual
Degree of freedom:	15	5

Time period: from 1994 to 2008

Tab. 1b: Regression results produced by the S+finmetrics software for the red king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for red king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

Coefficients:

	x1	x2	x3
(Intercept)	14.9706	3.7253	13.4841
(std.err)	14.6684	5.1382	5.8459
(t.stat)	1.0206	0.7250	2.3066
x1.lag1	-0.2657	0.2032	-0.2456
(std.err)	0.3920	0.1373	0.1562
(t.stat)	-0.6777	1.4796	-1.5724
x2.lag1	-0.2530	-0.1804	0.4548
(std.err)	1.4715	0.5154	0.5864
(t.stat)	-0.1719	-0.3500	0.7756
x3.lag1	0.8978	0.0640	1.2262
(std.err)	1.0821	0.3790	0.4313
(t.stat)	0.8297	0.1687	2.8433
x1.lag2	0.3138	0.0828	-0.1294
(std.err)	0.3531	0.1237	0.1407
(t.stat)	0.8885	0.6694	-0.9192
x2.lag2	-1.6299	-0.4287	-0.0738
(std.err)	1.0094	0.3536	0.4023
(t.stat)	-1.6146	-1.2124	-0.1833
x3.lag2	0.1153	0.4257	-0.7257
(std.err)	1.4111	0.4943	0.5624
(t.stat)	0.0817	0.8611	-1.2904
x1.lag3	0.7401	0.0325	0.1436
(std.err)	0.3458	0.1211	0.1378
(t.stat)	2.1403	0.2680	1.0423
x2.lag3	-1.2820	-0.2468	-0.4296
(std.err)	0.9542	0.3342	0.3803
(t.stat)	-1.3435	-0.7385	-1.1298
x3.lag3	0.0638	-0.1245	-0.0252
(std.err)	0.7740	0.2711	0.3085
(t.stat)	0.0824	-0.4591	-0.0817

Regression Diagnostics:

	x1	x2	x3
R-squared	0.7679	0.8417	0.8278
Adj. R-squared	0.3501	0.5566	0.5179
Resid. Scale	4.7812	1.6748	1.9055

Information Criteria:

logL	AIC	BIC	HQ
-75.4166	210.8331	232.0746	210.6069

	total	residual
Degree of freedom:	15	5

Time period: from 1994 to 2008

Tab. 1c: Regression results produced by the S+finmetrics software for the snow crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

Coefficients:

	x1	x2	x3
(Intercept)	25.7589	0.5604	16.2161
(std.err)	9.2731	5.6733	6.6265
(t.stat)	2.7778	0.0988	2.4472
x1.lag1	-1.2913	0.3923	-0.4306
(std.err)	0.4591	0.2809	0.3280
(t.stat)	-2.8129	1.3969	-1.3127
x2.lag1	0.1824	-0.0361	0.2547
(std.err)	0.7522	0.4602	0.5375
(t.stat)	0.2425	-0.0785	0.4739
x3.lag1	1.9130	-0.0644	1.3982
(std.err)	0.7753	0.4743	0.5540
(t.stat)	2.4675	-0.1358	2.5238
x1.lag2	-0.8875	0.3663	-0.4545
(std.err)	0.4590	0.2808	0.3280
(t.stat)	-1.9335	1.3043	-1.3857
x2.lag2	-0.3873	-0.4518	0.0031
(std.err)	0.5485	0.3356	0.3919
(t.stat)	-0.7060	-1.3465	0.0080
x3.lag2	0.5127	0.0914	-0.3982
(std.err)	0.7910	0.4839	0.5652
(t.stat)	0.6482	0.1888	-0.7045
x1.lag3	-0.0347	0.2637	-0.0389
(std.err)	0.3568	0.2183	0.2550
(t.stat)	-0.0972	1.2078	-0.1527
x2.lag3	-0.9666	-0.1250	-0.4620
(std.err)	0.5629	0.3444	0.4022
(t.stat)	-1.7172	-0.3629	-1.1486
x3.lag3	0.6287	-0.4282	0.2260
(std.err)	0.6132	0.3752	0.4382
(t.stat)	1.0252	-1.1413	0.5156

Regression Diagnostics:

	x1	x2	x3
R-squared	0.8307	0.8391	0.8156
Adj. R-squared	0.5260	0.5494	0.4836
Resid. Scale	2.7597	1.6884	1.9720

Information Criteria:

logL	AIC	BIC	HQ
-65.4744	190.9488	212.1903	190.7225

	total	residual
Degree of freedom:	15	5

Time period: from 1994 to 2008

Tab. 2: Unit root test results produced by the S+finmetrics software for the COAR all king crab wholesale price series, COAR snow crab wholesale price series, TPIS king crab import price series, COAR gold king crab wholesale price series, and COAR red king crab wholesale price series. The two tests are the Augmented Dickey-Fuller (ADF) with unit root null, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) with stationary (around a constant) null. For the KPSS test, the software only indicates significance at the 1% and 5% levels. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

TEST	COAR All King	COAR Snow	TPIS King Imports	COAR Gold king	COAR Red king
ADF	-1.574	-3.388	-2.524	-2.133	-1.611
P	0.470	0.029	0.130	0.236	0.453
KPSS	0.214	0.063	0.149	0.226	0.320
P	>0.05	>0.05	>0.05	>0.05	>0.05

Tab. 3a: Autocorrelation and Normality test results produced by the S+finmetrics software for the gold king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are Ljung-Box under the null of no autocorrelation in the residuals (LB1), Ljung-Box with squared residuals (LB2), and Shapiro-Wilk (SW) with the null of normally distributed residuals. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994. The null of no autocorrelation in the squared-residuals for gold king crab is rejected at the 5%-significance level, which indicates possible ARCH effects, though the failure of the SW test to reject the null of normality in this case does not indicate that ARCH effects are present.

	x1	x2	x3
LB1	0.300	0.016	0.152
P	0.584	0.900	0.697
LB2	4.646	0.622	0.608
P	0.031	0.430	0.436
SW	0.962	0.916	0.906
P	0.689	0.171	0.120

Tab. 3b: Autocorrelation and Normality test results produced by the S+finmetrics software for the red king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for red king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are Ljung-Box under the null of no autocorrelation in the residuals (LB1), Ljung-Box with squared residuals (LB2), and Shapiro-Wilk with the null of normally distributed residuals. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

	x1	x2	x3
LB1	0.416	0.278	0.907
P	0.519	0.598	0.341
LB2	1.519	0.676	0.384
P	0.218	0.411	0.535
SW	0.943	0.916	0.911
P	0.407	0.166	0.140

Tab. 3c: Autocorrelation and Normality test results produced by the S+finmetrics software for king crab and snow crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are Ljung-Box under the null of no autocorrelation in the residuals (LB1), Ljung-Box with squared residuals (LB2), and Shapiro-Wilk with the null of normally distributed residuals. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1994.

	x1	x2	x3
LB1	0.541	0.047	1.185
P	0.462	0.828	0.276
LB2	0.094	2.473	1.403
P	0.76	0.116	0.236
SW	0.944	0.929	0.952
P	0.427	0.260	0.528

Tab. 4a: Trivariate Granger Causality test results produced by the S+finmetrics software for the gold king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for gold king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are based on setting coefficients for all lags to zero for each variable in the equations for the other two variables. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1993.

	x1	x2	x3
WALD	1.672	4.196	5.987
P	0.947	0.650	0.425

Tab. 4b: Trivariate Granger Causality test results produced by the S+finmetrics software for the red king crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for red king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are based on setting coefficients for all lags to zero for each variable in the equations for the other two variables. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1993.

	x1	x2	x3
WALD	5.653	15.479	4.832
P	0.463	0.017	0.566

Tab. 4c: Trivariate Granger Causality test results produced by the S+finmetrics software for the snow crab VAR(3) and data 1991-2008 with three price series based on COAR wholesale values for king crab (x1), COAR wholesale values for snow crab (x2), and TPIS king crab imports (x3). The three tests are based on setting coefficients for all lags to zero for each variable in the equations for the other two variables. The regression runs through 2008 and 1991-1993 data are used as lags, so the time series actually used for estimation starts in 1993.

	x1	x2	x3
WALD	5.314	12.976	14.303
P	0.504	0.043	0.026

Tab. 5: Forecasts and standard errors (s.e.) for 2009-2038 for the gold king crab, red king crab, and snow crab whole price indices based on the respective VAR(3) models with data 1991-2008. The regression runs through 2008 with 30-step 90%-forecasts for 2009-2038. All values are in real 2005 dollars per kilogram.

Year	GOLD	s.e.	RED	s.e.	SNOW	s.e.
2009	17.46	2.43	19.19	4.78	7.595	1.688
2010	17.12	2.96	22.95	5.25	10.204	1.977
2011	16.69	3.23	25.82	6.26	11.308	2.729
2012	14.53	3.39	23.33	6.37	10.601	3.017
2013	13.61	3.64	19.42	6.94	9.082	3.068
2014	13.52	3.83	16.75	7.41	7.317	3.224
2015	14.45	3.96	16.82	7.49	6.306	3.472
2016	15.61	4.02	19.38	7.50	7.191	3.558
2017	16.12	4.14	21.71	7.67	9.016	3.596
2018	15.88	4.24	23.49	7.78	10.310	3.721
2019	15.14	4.27	24.20	7.87	10.791	3.821
2020	14.49	4.31	22.80	7.89	10.112	3.851
2021	14.32	4.36	20.41	7.98	8.600	3.865
2022	14.61	4.39	18.26	8.10	7.428	3.940
2023	15.10	4.40	17.62	8.19	7.118	4.013
2024	15.43	4.42	19.08	8.20	7.693	4.037
2025	15.46	4.44	21.34	8.25	8.932	4.046
2026	15.21	4.44	23.14	8.33	10.043	4.100
2027	14.91	4.45	23.64	8.39	10.336	4.165
2028	14.74	4.46	22.53	8.40	9.763	4.185
2029	14.79	4.46	20.60	8.43	8.668	4.193
2030	14.97	4.47	18.91	8.49	7.677	4.236
2031	15.15	4.47	18.33	8.54	7.409	4.287
2032	15.22	4.47	19.26	8.56	7.971	4.303
2033	15.16	4.47	21.02	8.58	8.968	4.310
2034	15.03	4.47	22.59	8.62	9.824	4.344
2035	14.93	4.47	23.14	8.67	10.045	4.383
2036	14.91	4.48	22.36	8.68	9.524	4.394
2037	14.97	4.48	20.79	8.69	8.619	4.400
2038	15.05	4.48	19.37	8.73	7.874	4.428

REFERENCE

Zivot, E., and J. Wang (2003). Modeling Financial Time Series with S-Plus. Springer-Verlag: New York.

APPENDIX 4: CORRESPONDANCE FROM NPFMC AND STATE OF ALASKA REGARDING THE COUNCIL'S JUNE 2010 PRELIMINARY PREFERRED ALTERNATIVE

Finding of No Significant Impact for Amendments 38 and 39 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs

National Marine Fisheries Service

One of the purposes of an environmental assessment is to provide the evidence and analysis necessary to decide whether an agency must prepare an environmental impact statement (EIS). The Finding of No Significant Impact (FONSI) is the decision maker's determination that the action will not result in significant impacts to the human environment, and therefore, further analysis in an EIS is not needed. The Council on Environmental Quality regulations at 40 CFR 1508.27 state that the significance of an action should be analyzed both in terms of "context" and "intensity." An action must be evaluated at different spatial scales and settings to determine the context of the action. Intensity is evaluated with respect to the nature of impacts and the resources or environmental components affected by the action. NOAA Administrative Order (NAO) 216-6 provides guidance on the National Environmental Policy Act (NEPA) specifically to line agencies within NOAA. It specifies the definition of significance in the fishery management context by listing criteria that should be used to test the significance of fishery management actions (NAO 216-6 §§ 6.01 and 6.02). These factors form the basis of the analysis presented in the environmental assessments (EAs) for this action. The results of these analyses are summarized here for those criteria.

Context: For this action, the setting is the Bering Sea and Aleutian Islands. Any effects of this action are limited to this area. The effects of this action on society within this area are on individuals directly and indirectly participating in the Federal Alaska crab fisheries and on those who use the ocean resources. Because this action concerns the use of a present and future resource, this action may have impacts on society as a whole or regionally.

Intensity: Considerations to determine intensity of the impacts are set forth in 40 CFR 1508.27(b) and in the NAO 216-6, section 6. Each consideration is addressed below in order as it appears in the NMFS Instruction 30-124-1 dated July 22, 2005, Guidelines for Preparation of a FONSI. The sections of the EA or the *Bering Sea Aleutian Islands Crab Fisheries Environmental Impact Statement* (Crab EIS)[a] that address the considerations are identified.

1) Can the proposed action reasonably be expected to jeopardize the sustainability of any target species that may be affected by the action?

Response: No. The proposed action amends the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP) to establish annual catch limits and accountability measures in compliance with the Magnuson-Stevens Fishery Conservation and Management Ac,t and revise the definition of rebuilt in the snow crab rebuilding plan. Amendments 38 and 39 provide added protection against overfishing and will not jeopardize the sustainability of any target species that may be affected by the action, as analyzed in chapters 4 through 13 of the EA.

[a] http://www.alaskafisheries.noaa.gov/sustainablefisheries/crab/eis/default.htm

2) Can the proposed action reasonably be expected to jeopardize the sustainability of any non-target species?

Response: No. Non-target species will not be impacted by annual catch limits and accountability measures for crab stocks under the FMP. Impacts of the crab fisheries on the sustainability of any non-target species are discussed in section 4.3 of the Crab EIS. The Crab EIS concludes that the crab fisheries have an insignificant effect on the sustainability of any non-target species. The proposed actions will not change the way the fisheries impact the sustainability of any non-target species under the Crab Rationalization Program and, therefore, the proposed actions will have an insignificant effect on these species.

3) Can the proposed action reasonably be expected to cause substantial damage to the ocean and coastal habitats and/or essential fish habitat as defined under the Magnuson-Stevens Act and identified in FMPs?

Response: No. Habitat and essential fish habitat will not be impacted by Amendments 38 and 39. Impacts of the crab fisheries on habitat, including the EFH assessment, are discussed in section 4.4 of the Crab EIS. The Crab EIS concludes that the crab fisheries have an insignificant effect on EFH. The proposed actions will not change the way the fisheries impact EFH and, therefore, the proposed action will have an insignificant effect on EFH.

4) Can the proposed action be reasonably expected to have a substantial adverse impact on public health or safety?

Response: No. Public health or safety will not be impacted by Amendments 38 or 39. Impacts of the crab fisheries on safety are discussed in section 4.6.9 of the Crab EIS. The Crab EIS concludes that the crab fisheries have an insignificant effect on safety. The proposed action will not change the way the fisheries impact safety under the Crab Rationalization Program and, therefore, the proposed action will have an insignificant effect on safety.

5) Can the proposed action reasonably be expected to adversely affect endangered or threatened species, marine mammals, or critical habitat of these species?

Response: No. Endangered or threatened species will not be impacted by Amendments 38 or 39. Impacts of the crab fisheries on endangered or threatened species, marine mammals, or critical habitat of these species, are discussed in section 4.3 of the Crab EIS. The Crab EIS concludes that the crab fisheries have an insignificant effect on endangered or threatened species, marine mammals, or critical habitat of these species. The proposed actions will not change the way the fisheries impact endangered or threatened species, marine mammals, or critical habitat of these species under the Crab Rationalization Program and, therefore, the proposed actions will have an insignificant effect on these species.

6) Can the proposed action be expected to have a substantial impact on biodiversity and/or ecosystem function within the affected area (e.g., benthic productivity, predator-prey relationships, etc.)?

Response: No. Biodiversity or ecosystem function will not be impacted by Amendments 38 or 39. The proposed actions will have an insignificant impact on biodiversity and ecosystem function. Impacts of the crab fisheries on biodiversity and ecosystem function are discussed in section 4.5 of the Crab EIS. The Crab EIS concludes that the crab fisheries have an insignificant effect on biodiversity and ecosystem function. The proposed actions will not change the way the fisheries impact biodiversity and ecosystem function under the Crab Rationalization Program and therefore, the proposed actions will have an insignificant effect on biodiversity and ecosystem function.

7) Are significant social or economic impacts interrelated with natural or physical environmental effects?

Response: No social or economic impacts are interrelated with significant natural or physical environmental effects, as discussed in chapters 4 through 13 of the EA.

8) Are the effects on the quality of the human environment likely to be highly controversial?

Response: The effects of these actions on the quality of the human environment are insignificant and not controversial, as discussed in the EA. No members of the public identified any controversial aspects of the predicted effects of the quality of the human environment. Development of these actions was a consensus process with the State of Alaska.

9) Can the proposed action reasonably be expected to result in substantial impacts to unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers or ecologically critical areas?

Response: No. Because the crab fisheries take place in offshore waters of the BSAI, these actions will not impact unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers or ecologically critical areas.

10) Are the effects on the human environment likely to be highly uncertain or involve unique or unknown risks?

Response: No. As discussed in chapter 2 of the EA, the annual catch limits and accountability measures were developed to incorporate new scientific information and to account for uncertainty in the overfishing limit in order to prevent overfishing. Chapter 3 contains the methodology used to create the annual catch limits and to analyze their impacts on crab stocks, the only component of the human environment impacted.

11) Is the proposed action related to other actions with individually insignificant, but cumulatively significant impacts?

Response: No past, present, or reasonably foreseeable future actions were identified that would combine with the effects of these action to result in cumulatively significant impacts (EA chapter 15).

12) Is the proposed action likely to adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural or historical resources?

Response: No. These actions will have no impacts on districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places and will not cause loss or destruction of significant scientific, cultural, or historical resources.

13) Can the proposed action reasonably be expected to result in the introduction or spread of a nonindigenous species?

Response: No. These actions will not affect the introduction or spread of non-indigenous species, because they do not change fishing practices that may introduce such organisms into the marine environment.

14) Is the proposed action likely to establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration?

Response: No. These actions will not establish a precedent for future actions.

15) Can the proposed action reasonably be expected to threaten a violation of Federal, State, or local law or requirements imposed for the protection of the environment?

Response: No. These actions pose no known risk of violation of federal, state, or local laws or requirements for the protection of the environment.

16) Can the proposed action reasonably be expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species?

Response: No. Chapter 15 of the EA analyzes the cumulative effects of the proposed actions. No past, present, or reasonably foreseeable future actions were identified that would combine with the effects of these actions to result in cumulatively significant impacts.

DETERMINATION

In view of the information presented in this document and the analysis contained in the supporting Environmental Assessment prepared for Amendments 38 and 39, I have determined that the proposed actions will not significantly impact the quality of the human environment as described above and in the supporting Environmental Assessment. In addition, all beneficial and adverse impacts of the proposed actions have been addressed to reach the conclusion of no significant impacts. Accordingly, preparation of an EIS for these actions is not necessary.

for Robert D. Mecum 2/22/11

James W. Balsiger, Ph.D. Date
Administrator, Alaska Region