ENVIRONMENTAL ASSESSMENT

FOR

AMENDMENT 1 TO THE FISHERY MANAGEMENT PLAN FOR THE COMMERCIAL KING AND TANNER CRAB FISHERIES IN THE BERING SEA/ALEUTIAN ISLANDS

Submitted by the
North Pacific Fishery Management Council

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Table of Contents

1.0 INTRODUCTION

1.1 Description of the problem and statement of action

The Magnuson Fishery Conservation and Management Act (MFCMA) contains seven "national standards" (see appendix B of Fishery Management Plan for the Commercial King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands (crab FMP)) with which all fishery management plans (FMP) and implementing regulations must be consistent. The first national standard states "conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."

The MFCMA places a high priority on preventing overfishing. However, the MFCMA does not define overfishing. In revised guidelines based on national standards and established by the National Oceanic and Atmospheric Administration (NOAA) to assist in the development and review of FMPs, (50 CFR Part 602) NOAA presented the following general definition "overfishing is a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY (maximum sustainable yield) on a continuing basis." The 602 guidelines make a distinction between the prevention of overfishing and the achievement of optimum yield. Therefore, the task of specifying an overfishing definition should not be confused with an attempt to articulate an optimal harvest strategy. The overfishing definition is to be used as a constraint and not a target.

The Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council (Council) has recommended a more conventional definition of overfishing as "fishing so hard that average long-term yield is reduced." The SSC believes this definition is consistent with the 602 guidelines and the Council's demonstrated preference for avoiding resource depletion. This definition is more conservative than a definition based on stock collapse.

Because of the generality of its overfishing description, NOAA believed it would be difficult to apply unambiguously. Therefore, the 602 guidelines include the following directive: "Each FMP must specify, to the maximum extent possible, an objective and measurable definition of overfishing for each stock or stock complex covered by that FMP, and provide an analysis of how the definition was determined and how it relates to reproductive potential." The objective and measurable definition is not intended to take the place of the general description, but is to constitute a specific method of implementing the general description. Whereas the general description is qualitative, the implementing definitions are quantitative.

The crab FMP was written as a cooperative State-Federal FMP in an attempt to avoid State-Federal coordination problems that were encountered in previous king and Tanner crab FMP's. It contains a general management goal to maximize the overall long-term benefit to the nation of Bering Sea/Aleutian Island stocks of king and Tanner crabs by coordinated Federal and state management, consistent with responsible stewardship for conservation of the crab resources and their habitats. Within the scope of this management goal, there are seven specific objectives. These objectives relate to stock condition, economic and social objectives of the fishery, gear conflicts, habitat, weather and ocean conditions affecting safe access to the fishery, access of all interested parties to the process of revising the crab FMP, and necessary research and management. However, the crab FMP contains only the following qualitative definition of overfishing: "Recruitment overfishing is the condition that occurs when the spawning stock is reduced by fishing to too low a level to ensure adequate production of young crabs--the recruits to the future fishery." Since the crab FMP contains no objective or measurable criteria for implementing a definition, the crab FMP must be amended. The deadline for submission of the crab FMP amendment is November 23, 1990.

1.2 Current stock conditions

The stocks of king crab and Chionoecetes bairdi Tanner crab in the Bering Sea/Aleutian Islands area have been low. Overfishing, however, does not appear to have been the cause. Both male and female king crab and C. bairdi Tanner crab have declined in parallel even though the fisheries only harvest male crab. An alternative explanation is that handling incurred during fishing may influence survival in females to the same degree that the fishery affects males. Abundance of C. bairdi has increased from 1988 to 1989. Chionoecetes opilio Tanner crab have not been low in abundance; in fact, the 1989 estimate of abundance is in excess of 9,500 million crab.

Available information indicates that recruitment to the adult segments of the king and Tanner crab populations can vary naturally by three orders of magnitude, and typically varies by one or two orders of magnitude on an inter-annual basis. This variability most likely comes from fluctuations in survival. The abundance of known predators and the apparent incidence of diseases have been higher during the 1980's than during the 1970's.

Directed commercial crab fisheries in the Bering Sea/Aleutian Islands area are regulated by restrictions on size, sex, fishing season, guideline harvest level (quota), and area fished. These restrictions, in combination, form a conservative biological management regime. Incidental catch of non-target species of crab in crab fisheries is regulated by the State of Alaska (State) emergency order authority.

Incidental catch of crab in non-directed fisheries is stringently controlled through time and area closures (including permanent closures) and quotas specified in Amendment 12a of the Bering Sea/Aleutian Islands area Groundfish Fisheries Management Plan. Bottom trawl fisheries are responsible in part for incidental catch of king and Tanner crab in the Bering Sea. These fisheries include Joint Venture and Domestic Annual Production of flatfish and other fisheries. Estimates of the joint venture bycatch rates of C. bairdi Tanner crab and red king crab in the Bering Sea (see Tables 2.1, 2.2, 2.5, and 2.6 in Chapter 2 of the May 16, 1990 EA/RIR for amendment 21 and 16 for the groundfish FMP) indicate 0.01 and 0.39 percent, respectively, of the population were caught incidentally in 1989. For comparison, the 1989 directed commercial harvest of C. bairdi Tanner crab in the Bering Sea was 0.31 percent of the population. Directed commercial harvest of red king crab in the 1989 Bering sea fishery was 3.3 percent of the population.

Three other types of fisheries occur on the crab stocks in the Bering Sea/Aleutian Islands management area besides commercial fisheries: subsistence, sport, and personal use fisheries. Should any crab stock decline below threshold, the State's emergency order authority will be used to insure conservation of the resource and meet the requirements of these fisheries as specified by law.

1.3 Alternatives

The crab FMP team met in Kodiak on May 7 and 8, 1990, and discussed possible options for a quantitative overfishing definition for the king and Tanner crab stocks managed by the crab FMP. On June 26, 1990, the SSC reviewed the crab FMP team's first draft EA and later on August 6, 1990, a subcommittee of the SSC reviewed a revised draft. On August 8, 1990, the SSC recommended that the Council ask for public comments on the draft EA for amendment 1 to the FMP for the commercial king and Tanner crab fisheries in the Bering Sea/Aleutian Islands, During the September 24 - 29, 1990, Council meeting the SSC, the Advisory Panel (AP) and the Council reviewed the draft EA for amendment 1. The SSC recommended alternative 3 as the preferred alternative and the AP concurred. The Council reviewed the recommendations of the SSC, AP, and public and selected alternative 3 as the preferred alternative definition of overfishing.

The consensus of the crab FMP team members was that under the current cooperative State-Federal management system overfishing should not occur. However, it is possible that crab stocks could reach a threshold level due to natural fluctuations. The threshold concept is pertinent to management in this event, since harvest at subthreshold levels may retard stock recovery. The crab FMP team therefore felt that it was necessary to establish threshold levels and maximum allowable fishing mortality rates for the crab stocks. The crab FMP team preferred alternative 2.

Fishing mortality (F) is defined as the total fishing mortality from directed (pot) and non-directed (trawl and pot) fisheries. Alternative fishing mortality definitions of crab overfishing are determined in terms of F on mature crab or F on legal crab. However, trawl fisheries tend to catch smaller crabs than pot fisheries (see Figures 2.4, 2.5, 2.6 and 2.7 in Chapter 2 of the May 16, 1990, EA/RIR for amendment 21 and 16 for the groundfish FMP) so adjustment would be necessary to convert small trawl-caught crab into mature or legal equivalents. No adjustment would be made to mature or legal crab caught in trawls. Non-directed fishing mortality would be added to directed catch to estimate the total fishing mortality. Total fishing mortality would be used in determinations of overfishing.

In the event a stock reached threshold level, or the rate of fishing mortality exceeded that defined as overfishing, or allocation of fishing mortality to commercial user groups was necessary, the Council may request a risk analysis be performed to determine whether or not the multispecies exemption clause (section 602.11(c)(8)) should be invoked.

As previously noted, the amount of information available for alternative definitions of overfishing is variable. Each of the alternatives presented here are divided into separate approaches to establish the same definition based on the type of data available. The crab FMP team will monitor and reassess the data available for determining overfishing for the Bering Sea/Aleutian Islands area crab stocks through preparation of the Stock Assessment and Fishery Evaluation (SAFE) report or annual report as required by the FMP. New information may change the definition of overfishing for a stock.

Four alternative means of defining overfishing are examined. Specifically, the following alternatives are considered:

1.3.1 Alternative 1: Status quo

Recruitment overfishing is the condition that occurs when the spawning stock is reduced by fishing to too low a level to ensure adequate production of young crabs--the recruits to the future fishery.

1.3.2 Alternative 2: Constant fishing mortality rate with threshold.

Overfishing is defined for each crab stock in the Bering Sea/Aleutian Islands, for which sufficient data exist, as the level of commercial harvest resulting in an F value exceeding F_{msy} in any year when stock size is above threshold or any level of commercial harvest when the stock is at or below threshold.

Three information levels were characterized for Alternative 2 definition of overfishing according to the data available to quantify threshold and fishing mortality rate. Each of the 17 stocks in the Bering Sea Aleutian Islands management area is assigned to one of the levels (Table 1).

1) Data available: Historical catch, sporadic inseason catch and effort data, and mortality. Overfishing for stocks with level 1 data is defined as a fishing mortality rate exceeding the natural mortality rate of mature male crab. Threshold cannot be defined with level 1 data because the discontinuous time series of fishery data precludes estimation of population abundance. For years in which sufficient catch and effort data are available, inseason fishing mortality rate may be based on a change in the inseason ratio of catch per unit effort (CPUE) of legal to mature male crab or a proportionate reduction in average weekly CPUE.

2) Data available: Historical catch, continuous inseason catch and effort data, and mortality. Overfishing for stocks with level 2 data is defined as fishing in excess of the maximum allowable fishing mortality rate estimated to equal the natural mortality rate of mature male crab or any commercial harvest when the stock is at or below threshold where the threshold is equal to 10 percent of the long-term average catch (MSY) estimate (see Table 6 of the crab FMP). Inseason fishing mortality rate may be based on inseason CPUE and cumulative catch of legal male crab.

3) Data available: Historical catch, continuous inseason catch and effort data, stock assessment, stock-recruitment, growth, maturity, and mortality parameters. Overfishing for stocks with level 3 data is defined as fishing in excess of the maximum allowable fishing mortality rate estimated as F_{msy} which is approximated by $F_{0.1}$, based on the size of first maturity for male crabs or any commercial

harvest when the stock is at or below threshold where threshold is equal to 20 percent of the pristine exploitable biomass defined as the best estimate of the equilibrium level of spawning stock. Guideline harvest levels are estimated annually for level 3 stocks, therefore the fishing mortality rate is established prior to a fishery.

1.3.3 Alternative 3: Constant fishing mortality rate (adopted as preferred alternative by the North Pacific Fisheries Management Council).
Overfishing is defined as any rate of fishing mortality in excess of F_{msy} for king and Tanner crab stocks in the Bering Sea/Aleutian Islands management area.

Three information levels were characterized for Alternative 3 definition of overfishing according to the data available to quantify maximum fishing mortality rate. Each of the 17 stocks in the Bering Sea Aleutian Islands management area is assigned to one of the levels (Table 1).

1) Data available: Historical catch, sporadic inseason catch and effort data, and mortality. Overfishing for stocks with level 1 data is defined as a fishing mortality rate in excess of F_{msy} where the maximum allowable fishing mortality rate is estimated to equal the natural mortality rate of mature male crab. Inseason fishing mortality rate may be based on a change in the inseason ratio of CPUE of legal to mature male crab or a proportionate reduction in average weekly CPUE.

2) Data available: Historical catch, continuous inseason catch and effort data, and mortality. Overfishing for stocks with level 2 data is defined as a fishing mortality rate in excess of F_{msy} where the maximum allowable fishing mortality rate is estimated to equal the natural mortality rate of mature male crab. Inseason fishing mortality rate may be based on inseason CPUE and cumulative catch of legal male crab.

3) Data available: Historical catch, continuous inseason catch and effort data, stock assessment, stock-recruitment, growth, maturity, and mortality parameters. Overfishing for stocks with level 3 data is defined as a fishing mortality rate in excess of F_{msy} where the maximum allowable fishing mortality rate for these stocks cannot exceed F_{msy} estimated as $F_{0.1}$, based on the size of first maturity for male crabs. Guideline harvest levels are estimated annually for level 3 stocks, therefore the fishing mortality rate is established prior to a fishery.

1.3.4 Alternative 4: Variable fishing mortality rate.

Overfishing is defined for each crab stock in the Bering Sea/Aleutian Islands area, for which sufficient data exist, as any rate of fishing mortality in excess of a specified maximum level where the maximum level would vary with stock size.

Three information levels were characterized for Alternative 4 definition of overfishing according to the data available to quantify a variable maximum fishing mortality rate. Information level 3 is further divided into an option (a) and (b). Each of the 17 stocks in the Bering Sea Aleutian Islands management area is assigned to one of the levels (Table 1).

1) Data available: Historical catch, sporadic inseason catch and effort data.

Default to Alternative 3, level 1.
2) Data available: Historical catch, continuous inseason catch and effort data, and mortality. Default to Alternative 3, level 2.

3 a) Data available: Historical catch, continuous inseason catch and effort data, stock assessment, stock-recruitment, growth, maturity, and mortality parameters. Overfishing for the one stock (Bristol Bay red king crab) with a stock-recruitment relationship is defined as a fishing mortality rate in excess of F_{msy} for all stock levels in excess of B_{msy}. The maximum allowable fishing mortality rate for the stock below B_{msy} will vary with stock level, starting from a value of zero at the origin and increasing to a value of F_{msy} at B_{msy}. The overfishing definition for all other stocks with historical catch, continuous inseason catch and effort data, stock assessment, growth, maturity, and mortality parameters would default to Alternative 3, level 3.

3 b) Data available: Historical catch, continuous inseason catch and effort data, stock assessment, stock-recruitment, growth, maturity, and mortality parameters. Overfishing is defined as a fishing mortality rate in excess of F_{msy} for all stock levels in excess of B_{msy}. The maximum allowable fishing mortality rate for the stock below B_{msy} will vary with stock level, starting from a value of zero at the origin and increasing to a value of F_{msy} at B_{msy}. The single stock-recruitment relationship developed for Bristol Bay red king crab would be extrapolated to other level 3 stocks to estimate B_{msy}.

1.4 Purpose of the document

This environmental assessment (EA) provides background information and assessments necessary for the Secretary of Commerce to determine that this proposed action is consistent with the MFCMA, and other applicable federal law, such as the National Environmental Policy Act (NEPA).

The specific purpose of an EA that is required by NOAA in compliance with NEPA is to analyze the potential impacts of proposed actions, and responsible alternatives, on the quality of the human environment. If the action is determined not to be significant, then the EA will result in a finding of no significant impact (FONSI); this EA would then be the final environmental document required by NEPA. If, however, a FONSI cannot be made, then a more detailed environmental impact statement (EIS) must be prepared.

2.0 ANALYSIS OF PROPOSED ALTERNATIVES

2.1 Introduction

Discussion and analyses are presented to evaluate the impacts that each of the proposed alternatives could have on the Bering Sea/Aleutian Islands king and Tanner crab fisheries. In all cases, evaluation of an alternative is in relation to the status quo. The best available scientific data was used for the supporting analyses, however, the crab FMP team did note that currently there are some crab stocks where insufficient information exists for calculating threshold and all stocks with one exception had insufficient data to calculate a variable fishing mortality rate. The team agreed that a comparison of current levels of exploitation to fishing mortality rates that would yield MSY supported the crab FMP team's assertion that overfishing should not occur under the current management strategy.

Analysis of each alternative is dependent on the amount of information available to define objective and measurable criteria for each king and Tanner crab stock in the Bering Sea/Aleutian Islands management area. Alternative 1 is the "status quo" requiring no objective or measurable criteria. The current FMP defines "recruitment overfishing" and provides for closure of the directed fishery when a stock is below threshold through the process of defining Acceptable Biological Catch (ABC). However, the FMP does not equate "threshold" to "overfishing", nor does it specify the criteria for threshold estimation. For Alternative 2 the minimum information requirements are estimates of natural mortality rate and $F_{0.1}$ for mature male crab to determine maximum rate of fishing mortality. To evaluate inseason fishing mortality rates estimates of fishery catch and effort are needed. In addition, Alternative 2 requires estimates of MSY to establish threshold for level 2 stocks and the equilibrium level of spawning stock to establish and extrapolate threshold for level 3 stocks. Alternative 2 also analyzes current exploitation rates in relation to MSY through the calculation of $F_{0.1}$ when estimates of population abundance, natural mortality, age and length of maturity are available for a stock. Alternative 3 requires estimates of natural mortality and $F_{0.1}$ for mature male crab to determine fishing rates at F_{msy}. To evaluate inseason fishing mortality rates estimates of fishery catch and effort are needed. Alternative 4 requires an estimate of population abundance and a stock-recruitment relationship to estimate B_{msy}.

2.2 Alternative 1: Status quo

The only definition of overfishing currently contained in the crab FMP is for recruitment overfishing. Recruitment overfishing could occur if a severely reduced stock results from fishing to too low a stock level so that not enough adult crab remain to produce sufficient offspring or recruits to the future fishery. Heavy fishing pressure could also lead to growth and ecosystem overfishing. Growth overfishing could occur if small crabs are caught before they have had a chance to put on weight. Ecosystem overfishing could occur when reduced stocks cause significant ecosystem instability or alteration. It is unknown if these overfishing mechanisms could occur singularly or in combination in crab stocks. Therefore, the overfishing definition for crab stocks should reflect the dynamics of all possible overfishing mechanisms to the extent of the best available data.

The current overfishing definition provides for closure of a directed fishery when the stock is below threshold but is qualitative and contains no objective or measurable criteria for either threshold estimation or equating threshold to overfishing. Lacking identifiable criteria, analysis of the impact of Alternative 1, the status quo, on Bering Sea/Aleutian Islands king and Tanner crab fisheries is unfeasible.

2.3 Alternative 2: Constant fishing mortality rate with threshold

Level 1:
Fishing effort on stocks with level 1 data is sporadic where the catches appear to vary with the amount of fishing effort and the continuation of other fisheries in the areas. Fisheries are currently opened and closed by state regulation based on previous season's catch estimates and inseason fishery performance. The intermittent nature of these fisheries results in biased estimates of the long-term average of the stock (MSY) and prevents calculation of threshold levels. No population estimates are made for any level 1 crab stocks so estimates of F_{msy} are unavailable. Overfishing for level 1 stocks is therefore defined as a fishing mortality rate in excess of F_{msy} where the maximum allowable fishing mortality rate for these stocks is estimated to equal the natural mortality rate of mature male crab.

Currently, stocks with level 1 data include: Bristol Bay brown king crab, Pribilof Islands brown king crab, Saint Lawrence blue king crab, Pribilof Islands red king crab, northern district brown king crab, and Adak C. bairdi Tanner crab. These stocks have only intermittent fisheries and no assessment surveys. The natural mortality rates of mature male crab in stocks with level 1 data are taken from Alverson (1980) for Bristol Bay red king crab, and from Somerton (1981) for Tanner crab. The best estimate of natural mortality rate for mature Bristol Bay brown king crab, Pribilof Islands brown king crab, Saint Lawrence blue king crab, Pribilof Islands red king crab, northern district brown king crab is equal to 0.3, the natural mortality rate for Bristol Bay red king crab. The best estimate of natural mortality rate for mature Adak C. bairdi Tanner crab is equal to 0.3, the natural mortality rate for Eastern Bering Sea C. bairdi Tanner crab. Based on the best estimates of natural mortality rate, the maximum allowable fishing mortality rate for level 1 stocks is 0.3.

Estimates of inseason fishing mortality are at best difficult to calculate for stocks with limited data on sporadic catch and effort. The use of CPUE data is problematic because sorting rates may vary with the duration of effort on an aggregation of crab and seasonal movement of effort from one aggregation to another aggregation of crab. The crab FMP team proposes three methods for determining fishing mortality rate on stocks with level 1 data. First, the Leslie method (Leslie and Davis, 1939) may be used if sufficient inseason fishery performance data (CPUE and cumulative catch) are available to estimate population abundance of legal male crab. The ratio of catch of legal male crab to the population abundance estimate of legal male crab may be used to estimate the fishing mortality rate of legal male crab. This calculated rate may then be compared with the maximum allowable fishing mortality rate to evaluate overfishing. Attempts to apply a leslie analysis to level 1 stocks have yet to produce a meaningful relationship between CPUE and cumulative catch. Second, an estimate of fishing mortality rate based on the ratio of CPUE of legal crab to CPUE of mature crab may be calculated. Data on CPUE of both legal and mature crab are available only from those fisheries with onboard observers. During a short fishery, abundance of sublegal mature crab should not change and the reduction in the legal/mature ratio could be used to estimate the fishing mortality rate. A correction for natural mortality of sublegal mature crab would be necessary for long fisheries. Third, an estimate of fishing mortality rate based on proportionate change in average weekly CPUE may be calculated. Weekly average CPUE may be compared to determine if a proportionate reduction in CPUE equal to the maximum allowable fishing mortality rate (F=M) has occurred. Data on CPUE would be available only in those fisheries with onboard observers or detailed fish ticket information. For unobserved fisheries with fish ticket data, only fishing mortality on legal male crabs can be estimated. Other methods may be employed that provide increased precision and accuracy in estimating actual fishing mortality.

Threshold cannot be defined for stocks with level 1 data because the discontinuous time series of fishery data associated with level 1 stocks prevents estimation of population abundance.

Level 2:

The crab FMP team felt protection would be provided to crab stocks with level 2 data by establishing a maximum allowable fishing mortality rate and threshold. No population estimates are made for any level 2 crab stocks therefore estimates of F_{msy} are unavailable. The maximum allowable fishing rate is therefore defined as a fishing mortality rate in excess of F_{msy} where the maximum allowable fishing mortality rate for these stocks is estimated to equal the natural mortality rate of mature male crab.

Currently, stocks with level 2 data include: Adak brown king crab, Adak red king crab, Eastern Aleutians brown king crab, and Eastern Aleutian C. bairdi Tanner crab. These stocks have directed fisheries but no assessment survey. The fisheries are open under state regulation based on the best available data. Fishing season closures are based on season date, average historical catch, closure of other fisheries or molting of non-targeted species.

The natural mortality rate of mature male crab in level 2 stocks is taken from Alverson (1980) for Bristol Bay red king crab, and from Somerton (1981) for Tanner crab. The best estimate of natural mortality rate for mature Adak brown king crab, Adak red king crab, and Eastern Aleutians brown king crab is equal to 0.3, the natural mortality rate for Bristol Bay red king crab. The best estimate of natural mortality rate for mature Eastern Aleutian C. bairdi Tanner crab is equal to 0.3, the natural mortality rate for Eastern Bering Sea C. bairdi Tanner crab. Based on the best estimates of natural mortality rate, the maximum allowable fishing mortality rate for level 2 stocks is 0.3.

The Leslie method may be used with inseason fishery performance data (CPUE and cumulative catch) to estimate population abundance of legal male crab. The ratio of catch of legal male crab to the population abundance estimate of legal male crab may be used to estimate the fishing mortality rate of legal male crab. This calculated rate may then be compared with the maximum allowable fishing mortality rate to evaluate overfishing. Other methods may be employed that provide increased precision and accuracy in estimating actual fishing mortality.

Stocks with level 2 data experience directed commercial fishing that allows computation of threshold criteria. The crab FMP team incorporated an additional conservation criterion for these stocks by defining thresholds. Commercial fisheries for Bering Sea/Aleutian Islands crab stocks have tended to be closed when the catch fell below 10 percent of the long-term average for a given stock. The crab FMP team feels that catch is indicative of stock size for those years when the fishery was not closed early by other management considerations. A review of the catch history of various fisheries that have been closed shows such a rule would be reasonably consistent with historical fishery closures (Figure 1). With the exception of Adak red king crab, all of the crab fisheries that have been closed were also surveyed so that we may compare the timing of closures under the 10 percent criterion with those proposed for stocks with level 3 data (Table 2). This comparison shows that application of the 10 percent criterion would have involved closures somewhat earlier in time than would occur under the level 3 threshold criteria. The 10 percent criterion also would have lead to earlier than actual closures of the eastern Bering Sea C. bairdi fishery and the Pribilof Islands blue king crab fisheries, however, catches in both of these fisheries hovered near 10 percent for several years before actual closure (Figure 1). For surveyed stocks the 10 percent criterion is slightly more conservative than either the level 3 threshold or actual management practice. Since, in general less is known about level 2 stocks such conservatism may be warranted. For example, there has never been an assessment survey of any brown king crab stocks.

While the 10 percent criterion provides a reasonable means of closing a fishery it provides no guidance as to when a fishery should be reopened. Also, continued fishing on a stock that is at low levels would lead to a declining threshold over time. In establishing the 10 percent criterion to set thresholds the crab FMP team proposes that fisheries be closed for a period of three years unless data from a survey or test fishery indicate that an opening is warranted. If the fishery is opened after 3 years, the leslie method will be used with inseason fishery performance data to evaluate the population level with respect to the threshold. From the catch history of fisheries that have been closed it appears loss of landings during such a three year period would be minimal. Further, the crab FMP team recommends that no run of catch statistics that is less than three years in length be used in calculating the long-term average catch from which the threshold is calculated. Years where fisheries were curtailed due to factors extrinsic to abundance such as occurrence of soft-shell crabs or bycatch problems might also be excluded. Current estimates of MSY from Table 6 of the FMP would be used to set thresholds and would be updated periodically (Table 3).

The crab FMP team believes that the 10 percent MSY threshold criterion is conservative when taken within the overall regulatory regime currently imposed on Bering Sea/Aleutian Islands crab fisheries. The 10 percent MSY criterion also leads to similar timing of fishery closures when compared to the actual history of fisheries or the proposed level 3 threshold criteria. There is some reservation, however, as to its effectiveness in rebuilding stocks that are at low levels of abundance. It appears that king crab stocks in particular may take long periods of time to recover. The Dutch Harbor red king crab fishery has been closed from 1983 to 1989 and the Adak red king crab catch has remained low from 1975 onwards. Brown king crab fisheries have been developed since 1980 and very little is known of their probable fluctuations. In this regard, the crab FMP team intends that the period of time chosen to calculate threshold values should be chosen to reflect conditions within the stock that maximize reproductive potential.

The crab FMP team will apply the Leslie method to level 2 stocks to estimate abundance and express threshold as a percentage of abundance, rather than a percentage of catch, when adequate inseason CPUE data are available.

Level 3:

The crab FMP team identified $F_{0.1}$ criteria and threshold levels that provide crab stocks with level 3 data added protection from overfishing. Level 3 data include estimates of population abundance and commercial fisheries CPUE enabling calculation of these criteria. In addition supporting analyses are presented to compare current levels of exploitation to fishing mortality rates that would yield MSY. Currently, stocks with level 3 data include: Eastern Aleutians red king crab, Bristol Bay red king crab, Pribilof Islands blue king crab, Saint Matthew blue king crab, Norton Sound red king crab, Bering Sea C. bairdi Tanner crab, and C. opilio Tanner crab. These stocks have both a directed fishery and an assessment survey.

The following analysis sets forth estimates of F_{msy} and compares them to current exploitation rates for crab stocks with level 3 data in the Bering Sea/Aleutian Islands management area. Based on the work of Clark (1990), this analysis assumes that his F_{mmy} approximates F_{msy}, and that $F_{0.1}$ is equal to or less than F_{mmy}. Crab are relatively slow growers, and in some cases recruitment may be delayed owing to overestimation of the size of maturity. Overestimation would lead to a situation where the true maturity size is less than the size of first capture used in the analysis. Values of $F_{0.1}$ have been estimated for level 3 stocks according to standard yield-per-recruit methods. Input parameters, estimates of $F_{0.1}$ and associated exploitation rates u(0.1), are given in Table 4 for Bristol Bay red king crab, and Bering Sea C. bairdi and C. opilio Tanner crab. Expected exploitation rates u(e), based on current harvest strategies are also given. It should be noted that ages of first capture are set at estimated sizes of first maturity for male crabs. Thus, exploitation biomass for the analysis is considered to be the stock of mature males. Input parameters M, k, W(inf), and t(0) were taken from Alverson (1980) for Bristol Bay red king crab and from Somerton (1981) for Tanner crabs. Ages at first capture, t(c), were estimated from the growth parameters and maturity sizes.

The proposed definition of overfishing for stocks with level 3 data indicates the maximum allowable fishing mortality rate cannot exceed F_{msy} estimated as $F_{0.1}$, based on the size of first maturity for male crabs. The estimated exploitation rate u(0.1) associated with $F_{0.1}$ for Bristol Bay red king crab is equal to 0.3 and is extrapolated to other level 3 king crab stocks, in the absence of growth and mortality estimates. The estimated exploitation rates u(0.1) for C. bairdi and C. opilio are both 0.2.

Maximum values for u(e) in Table 4 have been established by ADF&G (1990) for mature male king crabs at 0.2 and are less than the estimate for u(0.1). The results obtained for Bristol Bay red king crabs are assumed to hold for other level 3 king crab stocks lacking parameter estimates. The estimated values of u(e) for C. bairdi and C. opilio, based on long-term averages under constant harvest rate strategies of 0.4 and 0.58 on large males, respectively, are also less than the corresponding estimates of u(0.1). Therefore, unless these strategies are changed, or unless bycatch mortality on sublegal males of a species in its target fishery is greater than u(0.1)-u(e), it is not expected that fishing mortality on these crabs stocks will exceed F_{msy}.

In the following analysis, a threshold level is estimated for Bristol Bay red king crabs based on a stock-recruitment relationship for that stock. This estimate is then extrapolated to the other level 3 stocks in the absence of comparable stock-recruitment parameter estimates. Extrapolating stock-recruitment parameters was deemed acceptable for estimating thresholds because they serve to conserve a stock's long-term reproductive capacity.

The estimated Ricker stock-recruitment relationship for Bristol Bay red king crab, with replacement line, is shown in Figure 2. The intersection of the replacement line with the curve is defined as the equilibrium level of spawning stock, S_{eq}. Thompson (1990) has used this level, estimated in the absence of fishing, as an estimate of the pristine spawner biomass, to which he then applied an appropriate fraction to estimate the threshold. The appropriate fraction was determined by Thompson to be about 0.2 for a generalized groundfish stock. It should be noted that Quinn et al. (1989) arrived at a similar result of 0.25 for a pollock stock, using an age structured simulation model. Assuming Thompson's results can be applied to red king crab, where fishing is minimal on females and age 8 males, the threshold for the Bristol Bay stock is estimated as $0.2*S_{eq}$. By equating the stock-recruitment curve and the replacement line to a common R (Figure 2) it can be shown $S_{eq} = -[\ln(c)-\ln(a)]/b$. The stock-recruitment parameters a and b are estimated to be 3.2988 and 0.0664 by fitting the model to the data series through 1988. The slope, c, of the replacement line is estimated from the stock-recruitment time series, assuming an equal sex ratio in the total spawning stock, as the ratio of average abundance of age 8 male recruits to average spawning stock abundance: c = 8.8/45.4 = 0.2. The threshold is then calculated to be 8.4 million fertilized females, based on an S_{eq} estimated to be 42.2 million fertilized females.

Thompson's logic for threshold estimation requires the left hand limb of the stock-recruitment curve to have an inflection point. The model used for red king crab assumes no inflection point (Figure 2). However, the crab FMP team felt it more prudent to assume inflection at low stock levels, and therefore a depensatory mechanism with the attendant need for a threshold, rather than to assume that depensation does not exist. The consequences of a wrong assumption is less severe if depensation is absent as the stock should recover quickly from low levels - a phenomenon that has yet to be seen in Bering Sea/Aleutian Islands king crab stocks.

In the absence of stock-recruitment parameters, thresholds for the remaining level 3 stocks are estimated by assuming the threshold estimated for the Bristol Bay red king crab stock, relative to its long-term average spawning stock abundance, is the same for all stocks. Thus, $T_{(i)} = T_{(rk)}/S_{(avg,rk)}*S_{(avg,i)}$, with a variable period for computing $S_{(avg,i)}$, depending on the available data set. Mature male, rather than female crab, data series were used for the other level 3 stocks because of the greater overall apparent sampling reliability exhibited by males. Estimated thresholds are given in Table 5, as well as their hind casted performance compared to actual past management without thresholds. Under threshold management, closures would have occurred somewhat more often for Bristol Bay red king crabs and Pribilof blue king crabs, and a little less often for _C. bairdi_. Results for the other stocks are the same for hindcasts and actual management.

2.4 Alternative 3: Constant fishing mortality rate

The definition of overfishing for Alternative 3 differs from Alternative 2 by not requiring a threshold. Under Alternative 3, depensatory mechanisms acting to maintain a stock at low levels are assumed not to exist. Please refer to maximum allowable fishing mortality rate analysis for stocks with level 1, 2, and 3 data presented for Alternative 2 as it is the same as that necessary for Alternative 3. Please refer to maximum allowable fishing mortality rate analyses for stocks with level 1, 2, and 3 data presented for Alternative 2 as they are the same as those necessary for Alternative 3.

Threshold is not included in the Alternative 3 overfishing definition but the crab FMP does provide for closure of a directed fishery when a stock is at low levels through the ABC process.

2.5 Alternative 4: Variable fishing mortality rate

The definition of overfishing for Alternative 4, levels 1 and 2 is the same as for Alternative 3, levels 1 and 2. The definition of overfishing for Alternative 4, level 3 a) is the same as for Alternative 3, level 3 except for Bristol Bay red king crab. Please refer to maximum allowable fishing mortality rate analyses for stocks with level 1, 2 and 3 data presented for Alternative 2 as they are the same as those necessary for Alternative 4.

The definition of overfishing for Alternative 4, level 3 a) is a fishing mortality rate in excess of F_{msy} for all Bristol Bay stock levels in excess of B_{msy}. The maximum allowable fishing mortality rate for the Bristol Bay stock below B_{msy} will vary with stock level, starting from a value of zero at the origin and increasing to a value of F_{msy} at B_{msy}. A preliminary estimate of B_{msy} was calculated using the Bristol Bay stock-recruitment relationship. B_{msy} is calculated as the level of spawning stock where the slopes of the stock-recruitment curve and the replacement line are equal. The overfishing definition for all other stocks with historical catch, continuous inseason catch and effort data, stock assessment, growth, maturity, and mortality parameters would default to Alternative 3, level 3.

The definition of overfishing for Alternative 4, level 3 b) is a fishing mortality rate in excess of F_{msy} for all stock levels in excess of B_{msy}. The maximum allowable fishing mortality rate for the stock below B_{msy} will vary with stock level, starting from a value of zero at the origin and increasing to a value of F_{msy} at B_{msy}. A preliminary estimate of B_{msy} was calculated using the Bristol Bay stock-recruitment relationship. B_{msy} is the level of spawning stock where the slopes of the stock-recruitment curve and the replacement line are equal. A relationship between mature male crab abundance and Bristol Bay B_{msy} would need to be determined to extrapolate the Bristol Bay stock-recruitment relationship to other stocks with abundance data and derive the respective estimates of B_{msy}.

Alternative 4 was discussed during the May 7 and 8, 1990 meeting of the crab FMP team and excluded from this amendment because it is an approach different from the Westward Region FMP's endorsed by the Board of Fisheries during their March

1990 meeting. This alternative was added at the request of the Scientific and Statistical Committee proceeding their review of the amendment at the June Council meeting. The Westward Region FMP's for Bristol Bay red king crab, Kodiak red king crab, St. Matthew blue king crab, and Pribilof Islands blue king crab specify a new method of calculating guideline harvest level. The harvest rate is now based on an exploitation rate of 20% of the mature male crab. The exploitation rate remains constant at 20% with two exceptions: 1) when sorting rates of crab are high no more than 60% of the legal male crab can be removed; and 2) when abundances of crab are below estimated threshold values, the fishery will not be opened and the guideline harvest level will be set to zero.

Comparison of Alternative 4 to Alternative 2 is made for Bristol Bay red king crab in Figure 3. Alternative 4 would allow the exploitation rate to increase to 30% of the mature males, a level corresponding to F_{msy}, as stock abundance approached B_{msy}. Alternative 2 limits the exploitation rate to 20% of the mature male population regardless of stock size. Alternative 4 may result in lower exploitation rates as a stock approached the threshold than would Alternative 2 which would result in constant exploitation rate until a stock reaches threshold. Alternative 4 would continue to allow harvest below threshold, however, the exploitation rate would decline as the stock abundance decreased.

Analysis required for implementation of Alternative 4 would be extensive as it is anticipated the alternative would change current management strategies for stocks with abundance estimates.

2.6 Biological and physical Impacts

The task of defining overfishing in an objective and measurable manner has merited considerable research within fisheries science. Usually, the attempted solutions have implicitly defined overfishing as any harvest above an optimal level. The optimal fishing rate has usually been specified as the rate corresponding to MSY, or another optimum value that maximizes some specified objective function. This approach is very different from the one specified in the 602 guidelines which define overfishing in terms of jeopardizing a stock's long term capacity to return to the MSY level, not in terms of deviating from some optimum point such as the MSY level. The SSC definition of overfishing as "fishing so hard that the average long-term yield is reduced" is more conservative than the 602 definition based on stock collapse. The overfishing definitions for crab stocks in the Bering Sea/Aleutian Islands management area provide a set of constraints that keep the stocks from falling below a point of no return and insure the preservation of a stock's long-term reproductive capacity.

Commercial fishing mortality on the crab stocks managed under the crab FMP should remain sufficiently small in the future so that overfishing should not occur under the current management program. Protection would be achieved by preventing fishing mortality rates in excess of F_{msy}. Other environmental factors beyond management control have a great influence on the crab stocks. Because stock levels fluctuate greatly from year to year, an extra degree of safety to insure the preservation of a stock's long-term reproductive capacity can be obtained by specifying a stock-specific threshold level. Ideally, determination of such a threshold level would be based on detailed knowledge of stock and ecosystem dynamics, unfortunately such information is unavailable for all the crab stocks managed by the FMP with the exception of the Bristol Bay red king crab stock for which a spawner-recruit relationship has been calculated. The best scientific data available is used to estimate the threshold levels for stocks with level 2 and 3 data. Data is currently unavailable for estimation of threshold for crab stocks with level 1 data managed under the FMP.

The reason for developing an objective and measurable definition of overfishing is to protect the crab stocks managed by the FMP. While the designation of overfishing definitions is largely administrative for the crab FMP, it is anticipated that adoption of Alternatives 2, 3, or 4 would result in minimal impacts on the crab stocks. Predators on a crab stock would be largely unaffected unless a crab stock reached threshold and limited predator food availability or the Council determined use of the multispecies exemption clause was not advisable based on a risk analysis. Alternative 2 would provide the most protection because fishing mortality is kept below F_{msy} and because a threshold is already used in the ABC process.

2.7 Socioeconomic impacts

During 1989 approximately 500 catcher vessels, 23 catcher/processors, 21 shorebased processors, and 16 floating processors were engaged in harvesting and/or processing all shellfish resources in the entire Westward Region. The number of vessels participating in the 1989 fishery on each of the 17 stocks in the Bering Sea/Aleutian Islands management area is presented in Table 1.

For the Bering Sea/Aleutian Islands management area the 1989 king crab catch was approximately 22.9 million pounds valued at 92 million dollars and the 1989 Tanner crab catch was approximately 156.8 million pounds valued at 133.7 million dollars.

Alternative overfishing definitions 2, 3, and 4, (level 3a) should in practice not impose new constraints on any of the fisheries except those targeting brown king crab. The best information available indicates criteria used in each of the alternatives result in negligible deviations from current management practices with the one exception. No measurable impact is anticipated on Bering Sea/Aleutian Islands red and blue king crab and Tanner crab fisheries. It is anticipated the effect of the alternatives on brown king crab stocks will be to restrict the current level of fishing mortality. Since no objective method of measuring fishing mortality rate on these stocks has been tested the extent of the restrictions is uncertain.

Alternative overfishing definition 4, (level 3b), would alter the current exploitation rate for those stocks affected by the Westward Region FMP's. The extent of change in exploitation rates needs to be determined for all stocks affected by this alternative.

In the event a stock reached threshold or the rate of fishing mortality exceeded that defined as overfishing, Alternatives 2, 3, and 4 would affect non-directed fisheries by limiting fishing mortality unless the Council invoked the multispecies exemption clause. A risk analysis would be necessary to determine whether or not the multispecies exemption clause (section 602.11(c)(8)) should be invoked.

2.8 Reporting costs

No additional reporting costs are anticipated under any of the alternatives.

2.9 Administrative, enforcement, and information costs

No additional administrative or enforcement costs are anticipated under any of the alternatives. Information is collected from a limited number of crab stock assessment surveys and from all crab fisheries to provide the best available information on the status of Bering Sea/Aleutian Island crab stocks. The cost to assess additional stocks that are currently not surveyed would be substantial.

2.10 Distribution of costs and benefits

No significant redistribution of costs and benefits is anticipated under any of the alternatives.

3.0 EFFECTS ON ENDANGERED SPECIES AND ON THE ALASKA COASTAL ZONE

None of the alternatives described here would constitute an action that might affect endangered or threatened species or their habitats within the meaning of the regulations implementing Section 7 of the Endangered Species Act of 1973. For this reason, consultation procedures, pursuant to Section 7, are not necessary.

None of the alternatives described here would be a federal action directly affecting the coastal zone of Alaska within the meaning of Section 307 (c) (1) of the Coastal Zone Management act of 1972 and its implementing regulations. Each of these alternatives comply to the maximum extent practicable with the Alaska Coastal Management Program.

4.0 FINDINGS OF NO SIGNIFICANT IMPACT

For the reasons discussed above, neither implementation of the status quo nor any of the alternatives to that action would significantly affect the quality of the human environment, and the preparation of an environmental impact statement on the final action is not required by Section 102 (2) (c) of the NEPA or its implementing regulations.

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Asst. Administrator for Fisheries, NOAA Date

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6.0 COORDINATION WITH OTHERS

The crab FMP team is comprised of fishery scientists and managers from the National Marine Fisheries Service, the Alaska Department of Fish and Game, the North Pacific Fishery Management Council, and the University of Alaska. The team also coordinated with other staff of those agencies. The SSC and AP of the Council and the Council have reviewed the alternatives and analysis for amendment 1 to the FMP for the commercial king and Tanner crab fisheries in the Bering Sea/Aleutian Islands.

7.0 LITERATURE CITED

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Somerton, D.A. 1981. Life history and population dynamics of two species of tanner crab, *Chionoecetes bairdi* and *C. opilio*, in the Eastern Bering Sea with implications for the management of the commercial harvest. Ph.D. Dissertation, University of Washington, Seattle, WA. 220pp.

Thompson, G.G. 1990. A proposal for a threshold stock size and maximum fishing mortality rate. Appendix I in: Groundfish EA/RIR, Chapter 3. 20pp.

Table 1. Stocks of king and Tanner crab in the Bering Sea/Aleutian Islands management area categorized by amount of fishery and survey information available and the number of vessels participating in the 1989 fishery indicated.[1]

Level 1: Sporadic Fisheries with No Surveys	Number of Vessels	Level 2: Directed Fisheries with No Surveys	Number of Vessels	Level 3: Directed Fisheries with Surveys	Number of Vessels
Bristol Bay brown king crab	--[2]	Adak brown king crab	74	E. Aleutians red king crab	--
Pribilof Islands brown king crab	2	Adak red king crab	73	Bristol Bay red king crab	211
St. Lawrence blue king crab	5	E. Aleutians brown king crab	13	Pribilof Islands blue king crab	--
Pribilof Islands red king crab	--	E. Aleutians *C. bairdi* Tanner crab	12	St. Matthew blue king crab	69
Northern District brown king crab	2			Norton Sound red king crab	10
Adak *C. bairdi* Tanner crab	36			Bering Sea *C. bairdi* Tanner crab	109
				Bering Sea *C. opilio* Tanner crab	168

[1] Total number of individual vessels participating is less than a sum of all vessels in the table because many of the vessels participate in more than one fishery.
[2] No fishery.

Table 2. Comparison of actual and estimated fishery closures under a threshold criterion of 10 percent of MSY for stocks with fishery and/or survey data available.

Stock	Years the fishery is closed		
	Actual	10 percent MSY[2]	Threshold[2]
Bristol Bay Red king crab	1983	1983-1985	1985-1986
Adak Red king crab	1976	1976-1978	--
E. Aleutians red king crab	1983-1989	1983-1985	None
Pribilof Islands blue king crab	1988-1989	1984-1986	1985-1989
Eastern Bering Sea C. bairdi	1986-1987	1984-1986	1986

1 Minimum years if there were no survey or test fishery.
2 Refers to proposed level 3 crab fishery thresholds.

Table 3. Threshold estimates (millions of pounds) and actual and estimated fishery closures under threshold criterion for Alternative 2, level 2 crab stocks.

Stock	Threshold Years	Threshold MSY	Threshold 10% MSY	Threshold Closed Years	Actual Closed Years
Adak red king crab[1]	1960-1986	7.0	0.70	1976-1978	1976
Adak brown king crab	1981-1986	7.4	0.74	None	None
E. Aleutians Brown king crab	1981-1987	1.4	0.14	None	None
E. Aleutians C. bairdi	1973-1986	0.7	0.07	None	None

1 Assumes the 1979 catch of 0.47 would have been above threshold given the 1976-1978 fishery closure.

Table 4. Estimates of $F_{0.1}$, associated parameters, and comparisons with expected rates of exploitation for Alternative 2, level 3 crab stocks.

Parameter	Stock: Bristol Bay Red king crab	Stock: Eastern Bering Sea *C. bairdi*	Stock: Eastern Bering Sea *C. opilio*
M	0.30	0.30	0.30
k	0.17	0.16	0.19
L(inf) in mm	190	200	140
W(inf) in lbs	12.6	5.7	2.6
t(0) in yrs	0.7	0.8	0.9
t(c) in yrs	7	6	5.5
l(c) in mm	120	110	78
$F_{0.1}$	0.40	0.30	0.30
u(0.1)	0.30	0.20	0.20
u(e)[1]	0.20	0.09	0.04

[1] Maximum rate allowed by ADF&G policy for red king crab; 1976-1989 average for *C. bairdi*; 1982-1989 average for *C. opilio*.

Table 5. Threshold estimates, average spawning stock (millions of crabs), and actual and estimated fishery closures under threshold criterion for Alternative 2, level 3 crab stocks.

					Closures	
Stock	Threshold	Ratio	S(avg)	Years	Threshold	Actual
Bristol Bay red king crab (females > 89mm)	8.4	0.17	50.1	1969-1989	1985-1986	1983
E. Aleutian red king crab (males > 119mm)	0.75		4.41	1976-1987	1983-1987	1983-1989
Norton Sound red king crab (males > 120mm)	0.27		1.60	1976-1989	None	None
Pribilof Islands blue king crab (males > 109mm)	0.77		4.60	1974-1989	1985-1989	1988-1989
St. Matthew Island blue king crab (males > 104mm)	0.60		3.55	1978-1989	None	None
Eastern Bering Sea _C. bairdi_ (males > 109mm)	14.3		85.5	1976-1989	1986	1986-1987
Eastern Bering Sea _C. opilio_ (males > 78mm)	309.4		1845.9	1982-1989	None	None

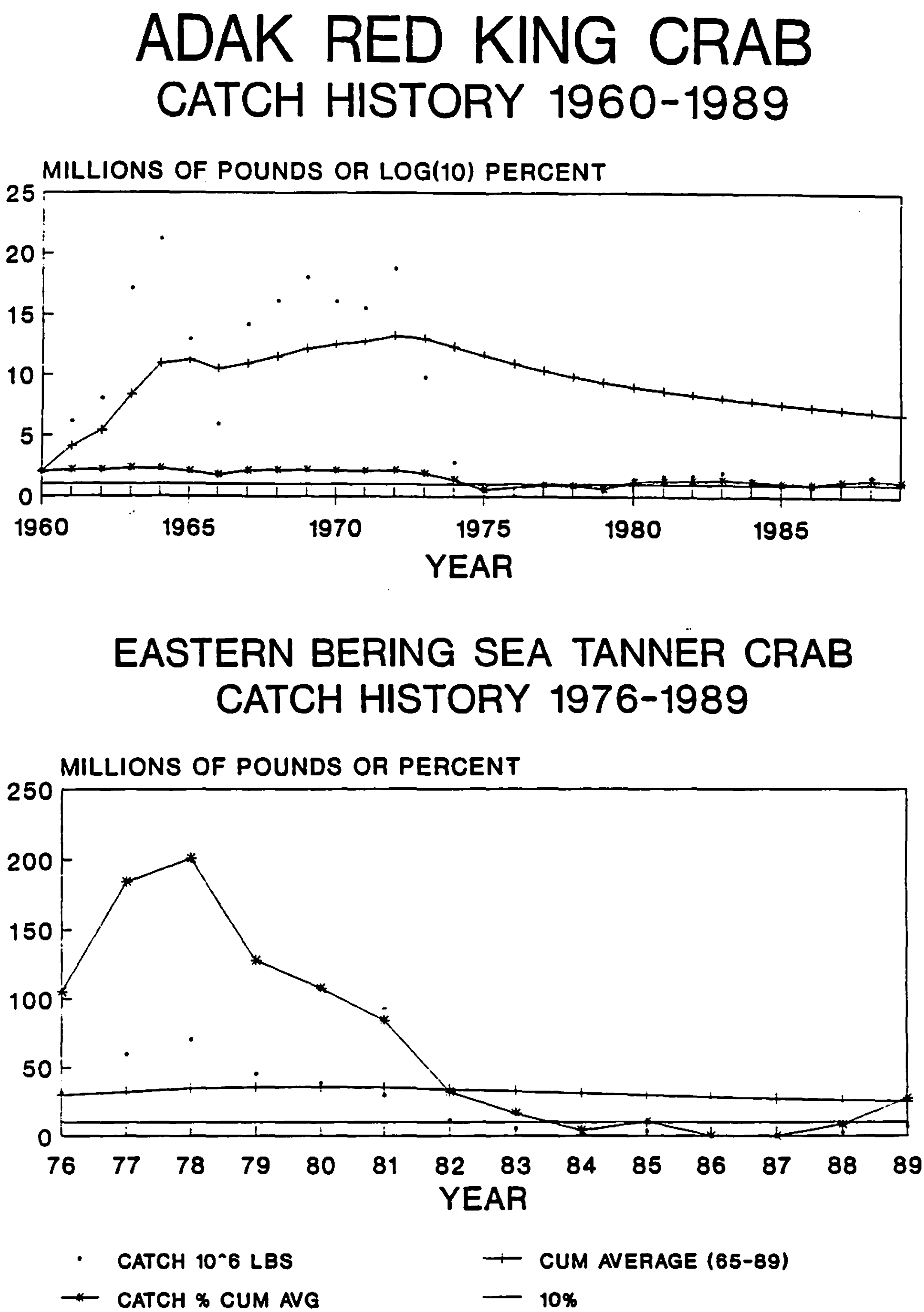
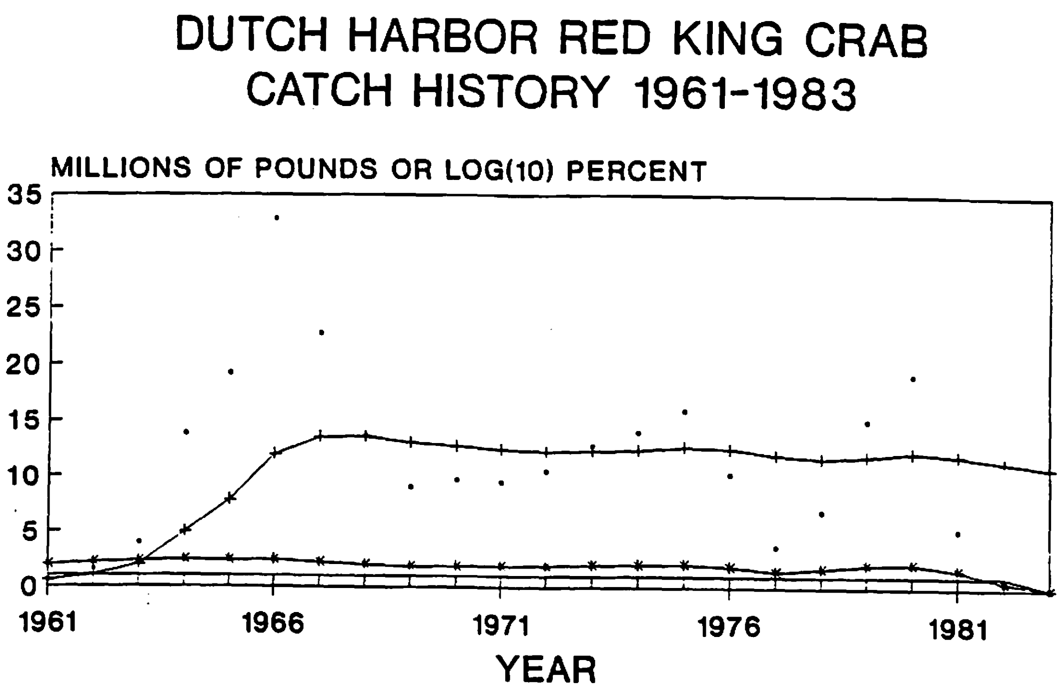


Figure 1. Catch histories of Bering Sea/Aleutian Islands crab stocks where closures have been imposed, showing application of proposed closure at a threshold of 10 percent of the historic (cum) average catch for the fishery (MSY).



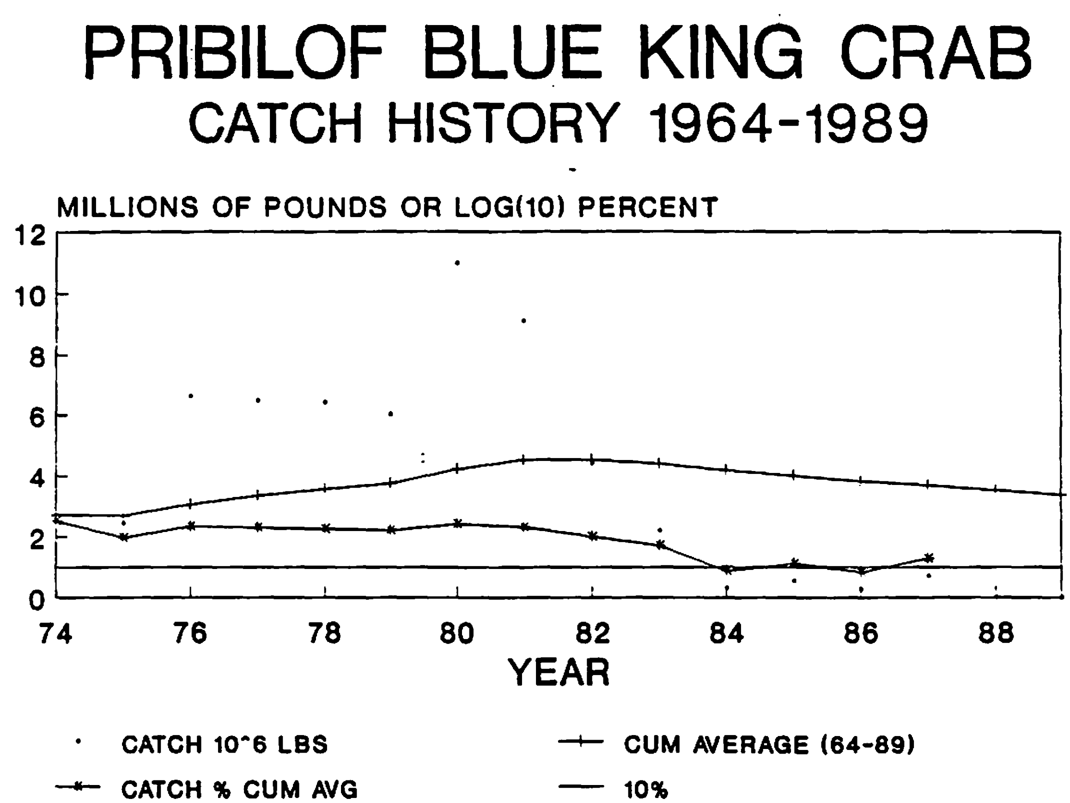


Figure 1. (cont.) Catch histories of Bering Sea/Aleutian Islands crab stocks where closures have been imposed, showing application of proposed closure at a threshold of 10 percent of the historic (cum) average catch for the fishery (MSY).

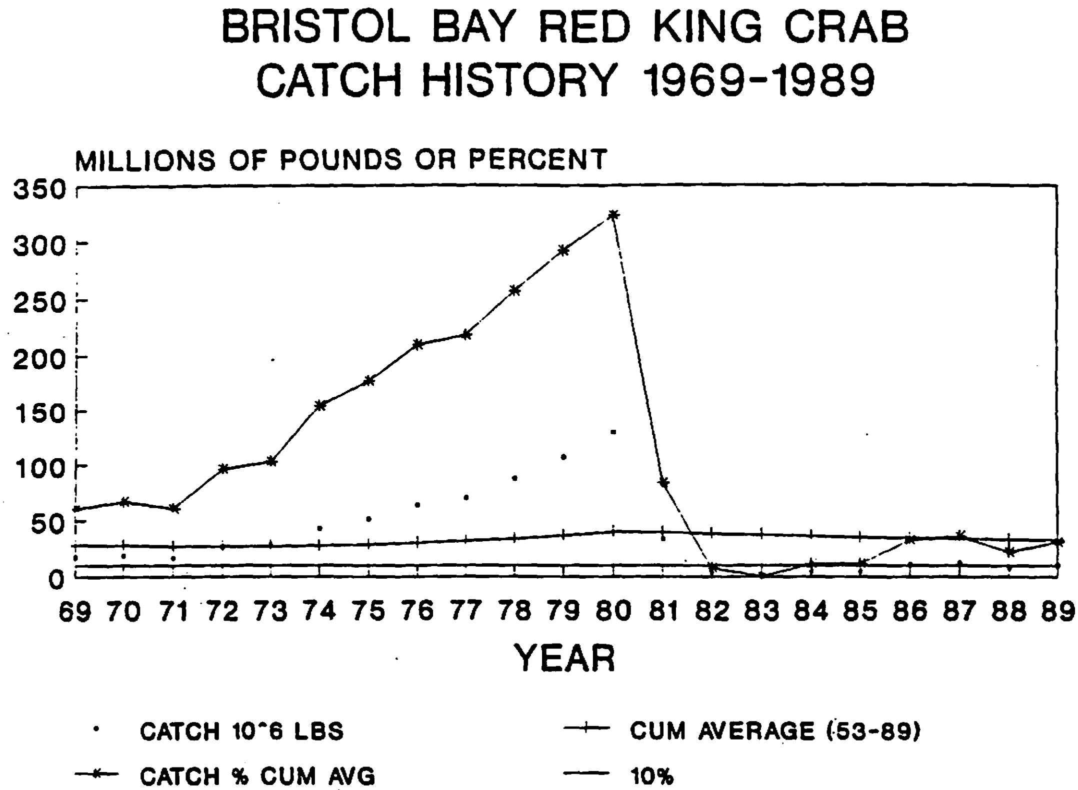


Figure 1. (cont.) Catch histories of Bering Sea/Aleutian Islands crab stocks where closures have been imposed, showing application of proposed closure at a threshold of 10 percent of the historic (cum) average catch for the fishery (MSY).

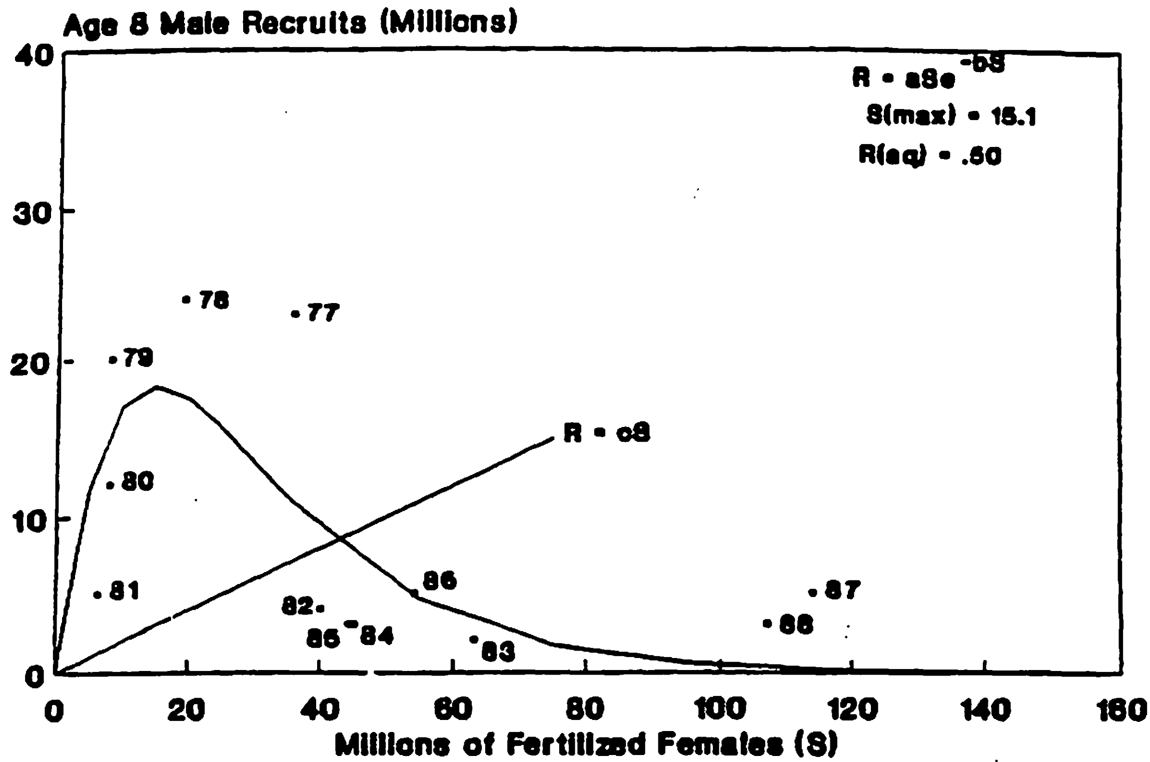


Figure 2. Bristol Bay red king crab stock-recruit relationship.

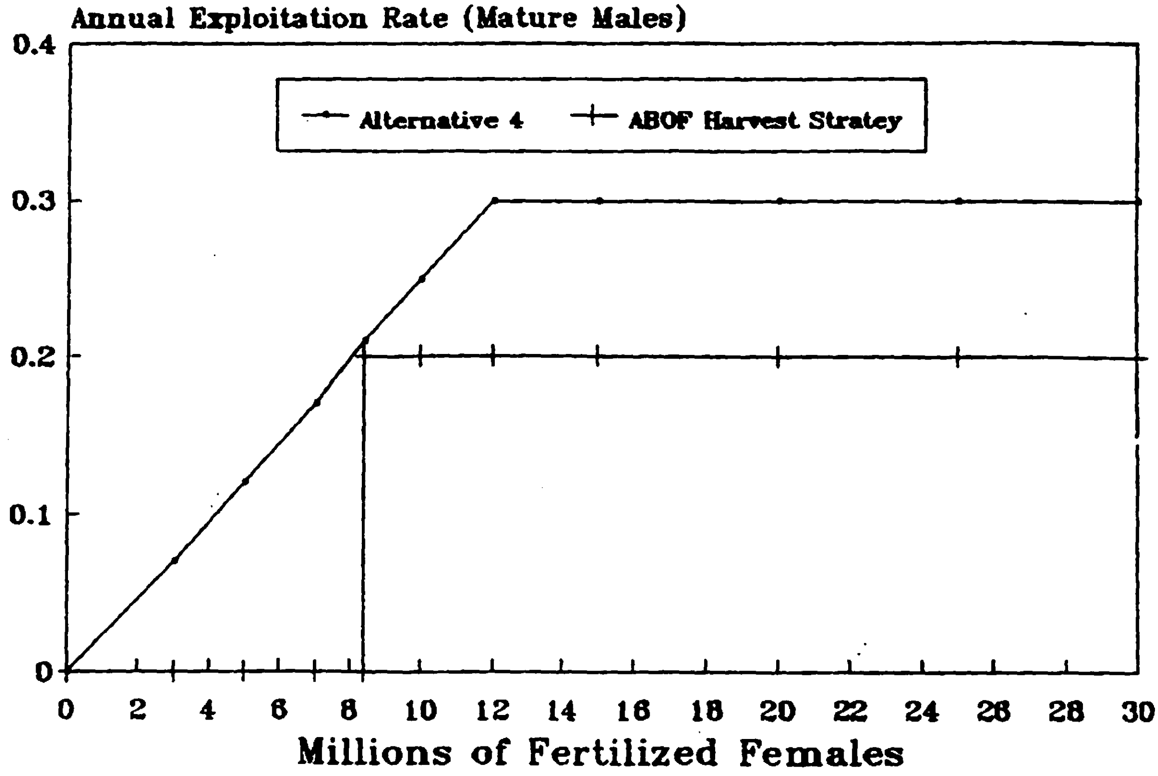


Figure 3. Bristol Bay red king crab comparison of harvest strategies.