DRAFT FOR SECRETARIAL REVIEW

ENVIRONMENTAL ASSESSMENT/REGULATORY IMPACT REVIEW/
FINAL REGULATORY FLEXIBILITY ANALYSIS
FOR

AMENDMENT 37

Measure 1: Establishment of a Bristol Bay Red King Crab Savings Area;

Measure 2: Management of Red King Crab (*P. camtschaticus*) Bycatch Limits in Bering Sea Groundfish Trawl Fisheries;

Measure 3: Establishment of a Trawl Closure Area in the Nearshore Waters of Bristol Bay

an Amendment to the Fishery Management Plan
for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area
including a Regulatory Amendment to rescind regulations (§ 675.22, paragraphs c,d,e)
that allow a trawl fishery for Pacific cod in the Port Moller area

as well as

Analysis of Alternatives for Tanner Crab (C. bairdi)
and Snow Crab (C. opilio) Bycatch Limits
in Bering Sea Groundfish Trawl Fisheries

Prepared by staff of the
North Pacific Fishery Management Council
Alaska Department of Fish and Game

November 19, 1996

Table of Contents

Executive Summary

Bering Sea crab stocks are currently at relatively low levels based on recent National Marine Fisheries Service (NMFS) bottom trawl surveys. Crab fisheries have been impacted by these low stock sizes, such that no Bristol Bay red king crab fishery occurred in 1994 or 1995, and harvests of Tanner and snow crabs have been much reduced. In January 1995, the Council initiated analysis of several proposals designed to reduce impacts of trawling on crab stocks and thus promote rebuilding of crab resources. The Council adopted three management measures for the current crab bycatch management regime for Bering Sea trawl fisheries. Specifically, these management measures are:

1. Revise the trawl closure time period for the Bristol Bay Red King Crab Savings Area;
2. Modify crab bycatch limits for trawl fisheries; and
3. Close nearshore waters of Bristol Bay to trawling.

The Council requested that staff examine the suite of management measures in one package, so that the impacts of these measures can be analyzed in a comprehensive manner. At it's June 1996 meeting, the Council identified and adopted its preferred alternatives for these management measures, and these actions were bundled together as Amendment 37. In September 1996, the Council approved an agreement negotiated by the industry regarding PSC limits for C. bairdi Tanner crab. This action will move forward under a separate amendment. The Council will take final action on snow crab at its December 1996 meeting. Proposed crab bycatch management measures, and potential impacts and interactions, are described below.

Bristol Bay Red King Crab Savings Area: The non-pelagic trawl closure period adopted by the Council in September 1995 (Bristol Bay Red King Crab Savings Area) does not encompass the entire molting and mating period of red king crabs. The Bristol Bay red king crab stock remains at low abundance levels, and the Council recommended that NMFS implement an emergency rule to continue the closure through June 15, 1996. Because unobserved impacts of trawling on softshell crab may impact crab rebuilding and future crab harvests by pot fisheries, the Council requested additional information be examined before they reconsider the previous preferred alternative (January 1 - March 31) for this Amendment.

Three alternatives were examined. In addition to the status quo, Alternative 1, additional impacts of seasonal closures were examined as well as a modified closure area. These alternatives and options are detailed below.

Alternative 1: Status quo, no action. Amendment 37 would be submitted to the Secretary based on the closure period adopted by the Council in September 1995. The Bristol Bay Red King Crab Savings Area (162° to 164° W longitude, 56° to 57° N latitude) would be closed to non-pelagic trawling from January 1 through March 31. The area bounded by 56° to 56°10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established.

Alternative 2: Extend closure period for the Bristol Bay Red King Crab Savings Area to provide increased protection for red king crab. Amendment 37 would be submitted to the Secretary based on one of the closure period options considered. [Note: The area bounded by 56° to 56°10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established.]

Option A: Six month closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through June 15. The June 15 date corresponds to the opening date for Area 516, which is the area from 162° to 163° W longitude that is closed March 15 to June 15 annually.

Option B (**Preferred**): Year-round closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through December 31.

Option C: Seven month closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through August 1.

Alternative 3: Close the area based on a modified version of the old pot sanctuary. Boundaries of the closure would close all waters in the Bering Sea east of a line originating at Cape Constantine, extending to 58°10' N, 160°W to 57°10'N, 163°W to 56°30'N, 163°W to 56°30'N, 164°W, then south to 56°N. After April 1, this closure would extend south to the Alaska Peninsula. This option would require 100% observer coverage for fishing north of 58°N and east of 162°W and would be limited to May and June. Further, the area between 163° and 164°W between 56°30'N and 57°00'N would not open until April 1 and would be closed upon reaching a red king crab cap in a range of 5,000 to 15,000 red king crab. (Note this alternative deals with both Bristol Bay Red King Crab Savings Area and nearshore Bristol Bay Trawl Closure Area.)

As a supplement to the original Amendment 37 analysis (NPFMC 1995) which examined a year round closure of the red king crab savings area, the Bering Sea Fishery Simulation model was run to estimate the net benefits to the nation from a three-month, six-month, or a seven-month closure to all trawling. Model runs predicted no substantial change in net benefits to the nation under any closure option.

The additional analysis provided by the model was based on data from 1993 and 1994 when there was essentially no trawling in the closure area between April and June. Thus the model was unable to predict the magnitude of red king crab savings by extending the closure to June 15. However, in some years, Zone 1 has remained open to yellowfin sole trawling until May or June, and there remains a potential for vessels to trawl in the proposed area. Because this area contains a significant number of molting adult red king crab during this time period, Alternative 2 (Options A, B, and C) may reduce the potential for bycatch and unobserved mortality, which may be higher when crabs are in softshell condition. Alternative 2, Option C (7-month closure) covers the duration of the molting period and an additional month to allow for shell hardening. Alternative 2, Option B (year-round closure) provides the maximum protection of crab and habitat.

Alternative 3 would provide more fishing opportunities for the yellowfin sole and rock sole trawl fisheries, as well as provide habitat protection for red king crab in nearshore areas. However, because areas containing a sizable portion of the mature red king crab stock would be open to trawling, Alternative 3 may result in increased impacts on red king crab.

Modify Existing Crab PSC Bycatch Limits, and Initiate Bycatch Limits for Snow Crab: Bycatch limits for red king crab and Tanner crab established for Bering Sea fisheries may be too high given current status of crab stocks, and bycatch may impact crab rebuilding and future crab harvests by pot fisheries. Bycatch limits for snow crab have not been established. Three main alternatives, developed by the Council's Advisory Panel and the State of Alaska, were examined for each crab species separately. An additional option for stairstep PSC limits for Tanner crab, proposed by the Alaska Crab Coalition in January 1996, was also examined at the request of the Council. The alternatives to the status quo included a reduced bycatch limit for crab and a crab PSC limit that fluctuates with crab abundance. Potential impacts of instituting a new bycatch limit for snow crab were also examined. The alternatives and options were as follows:

RED KING CRAB

Alternative 1: Status quo, no action. PSC limits would remain at 200,000 red king crab in Bycatch Limitation Zone 1.

Alternative 2: Reduce PSC limits of red king crab. PSC limits would be reduced to a fixed level at 180,000 red king crab based on a three year average (1992-1994)

Option A: Further reduce the red king crab PSC limit in Zone 1 to 35,000 crab, which was the number of red king crab bycaught in 1995 within Zone 1.

Alternative 3: Establish PSC limits for crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey. Limits would be established based on a rate specified, within the range 0.1-1.0% of red king crab in the Bristol Bay District.

Alternative 4 (**Preferred**): Establish a stairstep based PSC limit for red king crab in Zone 1. PSC limits would be based on abundance of Bristol Bay red king crab as follows:

(A) When the number of mature female red king is equal to or below the threshold number of 8.4 million crab, or the effective spawning biomass (ESB) is less than 14.5 million pounds, the Zone 1 red king crab PSC limit would be 35,000 crabs;

(B) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 14.5 but less than 55 million pounds, the Zone 1 red king crab PSC limit would be 100,000 crabs; and

(C) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 55 million pounds, the Zone 1 red king crab PSC limit would be 200,000 crabs.

Option A: Set a fixed upper limit for crab PSC at 200,000 red king crab in Zone 1.

TANNER CRAB

Alternative 1: Status quo, no action (**Preferred, June 1996**). PSC limits would remain at 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

Alternative 2: Reduce PSC limits of Tanner crab. PSC limits would be reduced to a fixed level of 900,000 Tanner crab in Zone 1, and within the range of 1,500,000 to 2,100,000 Tanner crab in Zone 2.

Alternative 3: Establish PSC limits for crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey. Limits would be established based on a rate specified, within the range 0.10-2.0% of Tanner crab in the Eastern District, as indexed by the survey. PSC limits for each zone would be set either by apportioning the overall cap among the zones (25% to Zone 1 and 75% to Zone 2) or by setting separate PSC rates for each zone, rather than apportionment of a single rate.

Option A: Set a fixed upper limit for crab PSC at 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

Option B: Establish PSC limits for Tanner crab based on abundance thresholds. Limits would be set as a percentage of population when abundance is less than 100 million crab. In years when Tanner crab abundance is more than 100 million, but less than 250 million, PSC limits would be established at 850,000 Tanner crab in Zone 1, and 1,500,000 in Zone 2. In years when Tanner crab abundance is more than 250 million, but less than 500 million, PSC limits would be established at 900,000 Tanner crab in Zone 1, and 2,300,000 in Zone 2. In years when Tanner crab abundance exceeds 500 million, PSC limits would be established at 1,000,000 Tanner crab in Zone 1, and 3,000,000 in Zone 2.

SNOW CRAB

Alternative 1: Status quo, no action (**Preferred, June 1996**). No PSC limits would be set for snow crab.

Alternative 2: Establish a fixed PSC limit for snow crab. Based on a three year average (1992-1994), a PSC limit would be established at a fixed level of 11,000,000 snow crab in Zone 2. No snow crab PSC limit would be established for Zone 1, as bycatch in this area has been minuscule by comparison.

Option A: Establish PSC limit at 6 million snow crab in Zone 2.

Alternative 3: Establish PSC limits for snow crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the NMFS bottom trawl survey index. Limits for Zone 2 would be set at a percentage within the range 0.005 to 0.25% of the snow crab total population index (all districts combined). No snow crab PSC limit would be established for Zone 1.

Option A: Set fixed upper limit for PSC at 12 million snow crab in Zone 2.

The biological impacts of this management measure on crab populations were measured on the basis of adult equivalents. The adult equivalent formula incorporated data from groundfish and crab fisheries including bycatch numbers, size and sex of catch and bycatch, discard mortality, and natural mortality. Results indicated that, assuming only observed crab are impacted, bycatch in groundfish fisheries has relatively small impact on crab populations, and therefore reducing PSC limits as proposed under Alternatives 2 and 3 may not drastically improve or rebuild crab stocks. For example, under the most restrictive PSC limit considered for red king crab (red king crab Alternative 2, Option A), the abundance of female spawning stock would be expected to be about 0.75% higher than under Alternative 1, based on average bycatch 1993-1995. It should be noted, however, that any reduction in mortality would slow the decline of the Bristol Bay stock. PSC limits for Tanner crab proposed under Tanner crab Alternative 2 would increase female spawning stock by about 0.38%.

The economic impacts of this management measure depend on the alternative chosen. If the Bristol Bay Red King Crab Savings Area is approved as an FMP amendment, reduced PSC limits for red king crabs in Zone 1 (as proposed under Alternative 2) may not further impact trawl fisheries, as bycatch was at or below this level in 1995 and 1996. For Tanner crab, recent data indicated that the current PSC limits (status quo) could be reduced from existing levels, yet not impact groundfish fisheries if the available PSC is optimally allocated. However, because PSC allocation becomes fixed for the year during the annual specification process, optimal allocation may be impossible to achieve. Bycatch of Tanner crab was much reduced in 1995, suggesting that the PSC limit proposed under Alternative 2 may be achievable without substantially impacting trawl fisheries. One major assumption regarding assessment of impacts for Alternative 2 is that crab stock abundance will remain relatively stable in future years.

The impacts of Alternative 3 depend on the PSC rate chosen for each crab species. On average 1992-1995, groundfish fisheries bycaught crab at the following rates (bycatch as percentage of total crab survey abundance): red king crab (Zone 1, 0.40%), Tanner crab (Zone 1, 0.39%; Zone 2, 0.79%), snow crab (Zone 2, 0.10%). As with other alternatives, PSC limits set at these rates (current bycatch use) would not impact groundfish fisheries if the available PSC is optimally allocated. Fixed upper limits would further constrain trawl fisheries when crab abundance is high. The threshold limits proposed for Tanner crab may also do the same. The potential benefit of threshold limits is that while they allow bycatch levels to fluctuate with crab abundance, they also would temper year-to-year variability in PSC limits caused by trawl survey abundance estimates. Some stability may also be beneficial to long-term financial planning for trawl companies.

Nearshore Bristol Bay Trawl Closure Area: Existing trawl closure areas in Bristol Bay were designed to protect adult and sub-adult red king crab from trawling. However, protection of juvenile habitat, which may be negatively impacted by trawling, may provide for improved recruitment and subsequent stock rebuilding. A trawl closure area may also provide additional protection for Pacific herring and Pacific halibut. In addition to the status quo, Alternative 1, the impacts of prohibiting trawling in three areas were examined.

Alternative 1: Status quo, no action.

Alternative 2: Establish a Northern Bristol Bay Closure Area, which would prohibit all trawling, on a year-round basis, in the area east of 162° W longitude and north of 58° N latitude.

Option A: Continue to allow bottom trawling within the area north of 58° N and bounded by 159° and 160° W longitude. This option may require 100% observer coverage for trawl vessels fishing in the area.

Alternative 3: Prohibit all trawling in Bristol Bay, on a year-round basis, in the area east of 162° W longitude. Because much of Bristol Bay (statistical area 512) is already closed to trawling year-round, the additional area encompassed by this alternative is statistical area 508 in eastern Bristol Bay and the area described under Alternative 2.

Option A (**Preferred**): Continue to allow bottom trawling within the area north of 58° N and bounded by 159° and 160° W longitude. This option may require 100% observer coverage for trawl vessels fishing in the area. (Note: the Council's preferred option would limit trawling to the area south of 58°43' N within the 159° and 160° W window and only during the period April 1 to June 15 each year.)

Alternative 4: Prohibit all trawling on a year-round basis the area north of 58°43' N and east of 162° W longitude. The area north of 58° N and east of 162° W longitude, exclusive of the area closed year-round, would be open to trawling during the period April 1 to June 15 each year. This alternative may require 100% observer coverage for trawl vessels fishing in the area.

Option A: Also prohibit all trawling on a year-round basis in Statistical Area 508, which is the area east of 160° W longitude and south of 58° N latitude.

All Alternatives to the status quo would include a regulatory amendment change that would rescind the trawl closure exemptions for the Pacific cod fishery off Port Moller. These regulations appear to be out-of-date given the current best scientific information on juvenile crab habitat and status of the Bristol Bay red king crab stock.

This analysis suggests that a nearshore trawl closure area designed to protect juvenile red king crab habitat may be a significant action managers can take to maintain and possibly increase recruitment of red king crab. Young-of-the-year red king crab require cobble or living substrate (such as sea onions and bryozoans) on which to settle and provide protection from predators. Much of this habitat is already protected by the area 512 trawl closure. Additional habitat for age-0 red king crab has been found to occur in the shallow waters (<50 m) of Area 508, and in the area north of 58° N latitude. By age 2, juvenile red king crab begin to form pods in deeper water (>50m) adjacent to settlement areas in Bristol Bay. Although Alternative 2 encompasses some habitat and podding areas, Alternative 3 would provide maximum habitat protection for young red king crab of the Bristol Bay stock. A trawl closure area in nearshore Bristol Bay may also provide some additional benefits for seabirds, herring, halibut, and marine mammals, but potential benefits remain unquantified.

Yellowfin sole are targeted by trawl fisheries in Bristol Bay (concentrated to the west of Cape Constantine), and consequently this fishery would be somewhat impacted by the proposed closure areas, particularly the northern Bristol Bay area (Alternative 2). A high of 50% of the yellowfin sole observed catch was taken in 1991 in Bristol Bay, however, this percentage has declined annually until only 2% of the directed catch was taken in Bristol Bay in 1994. The percentages of prohibited species bycatch taken in the Bristol Bay area are generally similar to the catch percentages with the exception of herring which generally constitutes a very high percentage of the total yellowfin sole bycatch of herring.

Estimates based on the Bering Sea fishery simulation model indicate that adoption of any of the Alternatives would lead to a slight decrease in the net benefits to the Nation over status quo based on both the 1993 and 1994 data. The approximately $1.1 million decrease in net benefits (1993 data) and $1.3 million decrease in net benefits (1994 data) result in approximately a 0.4% and a 0.5% decrease of the net benefits to the Nation under status quo from 1993 and 1994 data, respectively. Given the accuracy inherent in the data, and in the model procedures, these predicted changes in net benefits to the nation are probably not great enough to indicate an actual change from status quo. As with any closure, the tradeoffs between foregone groundfish catch, and savings in bycatch species are apparent in the model results. A closure of northern Bristol Bay would result in a slight decrease in retained catch and herring bycatch and an increase in Tanner crab bycatch. The minimal directed fishing activity in Area 508 during 1993 and 1994 resulted in minute changes in the model results due to the closure of this area.

1.0 INTRODUCTION

The groundfish fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) off Alaska are managed under the Fishery Management Plan for the Groundfish Fisheries of the Gulf of Alaska and the Fishery Management Plan for the Groundfish Fisheries of the Bering Sea and Aleutian Islands Area. Both fishery management plans (FMP) were developed by the North Pacific Fishery Management Council (Council) under the Magnuson Fishery Conservation and Management Act (Magnuson Act). The Gulf of Alaska (GOA) FMP was approved by the Secretary of Commerce and become effective in 1978 and the Bering Sea and Aleutian Islands Area (BSAI) FMP become effective in 1982.

Actions taken to amend FMPs or implement other regulations governing the groundfish fisheries must meet the requirements of Federal laws and regulations. In addition to the Magnuson Act, the most important of these are the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), Executive Order (E.O.) 12866, and the Regulatory Flexibility Act (RFA).

NEPA, E.O. 12866 and the RFA require a description of the purpose and need for the proposed action as well as a description of alternative actions which may address the problem. This information is included in Section 1 of this document. Section 2 contains information on the biological and environmental impacts of the alternatives as required by NEPA. Impacts on endangered species and marine mammals are also addressed in this section. Section 3 contains a Regulatory Impact Review (RIR) which addresses the requirements of both E.O. 12866 and the RFA that economic impacts of the alternatives be considered. Section 4 contains the Final Regulatory Flexibility Analysis (FRFA) required by the RFA which specifically addresses the impacts of the proposed action on small businesses.

This Environmental Assessment/Regulatory Impact Review/Final Regulatory Flexibility Analysis (EA/RIR/FRFA) addresses proposals to reduce the impacts of trawling on Bering Sea crab stocks and increase the probability of crab stock rebuilding.

1.1 List of Management Measures Considered

The Council is considering three management measures to resolve problems in the current crab bycatch management regime for Bering Sea trawl fisheries. Specifically, these management measures are:

1. Revise the trawl closure time period for the Bristol Bay Red King Crab Savings Area,
2. Modify existing crab PSC bycatch limits, and initiate bycatch limits for snow crab, and
3. Close nearshore waters of Bristol Bay to trawling.

1.2 Purpose of and Need for the Action

Bering Sea crab stocks are currently at relatively low levels based on 1995 National Marine Fisheries Service (NMFS) bottom trawl survey data, which indicated that exploitable biomass of Bristol Bay red king crab (Paralithodes camtschaticus), and Bering Sea Tanner crab (Chionoecetes bairdi) and snow crab (Chionoecetes opilio) stocks are about one-fifth record levels (Stevens et al. 1995). Red king crab stocks are at their lowest level since the fishery was closed after the first stock collapse in 1983. In 1994 and 1995, Bristol Bay was closed to red king crab fishing because the female threshold (8.4 million) was not reached. In addition, the annual trawl surveys indicated little prospect for increased recruitment of mature males or females, and low female spawning biomass. Although the Tanner crab fishery in the Bering Sea opened in 1994 and 1995 as scheduled, the guideline harvest levels were reduced. Also, the area east of 163°W was closed to Tanner crab fishing to minimize the bycatch of female red king crabs.

This situation has prompted the North Pacific Fishery Management Council to examine ways to rebuild red king, Tanner, and snow crab stocks in the Bering Sea. In September 1994, the Council recommended that NMFS implement by emergency rule, a trawl closure area in Bristol Bay (162° to 164° W longitude, 56° to 57° N latitude) to protect adult red king crabs. In September 1995, the Council adopted the same time/area closure under Amendment 37. The preferred alternative was to close the area from January 1 to March 31 each year to all non-pelagic trawling. In addition, the area bounded by 56°00' to 56°10' N latitude will be removed from the closure parameters during the years in which a guideline harvest level for Bristol Bay red king crab is established.

In January 1995, the Council formed a committee to develop a rebuilding plan for Bering Sea crab stocks. The committee synthesized available information on sources and magnitude of crab mortality and identified alternative management strategies the Council might use to enhance the survival of crab stocks and thus promote rebuilding (Witherell 1995). In addition to establishing the rebuilding committee, the Council initiated several analyses to examine impacts of proposals to control crab bycatch in the groundfish fisheries (see **Appendix 2**). Among these proposals are reduction of existing crab bycatch limits (with an option that the limits be based on crab abundance), and initiation of bycatch limits for snow crab. The Council suggested specific alternatives for PSC bycatch limits be examined, based on input from it's Advisory Panel and a proposal by the State of Alaska. Another proposal was to establish a trawl closure area in the northeast section of Bristol Bay (north of 58° N and south of 162° W) to protect juvenile red king crab.

At its January 1996 meeting, the Council expressed serious concerns about the continued low abundance of Bering Sea crab stocks. Based on 1995 NMFS survey data, the Council requested that NMFS take emergency action to extend the Bristol Bay Red King Crab Savings Area trawl closure (adopted by inseason authority for 1996 from January 1 through March 31) to June 15 to protect red king crab during the molting and mating period. The Council notified the public that it intended to revisit its previous action on Amendment 37 at the April meeting, and requested staff to provide additional information on potential impacts of modifying the closure time to 6 months or year-round. Additional information provided in this document is a supplement to the previous analysis of Amendment 37.

In addition, the Council requested that staff examine the suite of management measures (modified Crab Savings Area, crab PSC bycatch limits, and northern Bristol Bay closure area) in one package, so that the impacts of these measures can be analyzed in a comprehensive manner. An additional option (Tanner crab Alternative 3, Option B), proposed by the Alaska Crab Coalition in January 1996, was also added to the analysis at the request of the Council. The Council requested that its crab rebuilding committee review the document and provide scientific advice and recommendations.

At its April 1996 meeting, the Council reviewed a draft EA/RIR of the suite of crab bycatch management measures and released the document for public review with several modifications suggested by the Advisory Panel and Crab Rebuilding Committee. Modifications include the addition of two closure options that would continue to allow trawling in a portion of northern Bristol Bay, a 7-month closure for the Red King Crab Savings Area, options for further reduced PSC caps, and recision of the trawl exemption area off Port Moller. These modifications and revisions are included in this analysis.

At its June 1996 meeting, the Council took final action on several measures to protect the Bristol Bay red king crab stock from possible impacts due to groundfish fisheries. **These actions were bundled together as Amendment 37**. Based on its review of the draft EA/RIR and input from its advisory bodies and public testimony, the Council rescinded its previous action on Amendment 37 and adopted a new preferred alternative for a year-round closure of the Red King Crab Savings Area (162° to 164° W, 56° to 57° N). Hence, **the Council's preferred alternative for Management Measure 1 is Alternative 2, Option B**. An extended duration of the closure period provides for increased protection of adult red king crab and their habitat. To allow some access to productive rocksole fishing areas, the area bounded by 56° to 56°10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established. A separate bycatch limit for this area would be established at no more than 35% of the red king crab prohibited species catch (PSC) limits apportioned to the rocksole fishery.

To protect juvenile red king crab and critical rearing habitat, the Council recommended that all trawling be prohibited on a year-round basis in the nearshore waters of Bristol Bay. Hence, **the Council's preferred alternative for Management Measure 3 is Alternative 3, Option A** as modified. Specifically, the area east of 162° W (i.e., all of Bristol Bay) would be closed to trawling, with the exception of an area bounded by 159° to 160° W and 58° to 58°43'N that would remain open to trawling during the period April 1 to June 15 each year. It was felt that such a closure area would protect known areas of juvenile red king crab habitat while at the same time allow trawling in an area that can have high catches of flatfish and low bycatch of other species. The area north of 58°43'N was closed to reduce bycatch of herring. The time window was specified to reduce bycatch of halibut, which move into the nearshore area in June. In addition to establishing nearshore trawl closure areas, the Council also recommended that NMFS rescind the regulation that allow trawling for Pacific cod in the area off Port Moller, as these regulations are out of date given the current status of red king crab and scientific knowledge of critical habitat.

Also in June 1996, the Council recommended modifying PSC limits for red king crab taken in trawl fisheries. Specifically, the Council recommended adoption of a stairstep based PSC limit for red king crab in Zone 1.

The Council determined that a stairstep limit was preferable for this stock in that it addressed possible biases caused by rate based limits and smoothed year-to-year variability , yet provided for reduced bycatch limits at low stock sizes. These stairstep limits, originally recommended by the crab plan team, are based on both the number and weight of crab similar to the State's definition of threshold for Bristol Bay red king crab. Hence, **the Council's preferred alternative for Management Measure 2 is Alternative 4.** The Council's recommended PSC limits would be based on abundance of Bristol Bay red king crab as follows:

(A) When the number of mature female red king is equal to or below the threshold number of 8.4 million crab, or the effective spawning biomass (ESB) is less than 14.5 million pounds, the Zone 1 red king crab PSC limit would be 35,000 crabs;

(B) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 14.5 but less than 55 million pounds, the Zone 1 red king crab PSC limit would be 100,000 crabs; and

(C) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 55 million pounds, the Zone 1 red king crab PSC limit would be 200,000 crabs.

In years when red king crab in Bristol Bay are at or below the threshold of 8.4 million mature crabs, a PSC limit of 35,000 red king crab would be established in Zone 1. This limit was based on the level of bycatch observed in the 1995 flatfish fisheries operating in Zone 1 with the Red King Crab Savings Area closed to trawling. In years when the stock is above threshold but below the target rebuilding level of 55 million pounds of effective spawning biomass, a PSC limit of 100,000 red king crab would be established. The 100,000 crab PSC limit corresponds to a 50% reduction from the current PSC limit, the same percentage reduction as applied by the Alaska Board of Fisheries in 1996 to the harvest rate for the directed red king crab fishery when the stock is above threshold but below 55 million pounds of effective spawning biomass. A 200,000 PSC limit would be established in years when the Bristol Bay red king crab stock is rebuilt (above threshold and above 55 million pounds of effective spawning biomass).

The Council did not make any recommendations regarding PSC limits for Tanner and snow crabs at its June meeting. Rather, the Council formed an industry workgroup to review proposed PSC limits for these crab species. The workgroup will also review allocation of crab PSC among trawl fisheries to gain an understanding of how proposed actions may affect PSC use. Final action was taken on Tanner crab at the Council's September 1996 meeting and will move forward under a separate amendment. Final action on snow crab is expected at the December 1996 Council meeting.

The Council's discussion of crab bycatch management in June highlighted the need for additional information and future assessment of management actions. The Council recommended that all vessels (including vessels using pot and longline gear) fishing for groundfish in the Red King Crab Savings Area and the 159^{o} to 160^{o} area will require 100% observer coverage. In addition, the Council recommended that closure areas and crab PSC limits be re-evaluated on a regular basis because crab abundance and distribution change over time.

In addition, to maintain consistency with the Council's intent for implementation of Amendment 1 to the Fishery Management Plan for the Scallop Fishery off Alaska (Scallop FMP) NMFS also proposes to amend regulations at 679.62(d). The Council adopted Amendment 1 to the Scallop FMP in June of 1995 with publication of the final rule implementing this amendment on July 23, 1996 (61 FR 38099). Under Section 2.5.5 of the Scallop FMP the Council intended that areas closed to vessels fishing for groundfish with non-pelagic trawl gear to protect red king crab or red king crab habitat would also be closed to scallop dredging to ensure protection of red king crab. NMFS, therefore, is proposing to amend regulations at 679.62(d), to include the RKCSA and the Nearshore Bristol Bay Trawl Closure area as areas that would also be closed to scallop dredging. Historical data indicate that scallop fishing has not occurred in the RKCSA and the Nearshore Bristol Bay Trawl Closure area; therefore, scallop vessels should not be affected by these closures.

2.0 DESCRIPTION OF MANAGEMENT MEASURE 1 (BRISTOL BAY RED KING CRAB SAVINGS AREA) AND BACKGROUND INFORMATION

2.1 Problem Statement

The dates adopted by the Council in September 1995 for the Bristol Bay Red King Crab Savings Area trawl closure zone, (**Figure 2.1**) does not encompass the entire molting and mating period of red king crabs. Additionally, unobserved impacts of trawling on softshell crab may impact crab rebuilding and future crab harvests by pot fisheries.

2.2. Alternatives Considered

Three main alternative were examined. In addition to the status quo, Alternative 1, additional impacts of a seasonal and year-round closure, as well as an alternative that would seasonally open the northwest portion of the Savings Area, were examined. These alternatives and options are detailed below.

2.2.1 Alternative 1: Status quo, no action. Amendment 37 would be submitted to the Secretary based on the closure period adopted by the Council in September 1995. The Bristol Bay Red King Crab Savings Area (162º to 164º W longitude, 56º to 57º N latitude) would be closed to non-pelagic trawling from January 1 through March 31. The area bounded by 56º to 56º10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established.

2.2.2 Alternative 2: Extend closure period for the Bristol Bay Red King Crab Savings Area to provide increased protection for red king crab. Amendment 37 would be submitted to the Secretary based on one of the closure period options considered. [Note that under any option, the area bounded by 56º to 56º10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established.]

Option A: Six month closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through June 15. The June 15 date corresponds to the opening date for Area 516, which is the area from 162º to 163º W longitude.

Option B (**Preferred**): Year-round closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through December 31.

Option C: Seven month closure. Close the Bristol Bay Red King Crab Savings Area to non-pelagic trawling from January 1 through August 1.

2.2.3 Alternative 3: Close the area based on a modified version of the old pot sanctuary (**Figure 2.2**). Boundaries of the closure would close all waters in the Bering Sea east of a line originating at Cape Constantine, extending to 58°10' N, 160°W to 57°10'N, 163°W to 56°30'N, 163°W to 56°30'N, 164°W, then south to 56°N. After April 1, this closure would extend south to the Alaska Peninsula. This option would require 100% observer coverage for fishing north of 58° and east of 162° and would be limited to May and June. Further, the area between 163° and 164° between 56°30' and 57°00' would not open until April 1 and would be closed upon reaching a red king crab cap in a range of 5,000 to 15,000 red king crab. (Note this alternative deals with both Bristol Bay Red King Crab Savings Area and nearshore Bristol Bay Trawl Closure Area.)

2.3 Background

This analysis includes only new information made available since the Council's September 1995 action on Amendment 37. The EA/RIR draft for public review of Amendment 37, dated August 24, 1995, contained a thorough analysis of alternative areas proposed for closure. The original proposal was for a year-round closure (see section 1.2 of NPFMC 1995), however the document provided a significant amount of information on bycatch and impacts on a week-by-week basis. At its January meeting, the Council notified the public that it intended to revisit its previous action on Amendment 37 at the April meeting, and requested staff to provide additional information on potential impacts of modifying the closure time to 6 months or year-round in duration. At its April 1996 meeting, the Council added the option of a 7-month closure time, and added Alternative 3 for analysis.

This document simply provides supplemental information the Council will take into account when reconsidering their preferred alternative. Refer to the August 24, 1995 draft EA/RIR for more information.

2.4 Additional Information

2.4.1 Biological Information

Additional data on the status and distribution of crab from the 1995 NMFS trawl survey are available (Stevens et al. 1996). The survey revealed that red king crab remain concentrated in the Bristol Bay area, with lower abundance around Nunivak and the Pribilof Islands (**Figure 2.3**) The survey indicated reduced numbers of large red king crab (both sexes) in Bristol Bay. Additionally, the abundance of mature females was at or below threshold (8.4 million), and consequently, no fishery was permitted in 1995. The adjacent table shows the survey index for Bristol Bay and Pribilof Area red king crab by size category for the past few years. Survey indices of abundance for juvenile males and small females were the highest observed in several years. These crab may represent the cornerstone of stock rebuilding, as protection of these crab through maturity may pay off in terms of increased spawning and recruitment in future years.

Abundance of red king crab in from NMFS surveys, 1988-1995, Bristol Bay and Pribilof Areas combined.

		MALES			FEMALES	
		Juveniles	Prerec	Legal	Small	Large
		<110	110-134	>135	<90	>90
1990		8.2	10.2	9.2	7.2	17.5
1991		8.1	6.4	12.0	4.7	12.6
1992		7.0	5.5	5.8	2.2	13.4
1993		5.7	10.2	9.8	2.5	19.2
1994		6.1	6.7	7.5	3.4	10.1
1995	(BBay)	9.5	5.4	6.3	4.8	8.0
	(Pribs)	0.2	0.7	2.6	0.1	2.4

Analysis of red king crab distribution data from 1993-1995 suggests that the Bristol Bay Red King Crab Savings Area contains a significant portion of mature male red king crab (**Table 2.1**). Data indicate that about 40% of the mature males and 30% of all males occur in the savings area. The western portion (163º to 164º W longitude) of the area is comprised almost entirely of males, with less that 1/2% of the females found there. The eastern portion (162º to 163º W longitude) of the savings area (contained in statistical area 516) is occupied by red king crab of both sexes. Approximately 19% of the mature males and 17% of the mature females are found in the eastern portion. These data indicate that the Bristol Bay Red King Crab Savings Area provides substantial habitat for mature red king crab.

Dr. Bob Otto (NMFS-AFSC, Kodiak) has provided information on dates of occurrence for soft-shell king crabs. These materials include some old literature (USFWS Fish. Leaf. nos. 340 and 361. INPFC Annu. Rept. 1963 and 1965), the logbook of the F/V Deep Sea for 1953 (a king crab trawler), data from NMFS winter surveys (1981 and 1983), NMFS April 1976 trawl survey data and series of June data from the standard summer trawl survey. These materials are not entirely comprehensive but provide a sampling over the entire history of domestic king crab fishing in the eastern Bering Sea. They are sufficient to establish the spawning and molting period for king crab in Bristol Bay, however.

Various size-sex-maturity groups that have been vulnerable to trawling or other commercial fishing gear have been found in the process of molting or in a soft shell condition from the last week of January (NMFS trawl survey data 1985) to the end of June (fishery Agency of Japan tangle net data 1960-1965). There is considerable inter-annual variation in the timing of molting for various groups. For example, peak of the molting - mating period for mature females may vary by about one month from one year to the next and the duration of this period may be up to 3 months (26 to 56 days).

Within the first 3-4 years (generally well less than 80 mm carapace length, CL) both sexes may molt at any time of year and the frequency of molting declines from 8-10 molts in the first year of life to perhaps twice in the year leading up to the female primiparous (first maturity molt). The exact transition from multiple annual molts to single annual molts is not known for the Bristol Bay population but seems to be correlated with the onset of sexual maturity. Note also that juveniles smaller than 80 mm have not been commonly found in the area west of 162° W longitude over the past 10 years although they were common, especially at stations immediately adjacent to Unimak Island during the 1970s.

Among larger juveniles and adults, various size-sex-maturity groups molt at differing relative times in the late winter to early summer period. As they approach maturity females (50% mature at 89 mm CL, ca 4-6 years depending on thermal history), juveniles and all males tend to have a late winter-early spring molt. Mature females spawning for the first time tend to molt early relative to multiple spawners which are generally last (May-June) to molt and spawn in a given session.

Figures 2.4-2.5 illustrate the occurrence of soft-shelled king crab in late winter-spring NMFS surveys in 1976, 1983 and 1985. These data clearly showed that the onset on the molting period could be as early as late January and that in 1976 molting was essentially complete in April for both red and blue king crab. Note especially that red king crab in a wide range of sizes of both sexes were molting during late winter in 1983 and 1985. **Figure 2.6** shows the percent of females carrying eyed embryos or empty cases (i.e., the previous year's reproductive products) in June of each year from 1975 through 1989 (from Otto, MacIntosh and Cumminskey 1989). These are females that had not yet molted in the given year and hence give a good indication of the inter-annual variation in the timing of molting at least for females. Note also that, along with the January-February, this figure shows that molting occurred from February until at least June in 1983 and from the last week of January until at least June in 1985. Similar variation has occurred in the June data in subsequent years. In 1995, NMFS had a unique opportunity to look at crab in June due to the survey funded by the Bering Sea Crab Survey Fund. Molting and soft red king crab were still being taken on the last day, June 22, 1995, of this survey.

The bottom line is that for the size and sex groups likely to be encountered by survey or various types of commercial gear, the molting period may extend from late January to the end of June, and that timing varies by something like a month from year to year. Timing of last molting/spawning (May or June) seems to be more variable than the onset (ca February 1). After molting, it takes approximately 1 month for shells to harden from a softshell to hardshelled condition, based on laboratory observations (Tom Shirley, University of Alaska, personal communication).

Alternative 3 would provide habitat protection in nearshore areas, but may result in increased impacts on red king crab because a portion of Area 512, Area 516, and the Red King Crab Savings Area would be open to trawling. Survey data indicate that crab are found in abundance outside the Alternative 3 closure area (**Table 2.2**). Survey data, 1993-1995 indicate that about 38% of mature male and 12.5% of the mature female red king crab are found outside the proposed closure area. About 8% of the stock occurs in the portion of Area 512 and 516 (the triangle area) that would be open under this alternative. About 22% of the mature males (but almost no females) occur in the northwest corner block of the Red King Crab Savings Area that is proposed to be open after April 1 with a separate PSC cap. Although no king crab were taken in area south of 56° N and between 163° and 164° W during the 1993-1995 summer trawl surveys, the area is still considered to be red king crab habitat (B. Otto, NMFS, personal communication).

2.4.2 Economic Information

As a supplement to Amendment 37 (Bristol Bay Red King Crab Savings Area) which examined a year round closure of the red king crab savings area, the Bering Sea Fishery Simulation model was run to estimate the net benefits to the nation from a three-month or a six-month closure to all trawling. In addition, the history of directed fishing for yellowfin sole, flatfish, other flatfish, and rock sole in the closure area was examined from Joint Venture (JV) fisheries (1986-1989). The complete 1994 dataset was available and has been included in this section as well. The data are from observed hauls only (unexpanded) as has been presented in previous analyses. The JV data differs from previous uses of the data in that target assignment uses the current definition based on major species group. This may vary slightly from any reports based on the older algorithms for assigning target such as Amendment 21b (Chinook salmon bycatch).

The Bering Sea Fishery Simulation Model results in **Table 2.3** are for the entire season, for a three month closure (Jan. 1 - April 1) and for a 5.5 month closure (Jan. 1 - June 15) for Alternative Areas 2-4. Alternative Areas considered under Amendment 37 are detailed in the Executive Summary of the EA/RIR dated August 24, 1995 (see **Appendix 1**). As with the final analysis (Amendment 37), the model runs predicted no substantial change in net benefits to the nation due to the closure from status quo (no closure). Under the initial runs with an annual closure, the net benefits to the nations were estimated to increase from status quo by 1.4% under Alternative Area 3 (the preferred alternative; known as the Red King Crab Savings Area) based on the 1993 data. The net benefits to the nation were estimated to decrease from status quo by 2.3% under Alternative Area 3 using the 1994 data.

Examining the impacts of seasonal closures, the estimated net benefits to the nation under a three month closure increased by only approximately $10,000 over an annual closure, and the six month closure caused a $4,000 decrease in net benefits to the nation. Given the scale of revenues generated by BSAI fisheries, there is essentially no difference between these closure periods. Similarly, model runs with the 1994 data estimated the seasonal closures under Alternative Area 3 changed the net benefits to the nation by a negligible amount of less than $1,000 from an annual closure. There were no estimated differences in net benefits to the nation between a 3 month closure and a six month closure using the 1994 data which indicates no fishing activity in the area between March and July in 1994.

Table 2.4 provides the observed catch in metric tons, number of hauls, and observed bycatch in numbers of red king crab, tanner crab, and halibut in the yellowfin sole, flatfish, other flatfish, and rock sole fisheries during the period 1986-1994. The percentage of the total observed catch and bycatch that occurred within the Red King Crab Savings Area in these domestic and JV fisheries are provided as well. Whereas only the first four months of 1994 were available for inclusion in Amendment 37, the data provided in **Table 2.4** are for the entire year.

The percentage of yellowfin sole catch within the Red King Crab Savings Area increased from approximately 10% in the 1986 JV fishery to approximately 80% in 1989 (See also **Figure 2.7**). The importance of the area to the yellowfin sole JV fishery is in sharp contrast to that reported in Amendment 37. The domestic fisheries for yellowfin sole, as reported in the EA/RIR, took less than 1% of their catch from the closed area in three of the five years 1990 - 1994, and took 8% and 5% in 1992 and 1994, respectively. However, approximately 96% of the yellowfin sole bycatch of red king crab was taken in the closure area in 1989, and the high bycatch of red king crab was one of the reasons that the domestic fisheries for yellowfin sole and flatfish were delayed until May 1 between 1990 and 1993. In 1989, the majority of the yellowfin sole catch and bycatch of red king crab occurred during the first two months of the year.

Between approximately 60% and 80% of the JV flatfish fishery bycatch of red king crab was from the closure area in 1986, 1988 and 1989 (**Table 2.4** and **Figure 2.7**). This percentage was reduced between 1990 and 1993, possibly due to the delay of the flatfish season until May 1, but increased in 1994 to approximately 45% when the season was changed back to January 20 (see **Appendix 3** for history of season opening dates for the BSAI yellowfin sole fishery). The increasing importance of the closure area to the rock sole fishery, as reported in Amendment 37, was also apparent in the JV fisheries, and a fairly consistent percentage of red king crab bycatch to come from the closure area (40% - 80%) is also evident.

It is interesting to note that, with few exceptions, the percentage of halibut taken within the Red King Crab Savings Area is similar to the percentage of groundfish catch across fisheries. This indicates that the bycatch rate for halibut is similar inside and outside of the closure area. By contrast , the percentage of red king crab within the closure area is consistently higher than the catch percentage, and the percentage of Tanner crab bycatch is consistently lower.

The Council's preferred alternative (decision of September 1995) also specified that the area bounded by 56° to 56°10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established. This area has been productive to the rock sole fishery. The amount of groundfish taken in the rock sole fishery coming from Zone 1 within this 10' slice ranged from 13% to 35% during the years 1990- 1994. However, this area has also accounted for a relatively high percentage of the Zone 1 red king crab bycatch, ranging from 12% to 47% during the same period.

Red King Crab Closure Alternative 3

The orientation of Alternative 3, which is an approximation of the historic pot sanctuary, does not correspond with the boundaries of the Northern Bristol Bay closure, the Red King Crab Savings Area, or Areas 516 or 512, making it difficult to compare this alternative with the others proposed (**Figure 2.8**). For instance, if the percentage of directed catch within the pot sanctuary is similar to the percentage of directed catch within the Red King Crab Savings Area, it is difficult to discern whether the similarity is because of the portion of the areas which overlap or due to other factors such as coincidental additional fishing effort in northern Bristol Bay. It is also not possible to know the potential bycatch implications of opening the northwest corner of Area 512 to trawling since it has been closed since 1987. Similarly the impacts of opening the northern portion of Area 516 to trawling between March and June are unknown.

The pot sanctuary (Alternative 3) excludes the northwest block of the Red King Crab Savings Area after March 31. Because the rock sole fishery had been mainly focused in the southern and eastern blocks of the Red King Crab Savings area during the first 3 months of the year, the directed catch and bycatch of king crab are nearly identical between the pot sanctuary and the Savings Area in the rock sole fishery (see **Table 2.4** and **Table 2.5**). Since the areas fished by the rock sole fishery are within an area shared by the two boundaries, the catch and bycatch percentages between the two closure areas are comparable.

However, the yellowfin sole fishery utilizes portions of the Red King Crab Savings Area, the Northern Bristol Bay area, and portions of Area 516 which had historically been available to the fishery. The yellowfin sole fishery has also historically utilized the northwestern block of the Red King Crab Savings Area which is not included in the pot sanctuary (Alternative 3). In 1987, most of the effort by the yellowfin sole fishery in the Red King Crab Savings Area was in the northwest block, and 15% of directed catch and 6% of king crab bycatch came from this block. These percentages are essentially the same as those for the Red King Crab Savings area in that year (**Table 2.4**). As can be seen in **Table 2.5**, nearly 60% of the red king crab bycatch came from within Alternative 3, the pot sanctuary in 1987. That year was one of the few in which directed fishing occurred in Area 516, and 77% of the yellowfin sole observed bycatch of red king crab were taken in the portion of Area 516 which is north of the Red King Crab Savings Area during the month of April. The locations of the high bycatch hauls are provided in **Figure 2.9**.

As was discussed previously, the yellowfin sole fishery took an increasingly greater portion of its directed catch from the Red King Crab Savings Area in the Joint Venture fisheries during the period 1986-1989. This is reflected in the increasing proportions of catch and king crab bycatch within the Red King Crab Savings Area (**Table 2.4**) and within the pot sanctuary approximated by Alternative 3 (**Table 2.5**) in each year.

In 1991, the yellowfin sole fishery did not fish in the Red King Crab Savings Area, and 27% of the king crab taken in that fishery within the pot sanctuary (Alternative 3) were taken in the Northern Bristol Bay portion of the sanctuary. In 1992 and 1993, essentially all of the red king crab taken in the Red King Crab Savings Area were taken in the northwestern block not included in the pot sanctuary (27% and 17%, respectively), and virtually no king crab were taken within the proposed Alternative 3, because all of the effort was in the northwestern block of the Savings Area.

Compared with catch percentages, the highest bycatch percentages of red king crab taken by the yellowfin sole fishery occur within the Red King Crab Savings Area, and in the portion of the proposed Northern Bristol Bay closure area outside of the two blocks under Option A (See section 5). Relatively high percentages of king crab bycatch have also occurred in the northwest block of the Red King Crab Savings Area not included in the area bounded by Alternative 3, as well as in Area 516.

The extension of the pot sanctuary (Alternative 3) south of 56° N latitude to the Alaska Peninsula and east of 164° W longitude to Area 512 would not impact the yellowfin sole fishery since there has historically been little fishing activity by the fishery in that area (**Table 2.5**). The rock sole fishery is concluded prior to the proposed closure date (April 1) of this area, and the impacts on the flatfish or other flatfish fisheries would be negligible because these fisheries have rarely fished in the area after March in any year.

3.0 DESCRIPTION OF MANAGEMENT MEASURE 2 (MODIFY CRAB PSC BYCATCH LIMITS) AND BACKGROUND INFORMATION

3.1 Problem Statement

Bycatch limits for red king crab and Tanner crab established for Bering Sea fisheries may be too high given current status of crab stocks, and bycatch may impact crab rebuilding and future crab harvests by pot fisheries. Bycatch limits for snow crab have not been established.

3.2. Alternatives Considered

Three main alternatives were examined for each of the three crab species. In addition to the status quo, Alternative 1, the impacts of a reduced fixed bycatch limit and floating caps were examined. These alternatives, shown graphically by **Figures 3.1-3.4**, are listed separately for each crab species.

3.2.1 RED KING CRAB

Alternative 1: Status quo, no action. PSC limits would remain at 200,000 red king crab in Bycatch Limitation Zone 1.

Alternative 2: Reduce PSC limits of red king crab. PSC limits would be reduced to a fixed level at 180,000 red king crab based on a three year average (1992-1994)

Option A: Further reduce the red king crab PSC limit in Zone 1 to 35,000 crab, which was the number of red king crab bycaught in 1995 within Zone 1.

Alternative 3: Establish PSC limits for red king crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey[1]. Limits would be established based on a rate specified, within the range 0.1-1.0% of red king crab in the Bristol Bay District.

Option A: Set a fixed upper limit for PSC at 200,000 red king crab in Zone 1.

Alternative 4 (**Preferred**): Establish a stairstep based PSC limit for red king crab in Zone 1. PSC limits would be based on abundance of Bristol Bay red king crab as follows:

(A) When the number of mature female red king is equal to or below the threshold number of 8.4 million crab, or the effective spawning biomass (ESB) is less than 14.5 million pounds, the Zone 1 red king crab PSC limit would be 35,000 crabs;

(B) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 14.5 but less than 55 million pounds, the Zone 1 red king crab PSC limit would be 100,000 crabs; and

(C) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 55 million pounds, the Zone 1 red king crab PSC limit would be 200,000 crabs.

3.2.2 TANNER CRAB

Alternative 1: Status quo, no action (**Council's Preferred Alternative, June 1996**). PSC limits would remain at 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

---

[1] Total population index is the sum of all size/sex groups, which are calculated by extrapolating the average CPUE of each size/sex group over the geographic area of each district.

Alternative 2: Reduce PSC limits of Tanner crab. PSC limits would be reduced to a fixed level of 900,000 Tanner crab in Zone 1, and within the range of 1,500,000 to 2,100,000 Tanner crab in Zone 2.

Alternative 3: Establish PSC limits for crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey. Limits would be established based on a rate specified, within the range 0.10-2.0% of Tanner crab in the Eastern District, as indexed by the survey. PSC limits for each zone would be set either by apportioning the overall cap among the zones (25% to Zone 1 and 75% to Zone 2) or by setting separate PSC rates for each zone, rather than apportionment of a single rate.

Option A: Set a fixed upper limit for Tanner crab PSC at 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

Option B: Establish PSC limits for Tanner crab based on abundance thresholds. Limits would be set as a percentage of population when abundance is less than 100 million crab. In years when Tanner crab abundance is more than 100 million, but less than 250 million, PSC limits would be established at 850,000 Tanner crab in Zone 1, and 1,500,000 in Zone 2. In years when Tanner crab abundance is more than 250 million, but less than 500 million, PSC limits would be established at 900,000 Tanner crab in Zone 1, and 2,300,000 in Zone 2. In years when Tanner crab abundance exceeds 500 million, PSC limits would be established at 1,000,000 Tanner crab in Zone 1, and 3,000,000 in Zone 2.

3.2.3 SNOW CRAB

Alternative 1: Status quo, no action (**Council's Preferred Alternative, June 1996**). No PSC limits would be set for snow crab.

Alternative 2: Establish a fixed PSC limit for snow crab. Based on a three year average (1992-1994), a PSC limit would be established at a fixed level of 11,000,000 snow crab in Zone 2. No snow crab PSC limit would be established for Zone 1, as bycatch in this area has been minuscule by comparison.

Option A: Establish PSC limit at 6 million snow crab in Zone 2.

Alternative 3: Establish snow crab PSC limits for snow crab that fluctuate with crab abundance. Annual PSC limits would be set as a percentage of the NMFS bottom trawl survey index. Limits for Zone 2 would be set at a percentage within the range 0.005 to 0.25% of the snow crab total population index (all districts combined). No snow crab PSC limit would be established for Zone 1.

Option A: Set fixed upper limit for PSC at 12 million snow crab in Zone 2.

3.3 Background

In January 1995, the Council initiated several analyses to examine impacts of proposals to control crab bycatch in the groundfish fisheries. Among these proposals is a reduction of existing crab bycatch limits (with an option that the limits be based on crab abundance), and initiation of bycatch limits for snow crab. The Council suggested specific alternatives for PSC bycatch limits be examined, based on input from it's Advisory Panel and a proposal by the State of Alaska.

At its January 1996 meeting, the Council requested that staff examine the suite of management measures (modified Crab Savings Area, crab PSC bycatch limits, and northern Bristol Bay closure area) in one package, so that the impacts of these measures can be analyzed in a comprehensive manner. An additional option of establishing PSC limits for Tanner crab based on abundance thresholds, was proposed by the Alaska Crab Coalition in January 1996, and was added to the analysis at the request of the Council. One set of possible thresholds is analyzed as Alternative 3, Option B.

The threshold limits proposed under Tanner crab Alternative 3, Option B were developed from historical bycatch data. The lower threshold "steps" were based on average levels of bycatch observed when Tanner crab abundance was at that level. For Step 1 (100-250 million crab), the proposed PSC limit (850,000 Tanner crab in Zone 1, and 1,500,000 in Zone 2) would be established at approximately the average bycatch observed for 1994 and 1995. Average abundance in 1994/1995 was 191 million crab of all sizes. For Step 2 (250-500 million crab), the proposed PSC limit (900,000 Tanner crab in Zone 1, and 2,300,000 in Zone 2) would be established at levels intermediate between Steps 1 and 3. These levels for Step 2 are slightly lower levels than the average bycatch observed for 1992 and 1993. Average abundance of Tanner crab in 1992/1993 was 347 million crabs of all sizes. For Step 3 (years when Tanner crab abundance exceeds 500 million), PSC limits would be established at 1,000,000 Tanner crab in Zone 1, and 3,000,000 in Zone 2. These are the current PSC limits, which were negotiated in 1988 when abundance exceeded 500 million Tanner crabs.

Because over a year had passed before the Council had time available to address crab bycatch management, the analysts made several modifications to the Council's specified alternatives for proposed management measure 2. First, red king crab Alternative 2, Option A was added because implementation of the Bristol Bay Red King Crab Savings Area had greatly reduced bycatch of red king crab in Zone 1. Second, under Tanner crab Alternative 2, PSC limits for Tanner crab were based on a 2-year average (1993-94) rather than a three year average. An obvious trend in bycatch reduction from 1992 through 1994 was observed, and 1995 bycatch was about the level proposed under this alternative.

At its April 1996 meeting, the Council modified the alternatives to include reduced PSC limits for Tanner crab and snow crab. The range of PSC rates for red king crab and Tanner crab were also reduced, as data indicated that bycatch in 1995 was much lower than in previous years. The Council also requested the analysts also include some discussion regarding the Crab Rebuilding Committee's recommendation that PSC limits proposed under Alternative 3 be based on survey index of adult crab, rather than total population. The SSC noted that modification of PSC rates should occur as a separate, follow-up amendment.

Red king crab Alternative 4 was developed by the BSAI Crab Plan Team at its June 1996 meeting. The Team noted the SSC also had concerns with PSC limits based on an index of the entire crab population abundance and concurred with the SSC that new PSC limits should be analyzed in the future using more representative “currency”. The Team concluded that a currency based on both number and weight of crab similar to the State’s definition of threshold for Bristol Bay red king crab was an improvement over just using numbers of crab. The Council identified red king crab Alternative 4 as its preferred alternative for this species at its June 1996 meeting.

Final action was taken on Tanner crab at the Council's September 1996 meeting and will move forward under a separate amendment. Final action on snow crab is expected at the December 1996 Council meeting.

3.3.1 Bycatch Management

In harvesting groundfish, fisheries catch crab incidentally as bycatch. Among the objectives of the BSAI groundfish FMP is minimizing the impact of groundfish fisheries on crab and other prohibited species, while providing for rational and optimal use of the region's fishery resources. All gear types used to catch groundfish have some potential to catch crab incidentally, but the large majority of crab bycatch occurs in dredge and trawl fisheries.

Fishery managers and crab fishing representatives have been concerned with mortality of crab captured incidentally in scallop dredge and groundfish trawl fisheries and its impact on crab stocks (NPFMC 1986, Thomson 1989, NPFMC 1995). To address these concerns, crab bycatch limits were established for trawl fisheries beginning in 1986. Bycatch limits (termed Prohibited Species Catch limits, or PSC) for crab are apportioned into limitation zones (**Figure 3.5**), and allocated among groundfish trawl fisheries. Current crab PSC limits are 1,000,000 Tanner crab and 200,000 red king crab in Zone 1 and 3,000,000 Tanner crab in Zone 2. To allocate total groundfish harvest under established PSC limits, PSC is apportioned among trawl fisheries during the annual specification process (e.g., **Table 3.1**). When a target fishery attains a PSC apportionment or seasonal allocation specified in regulations, the bycatch zone to which the allocation applies closes to that target fishery for the remainder of the season.

Crab bycatch management has become increasingly complex over the past ten years. Bycatch limits for domestic fisheries were first established in 1987 under BSAI groundfish FMP Amendment 10, which specified red king crab and Tanner crab PSC limits for the yellowfin sole/other flatfish fishery only (NPFMC

1986). PSC limits of 135,000 red king crab and 80,000 Tanner crab in Zone 1, and 326,000 Tanner crab in Zone 2 were negotiated between representatives of crab and groundfish fishermen. In 1989, under FMP Amendment 12a, crab PSC limits were extended to the remaining trawl fisheries and crab PSC limits were increased to the current levels. These limits were further apportioned among joint-venture (JV) flatfish fisheries, other JV fisheries, domestic flatfish fisheries, and other domestic fisheries. FMP Amendment 16, adopted in 1990, authorized seasonal apportionment of PSC limits, and apportioned the trawl PSC limits for 1991 into allowances for domestic turbot, rock sole, yellowfin sole/other flatfish, other domestic groundfish, and JV flatfish. More recently, PSC limits for crab have been apportioned among the following trawl fisheries: yellowfin sole, rock sole/other flatfish, turbot/sablefish/arrowtooth, rockfish, Pacific cod, and pollock/Atka mackerel/other species. In 1996, crab PSC was also seasonally apportioned for the first time.

In addition to red king crab and Tanner crab, PSC bycatch limits for trawl fisheries are also established for Pacific halibut, Pacific herring, chinook salmon, and chum salmon. Halibut PSC is measured in metric tons of halibut mortality and allocated among trawl (3,775 mt) and hook & line (900 mt) gear. The annual trawl halibut PSC is allocated among the Pacific cod, yellowfin sole, rock sole, pollock/mackerel/other species, rockfish, and sablefish/turbot/arrowtooth fisheries. Both the trawl and hook and line PSC limits are seasonally allocated among fisheries. When a fishery exceeds its seasonal limit, the entire Bering Sea is closed for that fishery for the remainder of the season. The herring PSC limit is set at 1% of stock biomass. Attainment of herring PSC limits triggers seasonal trawl closures of one or all of the three designated Herring Savings Areas. The chinook PSC limit is 48,000 chinook salmon, which when reached would trigger three trawl closure areas. These areas would then re-open to trawling on April 16th for the remainder of the year. A chum salmon PSC reduction plan was established by Amendment 35. Under this plan, the Chum Salmon Savings Area is closed from August 1 to September 1, but this area opens September 2, until a 42,000 cap is reached (accounting to begin August 15 in the catcher vessel operational area). A triggered closure area reopens to trawling on October 15th.

Halibut PSC is the primary limiting factor for most fisheries harvesting groundfish (Smith 1992, 1993). In the majority of the groundfish fisheries the PSC closure is caused by attainment of the halibut PSC. In 1995, with the exception of Zone 1 Tanner crab PSC closures for yellowfin sole and Pacific cod, all of the Prohibited Species closures were caused by halibut. Halibut PSC also restricts the attainment of red king and Tanner crab PSC limits. Without the restrictive halibut PSC limits, the bycatch of both red king and Tanner crab could reach the full crab PSC.

In addition to crab PSC limits, other measures have been taken to reduce the incidental capture of crabs in groundfish fisheries, including a vessel incentive program (VIP) and gear restrictions. The intended effect of the VIP program is to increase the opportunity to harvest groundfish TACs (quotas) before established PSC limits are reached. The VIP program is based on specification of bycatch rate standards that, when exceeded, constitute a violation of the regulations implementing the VIP. In the BSAI, current bycatch rate standards are 2.5 red king crabs per ton of groundfish in the yellowfin sole and non-pollock trawl fisheries in Zone 1. Very few cases have been prosecuted for VIP violations, however. Minimum mesh sizes regulations recently adopted for trawl fisheries may reduce the bycatch of juvenile crabs. Gear restrictions have been implemented in the groundfish pot fishery to reduce the potential for ghost fishing by lost pots by requiring a biodegradable panel constructed of # 30 or less cotton thread that is a minimum of 18" long, parallel to and within 6" of the bottom of each pot.

Crab PSC limits have also been established for scallop dredge fisheries. Crab bycatch caps were instituted by the State for the weathervane scallop fishery beginning in 1993, along with a mandatory observer program (100% coverage). In areas other than the Bering Sea, crab bycatch caps were set at 1% of the population if the crab fishery was open, and 1/2% the population if the crab fishery was not open. In the Bering Sea, crab bycatch caps were based on a preferred bycatch rate, extrapolated to a limit based on the projected number of vessels participating and limited season length. For 1994, Bering Sea crab caps were 260,000 Tanner crab and 17,000 red king crab. Crab bycatch limits were also adopted by the Council in June 1995 as part of Amendment 1 to the Federal scallop FMP. For the Bering Sea scallop fishery, crab PSC limits would be set annually as a percentage of the NMFS survey abundance index of Tanner crab (0.13542%) and snow crab (0.003176%). These allowable bycatch percentages equated to about 260,000 Tanner crab and 300,000 snow crab based on 1994 abundance. A PSC limit for red king crab within the range of 500 to 3,000 crab would be set during the annual specification process. Amendment 1 to the Scallop FMP was implemented on August 29, 1995 (60 FR 42070, August 15, 1995).

3.3.2 Biology of Major Bering Sea Crab Resources

Red King Crab

Growth and maturation of red king crab are size and age dependent. King crab molt from 8 to 11 times during the first year and 8 more times by the age of 3 after which molting is annual. At larger sizes, king crab may skip molt as growth slows. Average growth increment for mature crabs between molts is 16-20 mm. Mean age at recruitment is 8-9 years (McCoughran and Powell 1977). Females grow slower and do not get as large as males (**Table 3.2**). Sexual maturity is reached at approximately 7 years (Schmidt and Pengilly 1990). Fifty percent maturity is attained males at 120 mm carapace length and 90 mm for females (Otto et al. 1980). Red king crab mate when they enter shallower waters (<50 m), generally beginning in January and continuing through June. Males grasp females just prior to female molting at which time the female is grasped and eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female abdomen. The female red king crab carries the eggs for 11 months before they hatch, generally in April.

An overview of year-class strength formation and survival of Bristol Bay red king crab is provided by Tyler and Kruse (1995b). After hatching, crab larvae drift generally from the spawning area nearshore along Unimak Island and the Alaska Peninsula in the direction of Bristol Bay (Armstrong et al. 1993). Red king crab spend 3 to 4.5 months in larval stages before settling to the benthic life stage . Young-of-the-year crab occur at depths of 50 m or less. They are solitary and need high relief habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans and stalked ascidians (Jewett and Onuf 1988, Stevens et al. 1992, Armstrong et al. 1993). McMurray et al. (1984) found that biological parameters were better correlated with juvenile crab distributions than were physical parameters. Age 0+ to two year old crab were statistically correlated with sea urchin biomass, and older juvenile crab were correlated with sea onion biomass (McMurray et al. 1984). Citing McMurray, in absence of epifauna, age 1+ crab were found to prefer medium-size rock over gravel, sand or small rocks, however the preference was for epifauna when available (Jewett and Onuf 1988). The survival of 1-yr-old crabs was found to be related to cohort density and cover, with mortality due to density (cannibalism) being significant only when no cover was available (Rounds et al. 1989).

Habitat requirements for red king crab are much different for older age crab. Between the ages of two and four years, there is a decreasing reliance on habitat and a tendency for the crab to form pods consisting of thousands of crab (Jewett and Onuf 1989, Dew 1990, Stone et al. 1993). Podding continues until approximately 65 mm or four years of age when the crab move to deeper water (>50 m) and join adults in the spring migration to shallow water for spawning and deep water for the remainder of the year. Adult red king crab generally live in deeper waters. Distribution of adult male red king crab in Bristol Bay is shown by **Figure 3.6**.

Natural mortality of adult red king crab is estimated at about 25% per year (M=0.3), due to old age, disease, and predation. There is little information available on red king crab predators across the range of life-stages (Jewett and Onuf 1988). Haflinger and McRoy (1983) reported on consumption of crab glaucothoe larvae in numbers which Jewett and Onuf (1988) considered to be insignificant. Livingston (1989) reported on Pacific cod predation of molting red king crab of which Livingston states that the percentages removed by cod form a small and declining part of the total population decline.

Tanner Crab

Tanner crab (C. bairdi) are distributed on the continental shelf of the North Pacific Ocean and Bering Sea from Kamchatka to Oregon. Off Alaska, Tanner crab are concentrated around the Pribilof Islands and immediately north of the Alaska Peninsula (**Figure 3.6**), and are found in lower abundance in the Gulf of Alaska. Tanner crab grow rapidly, with large molt increments (**Table 3.2**). Size at 50% maturity, as measured by carapace width, is 110 mm for males and 90 mm for females. The corresponding age of maturity for male BSAI Tanner crab is about 6 years. Growth during the next molt increases the size of males to about 120-140 mm. Mature male Tanner crabs may skip a year of molting before attaining legal size (Donaldson et al. 1981). The minimum harvest size is 140 mm (5.5", or about age 7). Natural mortality of adult Tanner crab is estimated at about 25% per year (M=0.3).

Tanner crab females are known to form high-density mating aggregations, consisting of hundred of crabs per mound. These mounds may provide protection from predators and also attract males for mating (Stevens et al. 1994). Mating need not occur every year, as female Tanner crabs can retain viable sperm in spermathecae up to 2 years or more (Paul 1984).

Snow Crab

Snow crabs 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 crabs are rare at depths greater than 200 meters (**Figure 3.6**). The eastern Bering Sea (EBS) population within U.S. waters is managed as a single stock, however, the distribution of the population extends into Russian waters to an unknown degree.

Growth patterns of snow crab in the EBS are extremely complex and not well understood. While 50% of the females are mature at 50 mm, the mean size of mature females varies from year to year over a range of 63 mm to 72 mm carapace width (CW). Females cease growing with a terminal molt upon reaching maturity, and rarely exceed 80 mm CW. Males similarly cease growing upon reaching a terminal molt when they acquire the large claw characteristic of maturity. The median size of maturity for males is 65 mm CW (approximately 4 years old). Males larger than 60 mm grow at about 20 mm per molt, but individuals vary widely in this regard. Average width at age is shown in **Table 3.2**.

Only adult males are harvested. Average sizes of crab taken in the EBS fishery ranged from 105 mm to 118 mm (0.5 kg to 0.63 kg) for the years 1977 to 1994. In recent years, only 1% of snow crabs harvested in the fishery exceeded 140 mm. The legal size limit is 78 mm and is thought to allow at least one opportunity to breed based upon a median size of maturity of 65 mm CW. Small males are not marketable and processors traditionally have not purchased crabs smaller than 102 mm CW (4.0 inches).

Female snow crabs are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Presumably, this reproductive strategy evolved to maintain reproductive potential of populations at times when distributional factors prevent females from finding mates.

Snow crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, crustaceans (including other snow crabs), polychaeta and other worms, gastropods, and fish. In turn, they are consumed by a wide variety of predators including Pacific cod, halibut and other flatfish, eel pouts, sculpins, and skates. In the northern part of the range, they are preyed upon by bearded seals and sometimes make up all of the seal's stomach contents.

3.3.3 Status and Management of Bering Sea Crab Stocks

Offshore areas of Bristol Bay have supported large fisheries for red king crab, Tanner crab, and snow crab. In the past few years, however, these stocks have declined to low levels, such that no fishery for king or Tanner crabs occurred in Bristol Bay east of 163° W in 1994 or 1995.

Crab stocks in the Bering Sea are managed by the State of Alaska through a federal BSAI king and Tanner crab fishery management plan (FMP). Under the FMP, management measures fall into three categories: (1) those that are fixed in the FMP and under Council control, (2) those that are framework measures that the State can change following criteria outlined in the FMP, and (3) those measures under complete discretion of the State. Under this plan, conservation and rebuilding of crab is mainly at the State's discretion.

The State sets pre-season guideline harvest levels for red king crab, Tanner crab, and snow crab. For red king crab, harvest rates have been set based on a mature male harvest rate of 20%, with a harvest cap of 60% of legal male abundance (Pengilly and Schmidt 1995). The Alaska Board of Fisheries recently approved reducing the harvest rate for Bristol Bay red king crabs to 10% of the mature males to allow stock rebuilding (see **Appendix 6**). Minimum legal size for Bristol Bay red king crab is 165 mm, or 6.5 inches in carapace width. [Note: 165 mm carapace width corresponds to a 137

Management measures used to manage king and Tanner crabs in the BS/AI management unit category.

Category 1 (Fixed in FMP)	Category 2 (Frameworked in FMP)	Category 3 (Discretion of State)
* Legal Gear	* Minimum Size Limits	* Reporting Requirements
* Permits Requirements	* Guideline Harvest Levels	* Gear Placement and
Removal		
* Federal Observer Requirements	* Inseason Adjustments	* Gear Storage
* Limited Access	* Districts, Subdistricts and Sections	* Gear Modifications
* Norton Sound Requirements	* Fishing Seasons	* Vessel Tank Inspections
		* State Observer
Superexclusive Registration Area	* Sex Restrictions	* Bycatch Limits (in crab fisheries)
	* Closed Waters	* Other
	* Pot Limits	
	* Registration Areas	

mm carapace length for Bristol Bay red king crabs (Pengilly and Schmidt 1995).] Harvest rates for Tanner crab and snow crab are set based on a mature male harvest rate of 40% for Tanner crab and 58% for snow crab larger than 4 inches (D. Pengilly, ADF&G, personal communication). Minimum legal size for Bering Sea Tanner crab is 140 mm (5.5 inches) carapace width. Although the minimum legal carapace width for snow crab is 78 mm (3 inches), the fishery generally harvests snow crab larger than 4 inches. [Note in 1995, for example, about 18.8% of snow crabs harvested were <4" (R. Morrison, pers. comm.).]

In addition to minimum size and sex restrictions, the State has instituted numerous other regulations for the Eastern Bering Sea crab fisheries. The State requires vessels to register with the state by obtaining licenses and permits, and register for each fishery and each area. Observers are required on all vessels processing crab in the BSAI. Season opening dates are set to maximize yield per recruit and minimize handling of softshell crabs. The season opening date for Tanner crab and Bristol Bay red king crab fisheries is November 1. The snow crab fishery opens January 15. Pot limits have been established based on vessel size. For these fisheries, the pot limits are 250 for vessels > 125 feet, and 200 for vessels < 125 feet. Gear restrictions have been implemented to reduce bycatch of non-target crab. A 3" maximum tunnel height opening for Tanner and snow crab fisheries inhibits bycatch of red king crab. A minimum mesh size of 7.75" stretched is required for Bristol Bay red king crab fishery. Escape rings were recently adopted by the Board to reduce capture and handling mortality of non-target crab (see **Appendix 6**). Other gear restrictions include a requirement that crab pots be fitted with a degradable escape mechanism consisting of #30 cotton thread or a 30-day galvanic timed release mechanism. Degradable escape mechanisms are designed to reduce ghost fishing by lost pots.

Red King Crab

After declining abundance throughout the 1960's and reaching a low during the years 1970-1972, recruitment to the Bristol Bay red king crab stock increased dramatically. New all-time record landings were established in each year from 1977 to 1980 (**Figure 3.7**), followed by an abrupt decline in 1981 and 1982. Removals of legal males exceeded the 20% harvest rate in 1980 and 1981, and these high harvest rates contributed to the crash of this stock (Zheng et al. 1995). The stock collapse led to a closure of the Bristol Bay fishery in 1983. In 1984 the stock showed some recovery and a limited fishery was reestablished. Between 1984 and 1993, the fishery continued at levels considerably below those of the late 1970's. Landings during this period ranged from 0.8 million crab to 3.1 million crab. Catches exceeded the 20% mature male harvest rate in 1990, 1991, and 1993 (Zheng et al. 1995). After 1993, the stock declined again, and no fishery occurred in 1994 and 1995.

The fishery was canceled due to low abundance of females. The abundance index for mature female crab fell from 14.2 million crab in 1993 to 7.5 million crab in 1994, and was hence below the threshold value of 8.4 million crab established pursuant to the Fishery Management Plan for King and Tanner crabs in the Bering Sea and Aleutian Islands. Adult male abundance also declined. The 1994 abundance index for legal male Bristol Bay red king crab was 5.5 million crab as compared to 7.3 million in 1993 (**Table 3.3**). These declines were corroborated by the length-based assessment model that was newly developed by the Alaska Department of Fish and Game (Zheng et al. 1994)(**Table 3.4**). Because the abundance of female crab was below threshold, the Bristol Bay red king crab fishery was closed in 1994, as was the fishery for Tanner crab in Zone 1 east of 163° West longitude. The red king crab fishery remained closed in 1995, as the 1995 NMFS survey indicated a female stock size at or below threshold. The Bristol Bay red king crab stock continues to suffer from a long period of low recruitment abundance indices for juvenile crab (**Figure 3.8**).

Tanner Crab

The eastern Bering Sea Tanner crab (C. bairdi) stock is currently at very low abundance (**Table 3.5**). The 1995 NMFS bottom trawl survey indicated relatively low levels of juveniles, pre-recruits, females, and large males (**Figure 3.8**). The 1995 Tanner crab season produced only 4.5 million pounds for the 196 vessels participating. This is the lowest catch since the fishery reopened in 1988. The stock is at historic low levels, however, a bycatch of Tanner crab was allowed in the red king crab fishery. The abundance estimated for Tanner crab indicateda directed fishery could take place but the State does not expect the guideline harvest level to be taken. The crab fishery is scheduled to open November 15, 1996.

The Bering Sea Tanner stock has undergone two large fluctuations. Catches increased from 5 million pounds in 1965 to over 78 million pounds in 1977 (**Figure 3.7**). After that, the stock declined to the point where no fishery occurred in 1986 and 1987. The fishery reopened in 1988, and landings increased to over 51 million pounds in 1991. Another decline ensued, and 1995 landings were only 4.2 million pounds.

Snow Crab

Abundance of large male snow crab increased dramatically from 1983 to 1991, but has since declined (**Figure 3.8)**. The 1993 NMFS Bering Sea trawl survey indicated the total abundance of large males (over 4 inches) at 135 million crab, a 48% decrease from 1992. Small (3-4") legal-size males also declined in the abundance, consistent with the decline in large males observed since 1991. The 1995 NMFS bottom trawl survey indicated relatively low levels of large male crab. However, the survey indicated an 88% increase in the numbers of pre-recruits, and a 44% increase in the number of large females (**Table 3.6**). These promising signs indicate strong recruitment in the next few years. .

Catch of Bering Sea snow crab (C. opilio) increased from under 1 million pounds in 1974 to over 315 million pounds in 1992. The 1992 peak catch was followed by reduced landings thereafter (**Figure 3.7**). The stock is currently at low abundance, but is expected to increase in coming years. The 1996 opilio fishery opened on January 15 with a preseason guideline harvest level of 50.7 million pounds. A total of 57.8 million pounds of snow crab were harvested.

3.3.4 Bycatch of Crab in Groundfish Trawl Fisheries

Crab bycatch is estimated by the National Marine Fisheries Service through the groundfish Observer Program. Observer coverage depends on vessel length; 100% observers on vessels > 125 feet, 30% coverage on vessels 60-125 feet, and 0% coverage on vessels <60 feet. Shoreside processors have 100% coverage. 100% coverage means that an observer is always onboard; it does not mean that every haul or landing is observed.

On trawl vessels, observers sample about 3 to 4 tows per 24 hour period, which equate to about 50-60% of the hauls observed on at sea processing vessels with 100% observer coverage. The tows to be sampled are pre-selected based on a random sequence. The two primary goals of biological sampling for the observer is to estimate total catch size and to determine species composition of the catch. Catch size is generally estimated volumetrically based on codend size and fullness. Species composition is estimated from basket samples or by whole haul samples. For basket samples, a 300 kg sample (about 8 baskets) is randomly taken from the catch (usually from holding bin below deck). The observer weighs each component of the sample. Crabs are counted and a portion of these sexed and weighed. Sampling for crab length frequency has not been a priority item for observers, and consequently data are sparse. Catch data are reported on a haul by haul basis to the NMFS-AFSC Observer Program in Seattle, where the sampled haul data are extrapolated to the entire catch. From there, the information is forwarded to NMFS in-season management division, where it is run through the BLEND program to estimate total catch. The observed PSC bycatch rate is then applied to total catch to get PSC bycatch numbers that are reported on the Bulletin Board and used for bycatch management.

3.3.4.1 Number of Crab Taken as Bycatch in Groundfish Fisheries

Bycatch data for crab are available for the 1992-1995 groundfish trawl fisheries in the BSAI by target fishery and regulatory areas (**Tables 3.7-3.10**). Regulatory areas are shown in **Figure 3.9**. The observer data base categorizes crab bycatch into king crab, Tanner crab (C. bairdi), and "other" crab categories. In the Bering Sea, the "other" crab category is comprised almost entirely of snow crab(C. opilio), whereas in the GOA, "other" crab consists mostly of C. tanneri and C. angulatus, with the bycatch of snow crab virtually nil.

Red King Crab

Bycatch of red king crab in BSAI groundfish fisheries totaled 48,191 in 1995 (**Table 3.10**), which was down significantly from a recent high of 281,023 in 1994. Most red king crab bycatch is taken in the trawl fisheries (97%) and to a lesser extent in the longline (1%) and groundfish pot fisheries (2%). Although red king crabs are bycaught in nearly every trawl fishery, the rock sole/other flatfish fishery accounts for a majority of red king crab bycatch. Bycatch has been consistently highest in NMFS statistical areas 509 and 516. Approximately, 80% of the red king crab bycatch has been taken from the area encompassed by the existing crab protection Zone 1. Bycatch of red king crab was significantly lower in 1995 due in part to the implementation of the Pribilof Islands Habitat Conservation Area and the Bristol Bay Red King Crab Savings Area. Even lower bycatch may occur in 1996; Zone 1 bycatch of red king crabs totaled only 12,132 crabs through 4/13/96 (NMFS Bulletin Board 4/18).

Red king crab bycatch in the 1992-1995 BSAI groundfish fisheries, by zone (all gears/targets).

	Zone 1	Other areas	Total
1992	131,921	47,427	179,348
1993	184,563	63,987	248,550
1994	244,716	36,307	281,023
92-94 Ave	187,067	49,240	236,307
1995	35,638	12,554	48,192

Data indicate that the recent level of red king crab bycatch in trawl fisheries (1991-1995 average of 0.16 million) is low relative to the 1978-1989 average of 0.44 million red king crab (**Table 3.11**). This reduction may be due in part to reduced crab abundance and increased regulation of the trawl fishery. Regulations in effect in 1989 and thereafter for domestic fisheries included current crab PSC limits and trawl closure areas 512 and 516 (see **Appendix 4**). Although bycatch numbers are lower, bycatch accounts for a higher proportion of the total crab population as indexed by the NMFS survey. Since 1992, bycatch removals have equated to 0.13 to 0.82 percent of the total red king crab population.

Tanner Crab

A total of 2.3 million Tanner crab were taken as bycatch in the 1995 BSAI groundfish fisheries (**Table 3.10**). Bycatch of Tanner crab has been reduced in recent years, down significantly from 4.3 million in 1992. Most Tanner crab bycatch is taken in the trawl fisheries (about 98%) and to a lesser extent in the longline (1.5%) and groundfish pot fisheries (0.5%). Although Tanner crabs are bycaught in nearly every trawl fishery, the yellowfin sole fishery takes the largest share, followed by the rock sole/other flatfish fisheries. Bycatch is highest in NMFS statistical areas 509 and 513; and large numbers of Tanner crab area also consistently taken in areas 517 and 521. Data indicate that the recent level of Tanner crab bycatch in trawl fisheries (1992-1995 average of 3.06 million) is high relative to the 1978-1987 average of 2.06 million (**Table 3.12**).

Tanner crab bycatch in the 1992-1995 BSAI groundfish fisheries, by zone (all gears/targets).

	Zone 1	Zone 2	Other areas	Total
1992	1,144,671	2,699,256	448,106	4,292,033
1993	1,040,166	2,329,840	51,820	3,421,826
1994	765,283	1,736,273	43,426	2,544,982
92-94 Ave	983,373	2,255,123	181,117	3,419,614
93-94 Ave	902,724	2,033,057	47,623	2,983,404
1995	923,088	1,341,894	34,874	2,299,856

Snow Crab

Bycatch of snow crab in BSAI groundfish fisheries totaled 5.4 million crab in 1995 (**Table 3.10**). Bycatch has been drastically reduced since 1992, when 17.66 million snow crab were taken in groundfish fisheries (**Table 3.13**). Most snow crab bycatch is taken in the trawl fisheries (99%) and to a lesser extent in the longline (0.7%) and groundfish pot fisheries (0.3%). Although snow crabs are bycaught in nearly every trawl fishery, the yellowfin sole fishery takes the vast majority (70% on average 1992-1994). Bycatch is highest in the areas north and east of the Pribilof Islands, corresponding to NMFS statistical areas 513, 514, and 521 (NPFMC 1994). Relatively few snow crab are taken in Zone 1. On the other hand, about 75% of the snow crab bycatch comes from the area encompassed by the existing crab protection

Snow crab bycatch in the 1992-1995 BSAI groundfish fisheries, by zone (all gears/targets).

	Zone 1	Zone 2	Other areas	Total
1992	104,844	11,996,347	5,561,358	17,662,549
1993	40,611	8,922,155	5,797,956	14,760,722
1994	25,334	11,424,057	1,032,736	12,482,127
92-94 Ave	56,930	10,780,853	4,130,683	14,968,466
1995	94,307	4,338,013	963,469	5,395,789

Zone 2. This is not surprising given that Zone 2 encompasses most of the adult population (**Figure 3.6**). Average snow crab bycatch in Zone 2 was about 10.8 million crabs, or about 0.11% of the NMFS total population index on average, 1992-1994. Bycatch of snow crab in 1995 was much lower than in previous years, totaling 5,395,788 crabs. Of the total, 4,338,013 snow crabs were taken in Zone 2, corresponding to 0.05 % of the total population index.

3.3.4.2 Size and Sex of Crab Taken as Bycatch in Groundfish Fisheries

Red King Crab

Examination of crab bycatch carapace length frequency suggests that on average, the size of red king crab taken is about the minimum legal size for males (137 mm carapace length), and larger than the size of 50% maturity for females (90 mm carapace length). Previous reports suggested that red king crab taken as bycatch has averaged about 106 mm for females and 132 mm for males (Guttormson et al. 1990, NPFMC 1995). Length frequency data from the 1993 and 1995 trawl fisheries, examined in this report, suggest that the average size may be slightly larger (**Figure 3.10**). A rough estimate on average length of crabs taken as trawl bycatch, based on these data and total crab bycatch by regulatory area, is 140 mm for males in 1993 and 145 mm for males in 1995. Similarly, a rough estimate of average length for females is 115 mm in 1993 and 110 mm in 1995. Note that the legal size (165 mm carapace width) corresponds to a 137 mm carapace length for Bristol Bay red king crabs. Only minimal length frequency data are available for red king crab taken in groundfish pot and longline fisheries; the six crab measured in 1993 ranged from 140 to 160 mm.

Examination of observer data for sex ratio information yielded some unexpected results. Data indicate that a majority of red king crab taken as bycatch in trawl fisheries are females. On average, 1993 and 1995, 57% of the red king crab measured by observers were female. Some caution is called for in interpreting these data however, as sample sizes are small (**Table 3.14**). In addition, the 1995 observer data for crab bycatch are still being compiled, and are only about 25% complete at the time this document was drafted (M. Loefflad, NMFS, personal communication). Previous analyses of observer data have indicated that a majority of crab caught incidentally in groundfish fisheries were males (Guttormson et al. 1990, Narita et al. 1994). Changes in regulations, fishing patterns, and crab stock structure may have contributed to this apparent shift in sex ratio in observed bycatch.

Tanner Crab

Examination of crab bycatch carapace width frequency information suggests that most trawl bycatch is smaller than legal size (140 mm), but about the size of 50% maturity for females (90 mm). Bycatch data from the 1994 and 1995 fisheries, examined in this report, suggest a consistent take of larger crab (**Figure 3.11**). A rough estimate on average width of Tanner crabs taken as bycatch, based on these data and total crab bycatch by regulatory area, is 125 mm for males in 1994 and 120 mm for males in 1995. Similarly, a rough estimate of average width for females is 85 mm in 1993 and 1995. These averages indicate that Tanner crabs taken as bycatch may be larger than in previous years. Narita et al. (1994) reported that smaller Tanner crab (average carapace widths of 93 mm for males and 68 mm for females) were taken as bycatch in 1991 domestic BSAI groundfish fisheries.

Observer data indicate that a majority of Tanner crab taken as bycatch in trawl fisheries are males. On average, 1993-1995, 75% of the Tanner crab measured by observers were male. A high male sex ratio of observed bycatch appeared throughout the data for all statistical areas and years examined (**Table 3.14**). This is not surprising due to size selection by trawl gear and location of groundfish trawling. Similar to this analysis, a 74:26 male:female sex ratio was observed for crab bycatch in 1991 (Narita et al. 1994).

Length frequency data collected by observers for the BSAI groundfish pot and longline fisheries were examined. As with BSAI trawl fisheries, pot and longline fisheries catch primarily males. Average carapace width for male Tanner crabs was about 110 mm in pot fisheries and 130 mm in longline fisheries (**Figure 3.12**). Average width of female Tanner crabs was about 85 mm.

Snow Crab

Examination of crab bycatch carapace width frequency suggests that most snow crab bycatch in trawl fisheries is smaller than market size (102 mm), but larger than the size of 50% maturity for females (50 mm). Width frequency data from the 1994 and 1995 trawl fisheries, examined in this report, suggest that the average size is relatively constant from year to year (**Figure 3.13**). A rough estimate on average width of snow crabs taken as bycatch, based on these data and total crab bycatch by regulatory area, is 75 mm for males in 1994 and 1995. A rough estimate of average width for female snow crab is 63 mm in 1993 and 1995 trawl fisheries. Narita et al. (1994) reported average carapace widths of 89 mm for males and 59 mm for females taken as bycatch in 1991 domestic BSAI groundfish fisheries.

As with Tanner crab, observer data indicate that a vast majority of snow crab taken as bycatch in trawl fisheries are males. On average, 1993-1995, about 80% of the snow crab measured by observers were male. A high male sex ratio appeared throughout the data for all statistical areas and years examined (**Table 3.14**). In BSAI groundfish pot and longline fisheries nearly all snow crab measured by observers were male. Average carapace width for male snow crabs was about 90 mm in pot fisheries and 110 mm in longline fisheries (**Figure 3.12**).

3.3.4.3 Bycatch Mortality

The impact of crab bycatch on crab stocks is somewhat tempered by survival of discarded crabs. There have been numerous studies done on crab bycatch mortality, with each study having different objectives, methodology, and results. A summary of these studies is provided below, but many questions remain unanswered. Stevens (1990) found that 21% of the king crabs and 22% of the Tanner crabs captured incidentally in BSAI trawl fisheries survived at least 2 days following capture. Blackburn and Schmidt (1988) made observations on instantaneous mortality of crab taken by domestic trawl fisheries in the Kodiak area. They found mortality for softshell red king crab averaged 21%, hard shelled red king crab 1.2%, and 12.6% for Tanner crab. Another trawl study indicated that trawl induced mortalities aboard ship were 12% for Tanner crab and 19% for red king crab (Owen 1988). Fukuhara and Worlund (1973) observed an overall Tanner crab mortality of 60-70% in the foreign Bering Sea trawl fisheries. They also noted that mortality was higher in the summer (95%) than in the spring (50%). Hayes (1973) found that mortality of Tanner crab captured by trawl gear was due to time out of water, with 50% mortality after 12 hours. Natural Resource Consultants (1988) reported that overall survival of red king crab and Tanner crab bycaught and held in circulation tanks for 24-48 hours was <22%. In previous analyses, the estimated mortality rate of trawl bycaught red king crab and Tanner crab was 80% (NPFMC 1993).

3.3.4.4 Unobserved Mortality

Not all crab in the path of a trawl are captured. Some crab pass under the gear, or pass through the trawl meshes. Non-retained crab may be subject to mortality from contact with trawl doors, bridles, footrope, or trawl mesh, as well as exposure to silt clouds produced by trawl and dredge gear. Only two studies have been conducted to estimate catchability of crabs by trawl gear, and these studies are summarized below.

In one experiment to measure non-observable mortality, 169 red king crab were tethered in the path of an Aleutian combination trawl (Donaldson 1990). The trawl was equipped with a footrope constructed of 14 inch bobbins spaced every 3 feet, separated by 6.5 inch discs. Thirty-six crabs (21.3%) were recovered onboard the vessel in the trawl. Divers recovered 46.2% of the crabs not captured by the trawl. Another 32.5% were not recovered but assumed to have interacted with the trawl. Of the 78 crab not retained in the trawl, but captured by divers, only 2.6% were injured. If all injured crabs die, the non-observable mortality rate for trawl gear on red king crab is estimated at 2.6% (Donaldson 1990). It should be noted that hard shelled crabs were used in this experiment; higher impacts would be expected if softshelled crabs were tested.

In 1995, NMFS used underwater video cameras to observe the interaction of trawl gear with king and Tanner crabs (Craig Rose, NMFS, unpublished data). The experiment was conducted in Bristol Bay in an area with large red king crabs and C. bairdi Tanner crabs. Three types of trawl footropes were examined and they are as follows: a footrope with 3-4 foot lengths of 6" discs separated by 10" discs (called disc gear), a footrope with 24" rollers (tire gear), and an experimental float/chain footrope with the groundgear suspended about 8" off the seafloor. For disc gear, preliminary analysis indicated that all red king crab encountered entered the trawl and about 76% of the Tanner crab were caught. Tire gear captured fewer king crab (42%) and Tanner crab (1%). The float/chain gear did not catch any of the crabs encountered. At the December 1995 Council meeting, excerpts of the NMFS video were shown to the Council and public. Trawl industry representatives testified that groundgear used to harvest finfish in this area depended on target species and bottom type, with tire gear type footropes used in hard bottom areas, and disc type gear used on smooth bottom areas. Testimony also indicated that there was also variability in groundgear used among vessels, but that on average, most gear used in Bristol Bay trawl fisheries would be comprised of groundgear with discs or rollers larger than the disc gear tested and smaller that the tire gear tested.

In order to compare the impacts of unobserved mortality caused by trawling with other sources of fishing mortality, it would be necessary to have reasonable estimates of retention rates and mortality of those crab not retained. At this time, however, there are too many uncertainties to generate valid estimates of unobserved crab mortality (C. Rose, NMFS, personal communication).

3.3.5 Other Anthropogenic Sources of Crab Mortality

In addition to bycatch in groundfish trawl fisheries, there are other sources of human induced mortality and mortality due to natural causes. Survival of juvenile crab after settlement until they reach maturity depends on natural mortality (due to predation, disease, and other sources) and fishing mortality. Natural mortality is estimated to be about 25% (M=0.3) for red king crab, Tanner crab, and snow crab (NPFMC 1990). As discussed in previous sections, fishing mortality attributed to groundfish fisheries include bycatch mortality, unobserved gear induced mortality, and indirect impacts of habitat alteration. Crab mortality is also attributable to the scallop fishery. Crab fisheries cause mortality through fishery removals of large males, handling mortality, ghost fishing by lost pots, pot bombing, and unobserved mortality caused by cannibalism and predation inside pots.

3.3.5.1 Bycatch Mortality in Other Groundfish Fisheries

Some crabs are caught incidentally by non-trawl gear in pursuit of groundfish, and a portion of these crabs die. No field or laboratory studies have been made to estimate mortality of crab discarded in these fisheries. However, based on condition factor information from the trawl survey, mortality of crab bycatch has been estimated and used in previous analyses (NPFMC 1993). Discard mortality rates for red king crab were estimated at 37% in longline fisheries and 37% in pot fisheries. Estimated bycatch mortality rates for Tanner crab were 45% in longline fisheries and 30% in pot fisheries. No observations had been made for snow crab, but mortality rates are likely similar to Tanner crab. In the analysis made in Section 5, a 37% mortality rate was assumed for red king crab taken in longline fisheries and an 8% rate for pot fisheries. Observer data on condition factors collected for crab during the 1991 domestic fisheries suggested lower mortality of red king crab taken in groundfish pot fisheries (**Table 3.15**). Bycatch mortality rates used in Section 5 for Tanner crab were 45% in longline fisheries and 30% in pot fisheries, based on previous analyses.

3.3.5.2 Bycatch Mortality in the Scallop Fishery

In 1993, the scallop fishery in the Bering Sea caught 6 red king crab, 276,000 Tanner crab, and 15,000 snow crab (D. Pengilly, ADF&G, unpublished data). Average sizes of crabs were 110 mm carapace length for red king crab, 100 mm carapace width for Tanner crab, and 100 mm carapace width for snow crab. The sex ratio was about 50:50 for red king and Tanner crab, but almost all snow crab taken were males. In 1994, 55 red king crab and 262,500 Tanner crab were captured incidental to scallop fishing in the Bering Sea (NPFMC 1995b). No fishery occurred in 1995.

Observations from scallop fisheries across the state suggest that mortality of crab bycatch is low relative to trawl gear due to shorter tow times, shorter exposure times, and lower catch weight and volume. For crab taken as bycatch in the Gulf of Alaska weathervane scallop fishery, Hennick (1973) estimated that about 30% of Tanner crabs and 42% of the red king crabs bycaught in scallop dredges were killed or injured. Hammerstrom and Merrit (1985) estimated mortality of Tanner crab at 8% in Cook Inlet. Kaiser (1986) estimated mortality rates of 19% for Tanner crab and 48% for red king crab bycaught off Kodiak Island. Urban el al. (1994) recorded that in 1992, 13-35% of the Tanner crab bycaught were dead or moribund before being discarded, with the highest mortality rate occurring on small (<40 mm cw) and large (>120 mm cw) crabs. Delayed mortality resulting from injury or stress was not estimated. Mortality in the Bering Sea appears to be lower than in the Gulf of Alaska, in part due to different sizes of crab taken. Observations from the 1993 Bering Sea scallop fishery indicated lower bycatch mortality of red king crab (10%), Tanner crab (11%) and snow crab (19%). As with observations from the Gulf of Alaska, mortality appeared to be related to size, with larger and smaller crabs having higher mortality rates on average than mid-sized crabs (D. Pengilly, ADF&G, unpublished data). Delayed mortality was not estimated. In the analysis made in Section 5, a 40% discard mortality rate was assumed for all crab species.

3.3.5.3 Crab Harvests

Harvest policies set by the State of Alaska for major BSAI crab stocks are based on an exploitation rate strategy, with additional size, sex, and season

Number of crab harvested from the Bering Sea 1993-1995.

	Bristol Bay Red king	EBS Tanner	EBS Snow
1993	2,022,165	7,209,948	169,558,842
1994	0	3,793,000	114,779,014
1995	0	1,877,303	60,611,411

regulations. Pre-season guideline harvest levels are set by applying exploitation rates to the projected number of legal male crab. Exploitation rates for Bering Sea crab have been 20% for mature male red king crab (up to a maximum of 60% removal of legal males over 6.5" carapace width), 40% for male Tanner crab over 5.5", and 58% for snow crab larger than 4" carapace width. Total number of crab harvested in recent years is shown in the adjacent table (data from Tracy 1995, Morrison 1996). Number of crab harvested include "deadloss", which is the portion of the harvest that dies prior to processing and is wasted. In recent years, deadloss in Bering Sea king and Tanner crab fisheries has amounted to about 1%- 2% of the total harvest.

3.3.5.4 Bycatch Mortality in Crab Fisheries

Another source of mortality is crab bycatch in directed crab fisheries. Crab bycatch includes females of target species, sublegal males of target species, and non-target crab. Numbers of crab taken as bycatch in recent major Bering Sea crab fisheries are listed in **Table 3.16**. Due to the difference in legal size versus market size for snow crab, a portion of the legal crabs are not retained as harvest, and are thus considered bycatch. For example, in 1994, over 57 million legal sized snow crab were discarded. Additional crab are bycaught in other fisheries for red king crab (Dutch Harbor, Adak), blue king crab (Pribilof Islands, St. Matthew), golden king crab (Dutch Harbor, Adak), Tanner crab (Aleutian Islands), and hair crab fisheries.

Some crabs taken as bycatch die due to handling mortality. Several laboratory and field studies have been conducted to determine mortality caused by handling juvenile and female crab taken in crab fisheries. There are a variety of effects caused by handling, ranging from sublethal (reduced growth rates, molting probabilities, visual acuity from bright lights, and vigor) to lethal effects. Studies have shown a range of mortality due to handling based on gear type, species, molting stage, number of times handled, temperature, and exposure time (Murphy and Kruse 1995). Handling mortality may have contributed to the high natural mortality levels observed for Bristol Bay red king crab in the early 1980's (65% for males and 82% for females), that along with high harvest rates, resulted in stock collapse (Zheng et al. 1995). However, another study concluded that handling mortality was not responsible for the decline on the red king crab fishery (Zhou and Shirley 1995a).

Byersdorfer and Watson (1992, 1993) examined red king crab and Tanner crab taken as bycatch during the 1991 and 1992 red king crab test fisheries. Instantaneous handling mortality of red king crab was <1% in 1991, and 11.2% in 1992. Stevens and MacIntosh (1993) found average overall mortality of 5.2% for red king crabs and 11% for Tanner crabs on one commercial crab vessel. Authors recommend these results be viewed with caution, noting that experimental conditions were marginal. Mortality for red king crab held 48 hours was 8% (Stevens and MacIntosh 1993, as cited in Queirolo et al. 1995). A laboratory study that examined the effects of multiple handling indicated that mortality of discarded red king crabs was negligible (2%), although body damage increased with handling mortality (Zhou and Shirley 1995a).

Delayed mortality due to handling does not appear to be influenced by method of release. In an experiment done during a test fishery, red king crab thrown off the deck while the vessel was moving versus those gently placed back into the ocean showed no differences in tag return rates (Watson and Pengilly 1994). Handling methods on mortality has been shown to be non-significant in laboratory experiments with red king crab (Zhou and Shirley 1995a, 1995b) and Tanner crab (MacIntosh et al. 1995). Although handling did not cause mortality, injury rates were directly related to the number of times handled.

Mortality of crabs is also related to time out of water and air temperature. A study of red king crabs and Tanner crabs found that crabs exposed to air exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs) (Carls and Clair 1989). For surviving females, there was no impact on eggs or larvae. Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality that occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure (measured as degree hours). Median lethal exposure was -8ºC for red king crab and -4.3ºC for Tanner crab. For example, if crabs were held on deck for 10 minutes and it was -23ºC or 10 degrees below zero (Fahrenheit) outside, about 15% of the king crab and 50% of the Tanner crab would die of exposure. Because BSAI crab fisheries occur during November through February, cold exposure could cause significant handling mortality to crabs not immediately returned to the ocean. Zhou and Shirley (1995) observed that average time on deck was generally 2 to 3 minutes, and they concluded that handling mortality was not a significant source of mortality.

3.3.5.5 Catching Mortality

Catching mortality is ascribed to those crabs that enter a pot and are eaten by other pot inhabitants before the pot is retrieved. Catching mortality likely occurs during the molting period, when crabs are more susceptible to cannibalism. Most crab fisheries are set to occur outside of the molting season, and catching mortality in these fisheries may be limited to octopus or large fish entering a pot. Because no evidence of crab is left in the pot, these mortalities remain unassessed.

3.3.5.6 Ghost Fishing

Mortality is also caused by ghost fishing of lost crab pots and groundfish pots. Ghost fishing is the term used to describe continued fishing by lost or derelict gear. The impact of ghost fishing on crab stocks remains unknown. It has been estimated that 10-20% of crab pots are lost each year (Meyer 1971, Kruse and Kimker 1993). Based on skipper interviews, about 10,000 pots were estimated lost in the 1992 Bristol Bay red king, and Bering Sea Tanner and snow crab fisheries (Tracy 1994). Fewer pots are expected to be lost under pot limit regulations and shorter seasons. Bob Schofield, a major crab pot manufacturer, testified at the January 1996 Council meeting that he was making fewer pots since inception of the pot limit. He estimated that 6,461 pots were replaced in 1995. It is not known how long lost pots may persist and continue to fish, or just litter the bottom.

A sonar survey of inner Chiniak Bay (Kodiak, Alaska) found a high density of lost crab pots (190 pots) in an area of about 4.5 km^2 (Stevens 1995). Underwater observations indicated that crabs and fish were common residents of crab pots, whether or not the pot mesh was intact. Eight intact pots recovered from the Chiniak Bay study area contained an average of 4 crab and 0.5 octopus (Stevens 1995). High (1985) and High and Worlund (1979) observed that 20% of legal sized male red king crab and 8% of the sublegals captured by lost pots failed to escape.

Crabs captured in lost pots may die of starvation or by predation. Captured crab are subject to cannibalism (Paul et al. 1993), and predation by octopus, halibut and Pacific cod (High 1976). Crabs also have limited abilities to withstand starvation. In a simulated field study, 39% mortality was observed after 119 days of starvation (Kimker 1992). In a laboratory study, 10% of the Tanner crabs tested died of starvation in 90 days. Of the 90% that had survived 90 days, all later died even though they were freely fed (Paul et al. 1993). To reduce starvation mortality in lost pots, crab pots have been required be fitted with degradable escape mechanisms. Regulations required #120 cotton thread from 1977-1993. Beginning in 1993, regulations required #30 cotton thread or 30-day galvanic timed release mechanisms. A #30 cotton thread section is also required in groundfish pots. The average time for #30 cotton twine to degrade is 89 days, and the galvanic timed release about 30 days to degrade. Pots fitted with an escape mechanism of #72 cotton twine had a fishable life of 3-8 years and documented retention of up to 100 crabs per lost pot (Meyer 1971). High and Wolund (1979) estimated an effective fishing life of 15 years for king crab pots. Pots without escape mechanisms could continue to catch and kill crabs for many years, however testimony from crabbers and pot manufacturers indicate that all pots currently fished in Bering Sea crab fisheries contain escape mechanisms.

Mortality of crab caused by ghost fishing is difficult to estimate with precision given existing information. Mortality caused by continuous fishing of lost pots has not been estimated, but unbaited crab pots do continue to catch crabs (Breen 1987, Meyer 1971), and pots are subject to rebaiting due to capture of Pacific cod, halibut, sablefish, and flatfish. In addition to mortality of trapped crab by ghost pots, and predation by octopus and fish, pot mesh itself can kill crabs. Lost pots retrieved by NMFS trawl surveys occasionally contain dead crabs trapped in loose webbing (Stevens 1995). It has been suggested that pot limits and escape mechanisms have greatly minimized ghost fishing due to pot loss in recent years.

3.3.5.7 Pot Bombing

Another source of human induced crab mortality that is considered is "pot bombing". Pot bombing is a term used to mean a pot landing on the ocean floor when it is being set, presumably impacting any crab on which it lands. With reasonable assumptions, pot bombing is only a very minor source of mortality, however. An estimate of the impact of pot bombing can be derived by multiplying the number of pot lifts, the area they occupy, and relative crab density within areas fished in the Bering Sea. In 1993, there were 253,794 pots lifted in the Bristol Bay red king crab fishery, 576,464 pots lifted in the Bering Sea Tanner crab fishery, and 971,046 pots lifted in the Bering snow crab fishery (Morrison and Gish 1995). A majority of pots used in these fisheries measure 7 feet by 7 feet and 8 feet by 8 feet (R. Morrison, ADF&G, personal communication). Regulations specify a maximum of 10 by 10 feet. Average area of seafloor covered by a pot is thus estimated to be about 56 square feet. Assuming that pots land on different areas after each lift, and crab pots are set non-randomly over areas with relatively high density of crabs in directed fisheries, the total number of crab impacted can be roughly estimated. For 1993 the red king crab fishery, assuming a density of 5,000 red king crab of all sizes per square mile (density data from Stevens et al. 1994), about two thousand red king crab were impacted by pot bombing. Roughly nine thousand Tanner crabs (assuming 10,000 crab/mile^2) and 110 thousand snow crabs (assuming 75,000 crab/mile^2) were impacted by pot bombing in respective crab fisheries in 1993. It is not known what proportion of these crab die when a crab pot lands on them, but it may be 100%. Due to reduced stock sizes and GHLs (and consequently fewer pot lifts), and area restrictions, the impacts of pot bombing were probably negligible in 1994 and 1995.

3.3.6 Natural Mortality and Predation

Survival of juvenile crab after settlement until they reach maturity depends on natural mortality (due to predation, disease, and other sources) and fishing mortality. Natural mortality is estimated to be about 25% (M=0.3) for adult red king crab, Tanner crab, and snow crab (NPFMC 1990). Predation by groundfish may be a major source of natural mortality for juvenile and molting crabs in the Bering Sea, particularly in recent years. Competition with groundfish may also lead to slower growth, as well as reduced resistance to disease and predation.

Crab predators and competitors have increased in recent years. Biomass of crab competitors (inshore benthic infauna consumers such as starfish and flatfish) has increased about 40% from 1979-1993 (Livingston et al. 1994). Most of this increase is attributable to a growing rock sole biomass, and to a lesser extent starfish and flathead sole biomass. Of the crab species, only snow crab comprises a substantial portion of the infauna consumer guild (species that eat clams, polycheates, etc.). Yellowfin sole had dramatically increased in abundance in the early 1980's to become the largest component of this guild until the early 1990's when rock sole became co-dominant. Mean size at age has declined for yellowfin sole and rock sole, indicating stress caused by competition, and to a lesser extent a decrease in average bottom temperature (Livingston et al. 1994).

Predation of crabs by groundfish removes large numbers of young Tanner and snow crab, but the impacts on populations remains unknown. For snow crabs, estimates of annual consumption by groundfish from May through September ranged from 9 billion to 31 billion crabs (Livingston et al. 1993). Snow crabs consumed were primarily age 1, and to a lesser extent age 2 and 3 crabs. Pacific cod is a primary predator of snow crab, particularly softshell female and juvenile crab (McLellan & Leong 1981, Livingston 1989, Livingston et al. 1991). Flathead sole, yellowfin sole, and rock sole also prey on young snow crabs (Haflinger and Roy 1983, Livingston et al. 1993). Annual consumption of Tanner crabs by groundfish ranged from 10 billion to 153 billion crabs, consisting primarily of Age 0 and Age 1 crabs (Livingston et al. 1993). Yellowfin sole and flathead sole were found to be the primary consumers of small Tanner crabs, whereas Pacific cod preyed on the larger juveniles. Although yellowfin sole and Pacific cod are known predators of juvenile and molting red king crab (Haflinger and McRoy 1983, Livingston 1989), data suggest that mortality caused by groundfish predators on adult red king crab may be low during summer months. It has been estimated that Pacific cod consumed about 1.4% to 3.8% of the female red king crab stock during the early 1980's, which suggested to Livingston (1989), that these rates were not the major factor behind the Bristol Bay red king crab stock crash. In the late 1980's, consumption by Pacific cod was estimated at 3.8% to 14.3 % of the female red king crab stock (Livingston et al. 1993).

Although it has been hypothesized that juvenile sockeye salmon may impact recruitment of red king crab in Bristol Bay (Wespestad et al. 1994), subsequent analysis has failed to support this. The following is an excerpt from Tyler and Kruse (1995):

" In a recent study, Wespestad et al. (1994) proposed that outmigrating juvenile sockeye salmon may adversely impact red king crab brood strength by predation of larvae. This premise is based on a negative correlation between sockeye salmon abundance (lagged 4 years earlier) and king crab recruits (lagged 8 years earlier). Although the potential for salmon-crab interactions is intriguing, these lags are questionable. Stevens (1990) showed that king crab recruits enter Bristol Bay fishery over ages 7-12 depending on temperature. Further, depending on the stock and brood year, sockeye salmon from Bristol Bay lake systems smoltify as 1- or 2-year -olds, or in their second or third year if measured from time of egg deposition, and return to spawn after spending 2-3 years at sea (Burgner 1991). Because peak cycle runs are predominated by fish that spent two years at sea (Eggers and Rogers 1987), the appropriate lag from adult salmon to juvenile outmigrants is 2 years not 4 years prior. This 2-years lag causes the abundance of outmigrants from strong salmon runs prior to 1970 to coincide with years of high crab recruitment, contrary to the recruitment hypothesis."

4.0 DESCRIPTION OF MANAGEMENT MEASURE 3 (NEARSHORE BRISTOL BAY TRAWL CLOSURE AREA) AND BACKGROUND INFORMATION

4.1 Problem Statement

Existing trawl closure areas in Bristol Bay were designed to protect adult and sub-adult red king crab from trawling. However, protection of juvenile habitat, which may be negatively impacted by trawling, may provide for improved recruitment and subsequent stock rebuilding. A trawl closure area may also provide additional protection for Pacific herring and Pacific halibut.

4.2 Alternatives Considered

Three alternative were examined. In addition to the status quo, alternative 1, the impacts of prohibiting trawling in three areas were examined. These alternative closure areas are shown in **Figure 4.1** and Options are shown in **Figure 4.2**.

4.2.1 Alternative 1: Status quo, no action.

4.2.2 Alternative 2: Establish a Northern Bristol Bay Closure Area, which would prohibit all trawling, on a year-round basis, in the area east of 162° W longitude and north of 58° N latitude.

Option A: Continue to allow bottom trawling within the area north of 58° N and bounded by 159° and 160° W longitude. This option may require 100% observer coverage for trawl vessels fishing in the area.

4.2.3 Alternative 3: Prohibit all trawling in Bristol Bay, on a year-round basis, in the area east of 162° W longitude. Because much of Bristol Bay (statistical area 512) is already closed to trawling year-round, the additional area encompassed by this alternative is statistical area 508 in eastern Bristol Bay and the area described under alternative 2.

Option A (**Preferred**): Continue to allow bottom trawling within the area north of 58° N and bounded by 159° and 160° W longitude. This option may require 100% observer coverage for trawl vessels fishing in the area. (Note: the Council's preferred option would limit trawling to the area south of 58°43' N within the 159° and 160° W window and only during the period April 1 to June 15 each year.)

4.2.4 Alternative 4: Prohibit all trawling on a year-round basis the area north of 58°43' N and east of 162° W longitude. The area north of 58° N and east of 162° W longitude, exclusive of the area closed year-round, would be open to trawling during the period April 1 to June 15 each year. This alternative may require 100% observer coverage for trawl vessels fishing in the area.

Option A: Also prohibit all trawling on a year-round basis in Statistical Area 508, which is the area east of 160° W longitude and south of 58° N latitude.

All Alternatives to the status quo would include a regulatory amendment change that would rescind the trawl closure exemptions for the Pacific cod fishery off Port Moller (§ 675.22, paragraphs c,d,e).

4.3 Background

In January 1995, the Council initiated an analysis to examine impacts of a proposal to establish a trawl closure area (Alternative 2) in the northeast section of Bristol Bay (north of 58°N and east of 162°W) to protect juvenile red king crab habitat. It was felt that such a closure would also be beneficial to juvenile halibut, seabirds, marine mammals, and spawning herring stocks. Based on preliminary examination of the distribution of juvenile red king crab habitat in Bristol Bay, Alternative 3 was added to the analysis. The area within 3 miles of shore within Bristol Bay has been closed to trawling year-round under State regulations (5 AAC 39.165) since 1993.

In April 1996, the Council added Option A to all alternatives and added Alternative 4 for analysis. In their review of the preliminary analysis, the Crab Rebuilding Committee recommended that the Council consider leaving open to trawling those areas where crab habitat is not known to occur and bycatch of other PSC species is limited. These areas have been important areas for groundfish trawling in some years.

This document examines the impacts of prohibiting trawling in nearshore EEZ areas of Bristol Bay to protect juvenile red king crab habitat. The document also examines the impacts of eliminating from regulations the exemptions for trawling for Pacific cod in the Port Moller area.

§ 675.22 Time and area closures.

(a) No fishing with trawl gear is allowed at any time in that part of Zone 1 in the Bering Sea subarea that is south of 58° 00' N. latitude and between 160° 00' W. longitude and 162° 00' W. longitude (see Figure 1) except as described in paragraph (c) of this section.

(b) No fishing with trawl gear is allowed at any time in that part of Zone 1 in the Bering Sea Subarea that is south of 58° 00' N. latitude and between 162° 00' W. longitude and 163° W. longitude during the period March 15 through June 15 except as described in paragraph (d) of this section.

(c) *NMFS may allow fishing for Pacific cod with trawl gear in that portion of the area described in paragraph (a) of this section that lies south of a straight line connecting the coordinates 56° 43' N. latitude, 160° 00' W. longitude, and 56° 00' N. latitude 162° 00' W. longitude, provided that such fishing is in compliance with a scientific data collection and monitoring program, established by the Regional Director after consultation with the Council, designed to provide data useful in the management of the trawl fishery, the Pacific halibut, Tanner crab and king crab fisheries, and to prevent overfishing of the Pacific halibut, Tanner and king crab stocks in the area.*

(d) During the period March 15 through June 15, NMFS may allow fishing for Pacific cod with trawl gear in that portion of the area described in paragraph (b) of this section that lies south of the line connecting 56° 00' N. latitude, 162° W. longitude, and 55° 38' N. latitude 163° 00' W. longitude, provided that such fishing is in compliance with a scientific data collection and monitoring program, established by the Regional Director after consultation with the Council, designed to provide data useful in the management of the trawl fishery, Pacific halibut, Tanner crab and king crab fisheries, and to prevent overfishing of the Pacific halibut, Tanner and king crab stocks in the area.

(e) If the Regional Director determines that vessels fishing with trawl gear in the areas described in paragraphs (c) and (d) of this section will catch the PSC limit of 12,000 red king crabs, he will immediately prohibit all fishing with trawl gear in those areas by notice in the FEDERAL REGISTER.

4.3.1 Management Background

Area closures in the BSAI have a long history as a management measure, and several trawl closure areas were in place prior to the Magnuson Fishery Conservation and Management Act (Fredin 1987). These closure areas were designed to reduce the impacts of foreign fishing on domestic crab and longline operations, and some were incorporated into the original BSAI groundfish FMP. Although most of these closures were along the Aleutian Islands, one of these closures included much of the Bristol Bay area, as discussed below.

A trawl closure zone (termed the Bristol Bay Pot Sanctuary) was established in 1959 by the Japanese fleet (Fredin 1987). This zone encompassed the area from Cape Sarishef to 55°16'N 166°10'W, northeastward to 55°28'N 165°34'W, and eastward along 55°28'N to the Alaska Peninsula. This zone was established to prevent conflicts between mobile gear and concentrations of crab pots, and to prevent the incidental catch of juvenile halibut. The zone was expanded northward to 55°54'N when the US/Japan agreements were negotiated in 1968. The final configuration of the pot sanctuary, shown in **Figure 4.3**, was in place with regulations implementing the Magnuson Act in 1977. This area was modified in 1984 under BSAI groundfish FMP Amendment 1 to allow year-round domestic trawling (but not foreign trawling) within the Bristol Bay Pot Sanctuary.

Numerous areas have closed to domestic trawling to provide protection for prohibited species (crab, halibut, salmon, herring), marine mammals (Steller sea lions and Pacific walrus) and their habitat in the Bering Sea, as shown in **Figure 4.4** (Witherell and Roberts 1995). Crab protection zones were implemented in 1987 under Amendment 10 to prevent the incidental catch of adult and juvenile red king crab in trawl fisheries. Crab protection area 512 is closed to all trawling year-round, and area 516 extends this closure seasonally from March 15 through June 15. Amendment 16a established three Herring Savings Areas, in which all trawling is prohibited upon attainment of a herring PSC limit. In 1992, Amendment 17 established 12 mile closure zones around Round Island, the Twins Islands, and Cape Pierce to minimize vessel interaction with walrus around these haulout sites in Bristol Bay. Steller Sea Lion Protection Areas, established in 1992 under Amendment 20, prohibit trawling year-round within 10 nautical miles of 26 rookeries in the BSAI area. These areas, six of which seasonally extend out to 20 nautical miles, were closed to reduce intentional and unintentional harassment of Steller sea lions and to reduce depletion of their prey. The Pribilof Islands Habitat Conservation Area was implemented in 1995 under Amendment 21a to protect blue king crabs and their habitat on a year-round basis. A Chum Salmon Savings Area, established in 1995 under Amendment 35, prohibits trawling on a seasonal basis to reduce bycatch of chum salmon. The Chinook Salmon Savings Areas were adopted by the Council as Amendment 21b in 1995 to reduce excessive bycatch of chinook salmon; these areas close when a bycatch limit of 48,000 chinooks are taken as bycatch. The Bristol Bay Red King Crab Savings Area, designed to protect adult red king crab, was implemented in 1995 by emergency order and adopted by the Council in September 1995 as a permanent seasonal closure (January 1 - March 31) to bottom trawling.

The Port Moller exemption area for trawl gear was established by Amendment 10 in 1987. A bycatch limit of 12,000 red king crab was adopted to support a fishery of about 6,000 mt of groundfish per year. Fisheries for Pacific cod occurred within the 25 fathom area in 1986 through 1990. About six vessels participated in the 1986, 1987, and 1988 fisheries. Data are confidential, however catch and bycatch rates from the 1988 have been summarized and reported (Hare 1988). The 1989 fishery was closed after 40 days when 13,940 red king crab were taken as bycatch (NMFS management report, September 1989), a majority of which were reportedly taken in only two tows (Thomson 1989). Only 2,800 mt of Pacific cod was caught in the area in 1989. Since 1990, NMFS has received no requests for exemption permits under this regulation, and no trawl fisheries have occurred in the Port Moller area.

4.3.2 Biological and Physical Environment

Physical Environment

Bristol Bay is a large bay in the easternmost area of the Bering Sea, bounded by the Alaska Peninsula to the south. The bay is generally shallow, and has predominantly sand/silt substrate. The bay is subject to strong wind-driven and tidal currents. The dominant water movement on the eastern Bering Sea continental shelf originates from Pacific waters entering the Bering Sea in the vicinity of Unimak Island. These waters move northward toward St. Matthews Islands and eastward toward Bristol Bay. The eastward flowing current along the Alaska Peninsula upon reaching the head of Bristol Bay is deflected westward by waters from the Kvichak and Nushagak Rivers. In some winters, the inshore areas of northern Bristol Bay are covered with ice. At its maximum the ice pack may cover the continental shelf south to the Pribilof Islands and extend from the Pribilof Islands eastward to the vicinity of Port Moller.

The physical, climatic, and oceanographic features in the eastern Bering Sea combine to create conditions highly favorable for primary biological productivity. These favorable conditions are only surpassed by some of the upwelling regions in the eastern Pacific and Atlantic Oceans (Hood and Kelly 1974). This productivity supports some of the largest fish, marine mammal, and bird populations in the world. Although the processes for this high productivity are not fully understood, they probably originate from the upwelling of nutrient-rich water along the Aleutian Islands chain (Sharma 1979), the mixing of Pacific Ocean and Bering Sea waters, the seasonable extremes in climate with a buildup of nutrients during the winter months and the expansive nature of the continental shelf, including the Bristol Bay area.

Biological Environment

Fish

The nearshore waters of Bristol Bay are used by a variety of fish species for spawning and nursery areas. In May of each year, Pacific herring enter Bristol Bay to spawn in the Togiak area. Eggs are demersal and adhesive to aquatic plants and benthic substrates. Herring fry remain in the coastal waters during the summer before moving out to the edge of the continental shelf where they grow for several years. Togiak also supports a stock of capelin, which move inshore to spawn along sandy beaches in May and June. Major capelin spawning areas in Bristol Bay include the Cape Pierce to Togiak region and an area off Port Heiden. Another forage fish species, sandlance, is widely distributed along the shallow waters of Bristol Bay. All five Pacific salmon species (chinook, chum, pink, sockeye, and coho) migrate through Bristol Bay as mature adults on their way to river spawning grounds. Sockeye salmon have been particularly abundant in recent years and support a large commercial gillnet fishery. Young salmon spend some time in Bristol Bay feeding on their way to offshore habitats.

Nearshore areas of Bristol Bay also serve as feeding and nursery grounds for groundfish, such as yellowfin sole, pollock, Pacific cod, and presumably, Pacific halibut. Yellowfin sole migrate into the shallow waters of Bristol Bay in the spring of each year to feed in the summer months (Bakkala et al. 1982). Yellowfin sole spawn in June and July on the inner shelf. In May 1995, NMFS conducted a beam trawl survey in the shallow waters of Togiak Bay to Cape Constantine (Nichol et al. 1995). Thirty stations were sampled with a small beam trawl equipped with a small mesh (4 mm) codend liner to retain small fish. Yellowfin sole were taken in abundance, along with lower numbers of starry flounder, Alaska plaice, rock sole, pollock and other fish species (**Table 4.1**). Interestingly, no halibut or red king crab were caught. Yellowfin sole length distributions were bimodal, with modes occurring at 12 cm (juveniles) and 30 cm (adults). Nearly all of the Alaska plaice were juveniles smaller than 20 cm.

Seabirds

Major breeding concentrations of seabirds are found in northern Bristol Bay in the area of Cape Pierce and Togiak. This area supports moderate to relatively high populations of common murres, pelagic and double crested cormorants, black legged kittiwakes, parakeet auklets, horned and tufted puffins. These species feed on invertebrates (e.g., squid, shrimp, euphausiids, and amphipods) and fish (e.g., pollock, cod, capelin, and sand lance). Lower numbers of seabirds are found at the southern edge of Bristol Bay along the Alaska Peninsula.

Numerous species of waterfowl use the Bristol Bay area for breeding and migrating stopover areas. The eastern area with its numerous rivers and bays is particularly important for breeding. Whistling swans, oldsquaw, common eider, and black scoters breed in this area. These species commonly feed on crustaceans, bivalves, and other marine invertebrates. The nearshore areas of Bristol Bay are important migratory stopovers for other species such as Steller's eider, black brant, Canada goose, and emperor goose.

Marine Mammals

Two pinniped species (walrus and harbor seals) are found in moderate to relatively high abundance in the waters of Bristol Bay. Pacific walrus, particularly females and young, stay with the ice pack, and thus are found in the Bristol Bay region primarily on a seasonal basis. A large portion of bulls remain in Bristol Bay during the summer in ice-free areas, and use small islands and peninsulas for haulout areas. Major walrus haulouts in Bristol Bay include Round Island, the Twins islands, and Cape Pierce. These areas must contain quantities of bivalve molluscs that are the primary component of to the walrus diet. Bristol Bay is the northern limit of harbor seal abundance. Several major haulout and breeding areas have been identified in Bristol Bay; all are along the Alaska Peninsula. Harbor seals feed on cephalopods (squid and octopus) and fish (pollock, cod, etc.). Steller sea lions also occur within Bristol Bay; haulouts at Cape Newenham and Round Island are listed as critical habitat for the species. Other pinnipeds, such as spotted seals and bearded seals, are found occasionally in the Bristol Bay area.

Several cetaceans also use the shallow waters of Bristol Bay. Gray whales migrate along the shoreline of Bristol Bay in April and May on their way northward to summer feeding areas around St. Lawrence Island.

The southward migration in the fall occurs in October. Minke whales and harbor porpoise inhabit Bristol Bay year-round, and are found in moderately high abundance. A population of belukha whales also resides in the Bristol Bay area.

Another marine mammal present along the Alaska Peninsula is the sea otter. Sea otters are found in abundance in Bechevin Bay, and at lower abundance eastward to Port Moller.

Invertebrates

Several species of large invertebrates are found in abundance in the nearshore waters of Bristol Bay. Juvenile red king crab have been found in shallow waters along the Alaska Peninsula, and around Kvichak and Togiak Bays. Within this area, juveniles live among epifaunal communities associated with gravel and cobble substrate, then the crab move to offshore areas of Bristol Bay beginning at age 3. Alaska surf clams have been found in large concentrations along the Alaska Peninsula from Port Moller to Ugashik Bay (Hughes and Bourne 1981). Sea stars, crangon shrimp, and Telmessus crab (helmut crab) are abundant in shallow waters of northern Bristol Bay (Nichol et al. 1995). Helmut crab are closely related to and sometimes confused with hair crab, but are generally smaller and not commercially harvested.

At the request of the Advisory Panel, data from National Marine Fisheries Service trawl survey areas were examined for the distribution of invertebrates found in association with juvenile red king crab. During the 1984-1988 surveys, NMFS scientists made a concerted effort to identify SHAB (shells, hermits, and associated biomass) to the lowest practicable taxon. Although dated, these are the highest quality and most consistent data of this type for the Bering Sea. Dr. Bob McConnaughey (NMFS-AFSC) has provided plots of Boltenia (sea onions), Bryozoans, Mytilidae (mussels), and sea urchins, which are the types of biota associated with juvenile red king crab. Distribution of these invertebrates are shown in **Figures 4.5 and 4.6**. Note that all these invertebrate species are abundant in Bristol Bay, particularly in the area east of 162° W longitude.

4.3.3. Subsistence Fisheries of Bristol Bay

Residents of Bristol Bay communities draw much of their livelihoods from the sea, shoreline, and surrounding areas (NPFMC 1994b). Use of resources for subsistence may differ somewhat among the communities depending upon what is available. In the northern Bristol Bay communities of Togiak and Dillingham, residents may harvest walrus, spotted seals, and sea lions year-round, whereas the southern communities along the Alaska Peninsula use fewer marine mammals. Groundfish such as cod, flounder, halibut, and freshwater fishes are taken throughout the year. Herring and smelt are netted in early summer and herring roe-on-kelp is also harvested. Salmon (especially sockeye) comprise a large portion of the subsistence diet for residents throughout the Bristol Bay area. Waterfowl and seabird eggs are also taken, along with inland game birds, mammals, plants and berries. Subsistence use by Dillingham residents in 1984 is shown by **Table 4.2**; detailed information on other Bristol Bay communities is not available.

4.3.4 Commercial Fisheries of Bristol Bay

Groundfish

Prior to 1987, foreign and joint-venture fisheries pursued yellowfin sole and other flatfish species throughout Bristol Bay. These fisheries had relatively high catch rates of 5-10+ mt per hour and relatively high bycatch rates of red king crab (Fisher 1980). Due to crab bycatch concerns, the area south of 58° N and west of 160° W was closed to trawling in 1987. This closure limited potential groundfish effort in Bristol Bay. However, some trawl fishing effort has been expended for yellowfin sole in the northern and eastern Bristol Bay areas, which have remained open to trawling. Relatively high levels of effort have been expended in this area during the spring and summer by vessels targeting flatfish using bottom trawl gear (**Figure 4.7**).

Halibut

The northeast area of Bristol Bay has been open to commercial halibut fishing since 1990. Prior to that time, the entire Bristol Bay area was closed to halibut fishing to protect juveniles. A survey done by the International Pacific Halibut Commission (IPHC) in 1987 found that although the area from Cape Newenham to Cape Seniavin had low catch per unit effort, the catch of juveniles was low. As a result, the IPHC determined that a limited commercial fishery would not have an adverse impact on juvenile stocks, and a commercial fishery began in nearshore waters in 1990 (Gilroy and Hoag 1993). Landings (pounds, head-off, eviscerated) from the eastern portion of area 4E are listed in the adjacent table. The number of vessels participating has been low and declining, from 97 in 1990 to 11 in 1993. All but one vessel fishing in 1993 and 1994 were vessels from local Bristol Bay communities (G. Williams, IPHC, unpublished data). Beginning in 1995, the halibut fishery was managed under the IFQ program. Under that program, 100% of the area 4E quota is allocated to Community Development Program. IPHC regulatory and closure areas in the Bering Sea are shown in **Figure 4.8**.

Catch of Halibut in Bristol Bay, 4E(NE).

Year	Catch (lbs)
1990	25,401
1991	25,743
1992	14,439
1993	27,479
1994	58,547

Herring and Capelin

Herring Fisheries in Bristol Bay are managed by the State of Alaska. In May of each year, Pacific herring enter Bristol Bay to spawn in intertidal waters of the Togiak area. These herring support a moderately large fishery for sac roe, spawn-on-kelp, and bait fishery. Regulations provide for a maximum exploitation rate of 20 percent of the herring stock as estimated by aerial surveys or preseason forecasts (5 AAC 27.865). The Department of Fish and Game allocates 1,500 tons for the spawn-on-kelp fishery and 7 percent of the remaining available harvest for a food and bait fishery prior to opening the sac roe fishery. The sac roe fishery quota if further allocated among the gillnet (25%) and purse seine fleet (75%). The Togiak fishing district is subdivided into six sections for registration and reporting purposes.

The Togiak herring stock has gone through rather large fluctuations over the past 20 years due to highly variable recruitment (**Figures 4.9 and 4.10**). Landings have been more stable, however, averaging about 15,000 short tons from 1979 to 1990. Catches have since increased. In 1994, the Togiak District herring sac roe and bait fishery took 30,177 tons with an average roe content of 10.2%. With additional harvests for the spawn-on-kelp fishery, the total value of the 1994 Togiak herring fishery was about $9.3 million ex-vessel (Funk 1994).

Togiak also supports a fishery for capelin, a forage fish species. When capelin move inshore to spawn along sandy beaches, they are prosecuted in some years by a small fishery. This fishery is managed by the State of Alaska, however regulations address only the disposal of capelin carcasses (5 AAC 06.560). Maximum recorded capelin harvest in the Togiak district was 1,321 mt in 1984. Only 2 mt were landed in 1994, due in part to lower abundance (NMFS 1995). It should be noted that the Council is analyzing a plan amendment proposal to restrict directed fisheries for forage fish such as capelin.

Salmon

Salmon stocks of the Bering Sea support large gillnet fisheries, which are managed by the State of Alaska. Sockeye salmon is the dominant species targeted, with lesser amounts of chum, chinook, and coho salmon harvested. In recent years, record numbers of sockeye salmon have been harvested, primarily in the Bristol Bay area. In 1995, for example, it is estimated that 44,430,000 sockeye salmon were harvested in Bristol Bay alone, along with 950,000 chums, 100,000 chinooks, and 50,000 coho salmon. The 1995 Bristol Bay salmon fishery generated about $185,000,000. North of Bristol Bay in the Arctic/Yukon/Kuskokwim area, chum salmon and chinooks dominate salmon catches.

Crab

Offshore areas of Bristol Bay have supported large fisheries for red king crab and Tanner crab. In recent years, however, both of these stocks have been at low levels, such that no fishery occurred in Bristol Bay east of 163^{o} W in 1994 or 1995. After declining abundance throughout the 1960's and reaching a low during the years 1970-1972, recruitment to the Bristol Bay red king crab stock increased dramatically. New all-time record landings were established in each year from 1977 to 1980. Declining recruitment, fishing pressure, and probably increased incidence of disease and predation led to an abrupt decline in fisheries in 1981 and 1982. These precipitous declines led to a closure of the Bristol Bay fishery in 1983. In 1984 the stock showed some recovery and a limited fishery was reestablished. Between 1984 and 1993, the fishery continued at levels considerably below those of the late 1970's. Landings during this period ranged from 1,900 t and 0.8 million crab (1985) to 9,240 t and 3.1 million crab (1990). Throughout the 1980's and 1990's there was little sign of a large year-class in this stock, and since 1987, very few immature crab have been captured during the trawl survey. Low recruitment has led to closure of the commercial fisheries fore Bristol Bay red king crab in 1994 and 1995. During these years, Tanner crab fisheries were restricted east of 163° W longitude to reduce handling of king crabs.

4.3.5 Red King Crab Biology and Habitat Requirements

A review of year-class strength formation and survival of red king crabs is provided by Tyler and Kruse (1995b). After hatching, which generally occurs between April and June (Armstrong et al. 1993), red king crab spend 3 to 4.5 months in larval stages before settling to the benthic life stage which can last to 20 years. King crab molt from 8 to 11 times during the first year and 8 more times by the age of 3 after which molting is annual. At larger sizes, king crab may skip molt as growth slows. Sexual maturity is reached at approximately 5 to 6 years; and 50% of males are mature at 120 mm carapace length (CL) (NOAA 1991). Fifty percent of females are mature between 86 and 90 mm CL (Otto et al. 1980). Red king crab can generally mate as early as January and through June when they enter shallower waters (<50 m). Males grasp females just prior to female molting at which time eggs are fertilized and extruded on the female abdomen. The female red king crab carries the eggs for 11 months before they hatch.

After hatching, crab larvae drift generally from the spawning area nearshore along Unimak Island and the Alaska Peninsula in the direction of Bristol Bay (**Figure 4.11** from Armstrong et al. 1993). Armstrong et al. (1993) concluded the following:

> Given the location of juvenile habitat and apparent larval drift, we would expect larvae hatched near the west end of the Alaskan Peninsula to have a better chance of reaching good habitat (and thus adulthood) than those hatched in central Bristol Bay. This expectation is partly borne out by the observed spawning distributions during the mid-1970's that led to high fishery abundance in 1979-80. Thus, nearshore spawning areas from Unimak Island to east of Port Moller (160-163°W) may be more important to maintaining the stock than areas within the midshelf basin of Bristol Bay.

Young-of-the-year red king crab occur at depths of 50 m or less. They are solitary and need high relief habitat or coarse substrate such as boulders, cobble and shell hash (Jewett and Onuf 1988). McMurray et al. (1984) found that biological parameters were better correlated with juvenile crab distributions than were physical parameters. A strong correlation was found between young-of-the-year crab and tube-building polychaete worms (McMurray et al. 1984). The survival of 1-yr-old crabs was found to be related to cohort density and cover, with mortality due to density (cannibalism) being significant only when no cover was available (Rounds et al. 1989).
Age 0+ to two year old red king crab were statistically correlated with sea urchin biomass, and older juvenile crab were correlated with sea onion biomass (McMurray et al. 1984). Bryozoans and mussels also provide important habitat (Stevens et al. 1991, Armstrong et al. 1993). Distribution of these invertebrates is shown in **Figures 4.5 and 4.6**. Citing McMurray, in absence of epifauna, age 1+ crab were found to prefer medium-size rock over gravel, sand or small rocks, however the preference was for epifauna when available (Jewett and Onuf 1988).

The necessary juvenile red king crab habitat is patchy in Bristol Bay. Generalized areas of habitat have been described (**Figure 4.12** from Armstrong et al. 1993, and **Figure 4.13** from Witherell and Harrington 1995), and critical habitat is distributed within these areas. Jewett and Onuf (1988) state the following:

> Young crab depend on an environment which provides for adequate food (i.e. hydroids and bryozoans) and protection from predators (demersal fishes). The distribution of such suitable substrates in some locations (e.g. Bristol Bay) is extremely patchy, and it is believed that settling in areas where such substrates are absent or limited will hasten natural mortality. Settlement on unprotected bottom presumably will leave them exposed to predation, waves, and currents.

Between the ages of two and four years, there is a decreasing reliance on habitat and a tendency for red king crab to form pods consisting of thousands of crab (Jewett and Onuf 1989, Dew 1990, Stone et al. 1993). Podding continues until approximately 65 mm or four years of age when the crab move to deeper water (>50 m) and join adults in the spring migration to shallow water for spawning and deep water for the remainder of the year.

Adult red king crab generally live in the deeper areas of Bristol Bay. **Figure 4.14** provides the location and relative abundance of red king crab encountered in a recent NMFS annual trawl survey. The information from the trawl surveys indicates the general distribution of red king crab during the summer months when the trawl survey is conducted. The circle centers indicate the locations of individual hauls, and the size of the circle indicates the total number of crab encountered in the trawl. A large circle does not represent an expansion into adjacent areas beyond the location of the haul.

There is little information available on red king crab predators across the range of life-stages (Jewett and Onuf 1988). Haflinger and McRoy (1983) reported on consumption of crab glaucothoe larvae in numbers which Jewett and Onuf (1988) considered to be insignificant. Livingston (1989) reported on Pacific cod predation of molting red king crab of which Livingston concludes that the percentages removed by cod form a small and declining part of the total population decline.

4.3.6 Pacific Herring Biology and Habitat Requirements

Pacific herring spawning commences in January in the southern end of its range (California) and starts progressively later to the north. As shown in **Figure 4.15**, spawning in the Bering Sea generally begins in May in the Alaska Peninsula and Bristol Bay areas, and from June to mid-July in more northern areas. Spawning has been noted to occur over a range of 6-10°C in the Togiak area . The duration of spawning may range from a few days to almost a month depending on location and year.

Herring generally spawn in sheltered bays and avoid exposed coastlines. Spawning in the North Pacific takes place near the shoreline between the high tide level and 11 meters (Hart 1973). Herring deposit eggs on vegetation, primarily rockweed (Fucus sp.) and eelgrass (Zostera sp.) (Taylor 1964). Herring eggs are adhesive, measure approximately 1 mm in diameter, and one square inch of seaweed may be covered with up to 1,000 eggs in several layers. Eggs take 10-21 days to hatch depending on the water temperature. Herring hatch as larvae averaging 8 mm in size. The planktonic larval stage lasts for approximately 6-10 weeks at which time the larvae have grown to approximately 30 mm and begin to metamorphose into juveniles (Taylor 1964).

Upon completion of metamorphosis, juvenile herring are free swimming and begin to form schools. The schools enlarge and move out of the bays as summer progresses (Taylor 1964). Little is known about the juvenile stage in the Bering/Chukchi Sea region from the time they leave the coast in their first summer until they are recruited to the adult population. Immature herring feed in coastal waters in summer and move to deeper water in winter. Juvenile herring in British Columbia and southern Alaskan waters winter offshore and reappear in bays the following summer (Taylor 1964).

Mortality is high during embryonic development. Taylor (1964) found egg mortality in British Columbia to range from 55 to 99% and average 70-80%. The major causes of mortality were wave action, exposure to air, and bird predation. Bird predation was the largest source of egg mortality (30-55%), but was a constant mortality source and did not appear to influence relative year class abundance. Haegele and Schweigert (1990) estimated that 7.1% of the eggs in Georgia Strait, British Columbia were lost to predation, primarily by birds and invertebrates such as crabs, snails, and starfish. The majority of deposited spawn and kelp in the upper intertidal region along the south shore of Cape Romanzov, in the Bering Sea, was destroyed or washed away during a severe storm in 1978 which indicates that wave action may be a serious limitation to herring productivity (Gilmer 1978).

Bering Sea herring populations overwinter in an area northwest of the Pribilof Islands (NPFMC 1981), and return to coastal areas to spawn beginning at ages 3 to 5. The 1994 Togiak purse seine fishery was dominated by age 7 and age 8 fish, coinciding with strong year-classes (Funk 1994). The commercial gillnet fishery selects older and larger herring (mostly females), and consequently caught primarily age 9 fish and older. Herring are iteroparous, and may live to age 15.

In the eastern Bering Sea, predation on juvenile and adult herring is low relative to biomass removal by the commercial fishery (Livingston 1993). Herring were eaten primarily by fish (Pacific cod), followed by marine mammals (harbor seals, ringed seals, and spotted seals), and birds (common and thick-billed murres). The relative size of Pacific herring removed due to mortality is shown in **Figure 4.16**. Total removals relative to stock size were relatively small.

4.3.7 Pacific Halibut Biology and Habitat Requirements

Pacific halibut are distributed on the continental shelf of the North Pacific Ocean from Japan to California. Halibut undergo seasonal spawning migrations, moving to shallow water in the summer to feed and to deeper water in the winter to spawn. Extensive coastwide migrations also occur, with large halibut showing an overall migration from north to south, based on tag returns.

In the Bering Sea, halibut movements are based to a large extent on water temperature. During the winter months, ice covers much of the Bristol Bay halibut nursery area and water temperatures near bottom drop to 0°C or less. As the bottom temperatures drop past acceptable levels, halibut tend to concentrate into the deeper, warmer waters along the continental edge and also into the shallower (50 to 90 m) warmer waters originating from coastal Gulf of Alaska waters flowing into the Bering Sea through Unimak Pass and extending along the north shore of Unimak Island to Amak Island. With the advent of spring, as the warming progresses, young halibut move eastward along the north side of the Alaska Peninsula and usually are found throughout Bristol Bay in June. By late June, they spread northward toward Nunivak Island and as far as St. Matthew Island. Many of the tags released in the Bering Sea have been recovered within the area and have confirmed the annual migration from deep areas in winter to shallow in summer and return to deep water in the winter (Best 1977).

In the eastern Bering Sea, the youngest halibut have been found on the southern flats and in the shallow waters along the Alaska Peninsula, the north shore of Bristol Bay and the Aleutian Islands. Larger, older juveniles and adults are known to range into the more northerly part. The younger fish possibly do not have the strength and endurance to make the longer migration and compete with the larger individuals even though the environment is suitable during the summer. Although the percentage of juvenile halibut in Bristol Bay is higher than in other Bering Sea areas, the abundance of both juveniles and adults is quite low in nearshore areas of Bristol Bay (**Figure 4.15**, from Gilroy and Hoag 1993).

4.3.8 Impacts of Fishing Gear on Benthic Habitat

Groundfish fishing can impact crab through gear interaction. Impacts on crab that come into contact with the gear but are not captured, has proven difficult to quantify because they occur on the ocean floor and cannot be directly observed. Studies on the potential effects of trawls, dredges, longlines, and pots as they may relate to benthic habitat are summarized below.

Trawl Gear

Jones (1992) provides an overview of available knowledge on impacts of bottom trawling on the benthic environment. For this review, bottom trawling includes otter trawls, beam trawls, dredges, and Danish seines. Jones categorizes the ways in which trawling can disrupt the habitat: 1) scraping and plowing the sea-floor, (2) sediment re-suspension, (3) damaging or removing non-target benthic organisms, and (4) dumping of processing waste. Evidence of trawling, such as furrows from the trawl doors, varies in its depth into the sea-floor and its duration depending upon the "softness" of the bottom being trawled. In terms of sediment re-suspension, the report notes that there are two facets to this issue: (1) increased, and usually temporary turbidity and (2) vertical redistribution of sediment layers. Both of these results of bottom disturbance by trawl gear were noted to vary in their duration, primarily dependent upon the depths at which they occurred. The report also concludes that "From the work performed under the aegis of ICES, it would appear that beam trawls, otter trawls, and dredges are all basically similar in their effects. Generally, the heavier the gear in contact with the seabed, the greater the damage. The effects vary greatly, depending on the amount of gear contact with the bottom, together with the depth, nature of the seabed, and the strengths of the currents or tides....The removal of the macrobenthos has variable effects. In shallow water areas where the damage is intermittent, recolonization soon occurs. However, where the macrobenthos is substantially removed and recovery is not permitted, the change is permanent....The evidence is that bottom trawling has an impact on the environment, but that the extent and duration of that impact varies depending on local conditions."

Another review of the impacts of trawling on the seabed and benthic community (Thompson 1993) concludes that " it is clear that trawling can impact both the seabed and the benthic community. The extent of these impacts depends on the weight of the gear, the towing speed, the nature of the bottom sediments, and the strengths of tides and currents. Bottom trawl doors leave scars on the seabed that can last for minutes, hours, or years. Trawls can damage benthic organisms, thereby causing changes in community species composition and population age structure, but perhaps also leading to an increase in the availability of forage for commercial species. Whether changes in community species composition would tend to come at the expense of commercially important species such as crab is difficult to determine."

The following excerpt from the groundfish plan team's Ecosystems Considerations Chapter (NPFMC 1994), discusses observations of habitat impacts in the Gulf of Alaska. "Substrate indentations caused by trawl doors were common at many of the dive sites in submersible studies conducted by the NMFS Auke Bay Lab. The depth of the indentations ranged from a few inches on hard, pebble substrate to three feet on soft sand. Trawl marks were numerous on hard substrate. No obvious differences were noticed in kinds or amounts of fauna and flora within or without the trawl paths. Trawl marks were also common at some soft bottom sites off Yakutat (videos shown at council meeting in Sitka). These marks were probably of recent origin because silt had not filled in the furrows dug by the trawl doors, and displaced habitat was evident -- boulders and cobble were displaced, silt was brushed off the habitat, and flora were knocked down or missing. Displaced habitat and flora between the trawl door marks were obvious at these sites."

Dredge Gear

Similar to trawling, dredging may place fine sediments into suspension, bury gravel below the surface, and overturn large rocks that are embedded in the substrate (NEFMC 1982, Caddy 1968, 1973). A study of scallop dredging in Scotland showed that dredging caused significant physical disturbance to the sediments, as indicated by furrows and dislodgement of shell fragments and small stones (Eleftheriou and Robertson 1992). The authors note that these changes in bottom topography did not change sediment disposition, sediment size, organic carbon content, chlorophyll content, or biomass and abundance of infuanal community components. However, direct observations in dredge paths indicated that large numbers of mollusks, echinoderms, and crustaceans were killed or damaged by dredging operations (Eleftheriou and Robertson 1992). Observations of the Icelandic scallop fishery off Norway indicated that dredging changed the bottom substrate from shell-sand to clay with large stones within a three-year period (Aschan 1991). Messieh et al. (1991) found that dredge marks on the sea floor tend to be short-lived in areas of strong bottom currents, but may persist in low energy environments. Mayer et al. (1991) investigating the effects of a New Bedford scallop dredge on sedimentology at a site in coastal Maine found that vertical redistribution of bottom sediments had greater implications than the horizontal translocation associated with scraping and ploughing the bottom. The scallop dredge tended to bury organic matter below the surface, causing a shift in sediment metabolism away from aerobic respiration that occurred at the sediment-water interface and instead toward subsurface anaerobic respiration by bacteria.

Longline Gear

Very little information exists regarding the impacts of longlining on benthic habitat. Observations of halibut longline gear made by NMFS scientists during submersible dives off Southeast Alaska provide some information (NPFMC 1992). The following is a summary of these observations: "Setline gear often lies slack on the sea-floor and meanders considerably along the bottom. During the retrieval process the line sweeps the bottom for considerable distances before lifting off the bottom. It snags on whatever objects are in its path, including rocks and corals. Smaller rocks are upended, hard corals are broken, and soft corals appear unaffected by the passing line. Invertebrates and other light weight objects are dislodged and pass over or under the line. Fish, notably halibut, frequently moved the groundline numerous feet along the bottom and up into the water column during escape runs disturbing objects in their path. This line motion was noted for distances of 50 feet or more on either side of the hooked fish."

Pot Gear

Pot gear may also impact habitat by sediment re-suspension and upending small rocks, shells, ascidians, bryozoans, and other bottom structure during the process of setting and retrieving pots; however, no literature regarding these impacts could be found.

5.0 NEPA REQUIREMENTS: ENVIRONMENTAL IMPACTS OF THE ALTERNATIVES

An environmental assessment (EA) is required by the National Environmental Policy Act of 1969 (NEPA) to determine whether the action considered will result in significant impact on the human environment. The environmental analysis in the EA provides the basis for this determination and must analyze the intensity or severity of the impact of an action and the significance of an action with respect to society as a whole, the affected region and interests, and the locality. If the action is determined not to be significant based on an analysis of relevant considerations, the EA and resulting finding of no significant impact (FONSI) would be the final environmental documents required by NEPA. An environmental impact study (EIS) must be prepared for major Federal actions significantly affecting the human environment.

An EA must include a brief discussion of the need for the proposal, the alternatives considered, the environmental impacts of the proposed action and the alternatives, and a list of document preparers. The purpose and alternatives were discussed in Section 1, and the list of preparers is in Section 10. This section contains the discussion of the environmental impacts of the alternatives including impacts on threatened and endangered species and marine mammals.

5.1 Environmental Impacts of the Alternatives

The environmental impacts generally associated with fishery management actions are effects resulting from 1) harvest of fish stocks which may result in changes in food availability to predators, changes in the population structure of target fish stocks, and changes in community structure; 2) changes in the physical and biological structure of the benthic environment as a result of fishing practices, e.g., effects of gear use and fish processing discards; and 3) entanglement/entrapment of non-target organisms in active or inactive fishing gear. A summary of the effects of the 1995 groundfish total allowable catch amounts on the biological environment and associated impacts on marine mammals, seabirds, and other threatened or endangered species are discussed in the final environmental assessment for the 1995 groundfish total allowable catch specifications.

5.1.1 Potential Impacts of Extending the Bristol Bay Red King Crab Savings Area on Red King Crab

In order for the population of red king crab in Bristol Bay to be stable or rebuild, the annual replacement by young crab must, on the balance, meet or exceed removals of all crab. The relationship of population removals to population additions may be useful as a general indication of the health of the red king crab population in Bristol Bay. The total removals of red king crab, by natural mortality, directed fishing, and bycatch, were estimated over a series of years and compared with estimates of recruitment which would add to the population in the following year. The population estimates, recruitment and mortality parameters were as estimated by Zheng et. al. in the series of papers outlining the length-based assessment (LBA) population model for Bristol Bay red king crab.

The population estimates of red king crab for which mortality estimates were available as used in the LBA (small and mature male crab and mature female crab) are provided in **Table 5.1**. The associated natural mortality parameters (m) are provided as well. The annual rate of natural mortality was projected as $(1-e^{(-m)})$. In the LBA analysis, the year is assumed to begin when the annual trawl survey is conducted in June of each year. Since directed harvest of red king crab occurs after approximately 40% of this year has passed, the directed catch of red king crab was adjusted by 60% of natural mortality (m) because the crab in the fishery would have been removed due to natural mortality had the fishery not occurred. Bycatch numbers were not adjusted because bycatch, as natural mortality, is estimated to be possible throughout the year.

The recruitment of new crab to the population from LBA estimates are provided in **Table 5.1** as well. The recruited crab have been lagged in the table by one year. The reason for the lag is so that the total removal of crab in a year can be compared with the number of crab which would replace them at the start of a new year.

The additions and subtractions to the population are summarized in **Figure 5.1**. Recruits to the population in year $i + 1$ are represented as positive on the Y axis and have been lagged to year i. The population mortalities in year i are represented as negative numbers on the axis. The general trend apparent from the figure shows a declining magnitude of the numbers over time. The additions exceeded removals until 1977. During the period 1977 - 1982, removals exceeded additions to the population. As has been described in the previous analysis (NPFMC 1995), the red king crab population in Bristol Bay increased in numbers through the late 1970's and reached a peak abundance in 1980. The population declined dramatically in the early 1980's and there was no directed fishing allowed in 1983, with reduced harvest in subsequent years. It appears that in spite of high population numbers in the late 1970's, the continued removals from the population exceeded recruitment, and the population was not able to sustain the high abundance levels. In recent years, the magnitude of both recruitment and mortalities has been relatively low.

The net changes in the Bristol Bay red king crab population are provided in **Figure 5.2**. Estimates of recruitment were added to the negative mortalities to arrive at the net changes to the population. As discussed above, additions exceeded removals until 1977, removals exceeded additions during the period 1977 - 1982, additions generally exceeded removals again between 1983 and 1988, however, since 1988 the removals have generally been greater than additions.

Recruitment in recent years has been at historical lows, and the cumulative effect of natural and man-induced mortalities has exceeded the ability of the population to replace itself. The need for factors leading to high recruitment events is apparent and vital to the red king crab population in Bristol Bay.

Alternative closure periods that encompass the molting period of red king crabs would reduce mortality of crab taken as bycatch and those crab not retained by trawl gear. Studies have shown that trawl damage to crabs and lobsters is greater on softshelled animals. Smith and Howell (1987) found that major damage rates of lobster due to trawling ranged from 12.6%-14.0% during molting periods but only 0-5.6% when lobsters were in hardshell condition. Stevens (1990) found that immediate mortality of red king crabs taken as bycatch in trawls was inversely related to shell age. Red king crabs are thus more susceptible to injury and mortality during the period January through June when molting occurs in the Bering Sea. Stevens (1990) concluded that "reduction of king (and probably Tanner) crab mortality could be achieved by conducting the trawl fishery during periods of the year when molting activity is at a minimum". This reduction in mortality can be achieved by Alternative 2. Option A (6-month closure) would eliminate trawling in the area during the molting period. Option C (7-month closure) would also protect red king crab during the shell hardening period. Alternative 2, Option B (year-round closure) would reduce mortality of softshell crab and hardshell crab in the area.

Alternative 3 would provide habitat protection in nearshore areas, but may result in increased impacts on red king crab because a portion of Area 512, Area 516, and the Red King Crab Savings Area would be open to trawling. It is difficult to estimate what the impacts of this alternative might be without data on bycatch rates. Survey data indicate that crab are found in abundance in the proposed open area, however. As discussed in Section 2, survey data show that 38% of mature male and 12% of the mature female red king crab are found outside the closure area. These crab would be exposed to trawling.

5.1.2 Potential Impacts of Modifying Crab Bycatch Limits on Groundfish Stocks

None of the management measures considered in this document is likely to have significant impacts on groundfish stocks. Catch of all groundfish is counted against the TAC, regardless where it is caught. Closure of areas to groundfish trawling will likely be offset by increased effort outside the closure areas. No changes to groundfish stock status from the status quo are expected, as it is likely that fisheries will continue to remove about two million metric tons of groundfish per year from the BSAI region.

5.1.3 Potential Impacts of Modifying Crab Bycatch Limits on Crab Stocks

There are several ways to measure relative crab mortality caused by the trawl fishery. The simplest way is to compare current levels of bycatch as a percentage of total crab population. For example, current bycatch amounts to about 0.5% of the red king crab population, 1.2% of the Tanner crab population, and 0.14% of the snow crab population based on recent NMFS survey indices of abundance. It should be noted that the NMFS survey provides population estimates as an index only; small crab are not fully vulnerable to the trawl gear used, and consequently the "real" crab population size is likely much larger than the survey index. Therefore, bycatch accounts for a smaller percentage of the actual population than indicated by the survey index comparisons.

Crab bycatch in trawl fisheries as a percentage of total crab abundance as indexed by NMFS surveys.

	Bristol Bay Red king	EBS Tanner	EBS Snow
1992	0.49 %	0.92 %	0.22 %
1993	0.52 %	1.34 %	0.13 %
1994	0.82 %	1.30 %	0.13 %
1995	0.13 %	1.21 %	0.06 %
AVERAGE	0.49 %	1.19 %	0.14 %

A better measurement of impacts would take into account other factors such as the size and sex of crab taken. In January 1995, the Council's Scientific and Statistical committee recommended that the impacts of crab bycatch should be measured by adult equivalents. This also provides better estimates of impacts across fisheries.

Based on information summarized in Section 1, a simple accounting formula was used to estimate mortality in adult equivalents for males and females of all three crab species examined. Inputs to the formula were discussed in Section 3, and summarized in **Table 5.2**. Adult equivalents were calculated based on the following equation:

$$\mathbf{Q = (N*n*D)*(A)^t}$$

where:

Q = adult equivalents, measured in number of crab of the sex and species examined

N = Number of crab bycaught of that species
n = proportion of bycatch observed to be male (of female depending on application)
D = discard mortality rate; the proportion of crab bycaught that die due to capture and handling (trawl, 0.80; longline, 0.37 (rkc) 0.45 (Tanner and snow crab); groundfish pot, 0.08 (rkc) 0.30 (Tanner and snow crab); scallop dredge 0.40; crab pot 0.08)
A = conditional annual survival rate set at 0.75, based on (e^{-M}) where M=0.30
t = years to recruitment in fishery (males) or spawning stock (females); based on average age of bycatch versus average age of crab in directed fishery (males) or average age to maturity (females).
(N*n*D) = number of crab of killed for the sex and species examined
$(A)^n$ = adjustment factor to account for age

Results of this exercise indicate that the effects of trawling and other human activities on crab mortality depend on species, sex, and year examined. Results are shown separately for 1993-1995 for male and female red king crab (**Tables 5.3-5.5**), Bering Sea Tanner crab (**Tables 5.6-5.8**), and snow crab (**Tables 5.9-5.11**). [Note that the impacts calculated for 1995 do not include crab fishery bycatch data, which were not available at the time of document preparation. Hence, the analysis underestimates the impact of bycatch in crab fisheries for 1995.] A summary of the relative impacts of the groundfish, scallop, and crab fisheries, in terms of adult equivalents, is shown in **Table 5.12**. A summary of the impact of these fisheries relative to crab populations is shown in **Table 5.13**.

This exercise of determining adult equivalents provided two major insights into the impact of trawl bycatch. First, a comparison of adult equivalent mortality across fisheries is instructive for developing a crab rebuilding policy. In years when a GHL is established, the single largest source of human induced crab mortality is removals of legal males by directed crab fisheries. This is true for male crab of all three species. Crab fisheries accounted for about 98% of the male red king crab, 85% of male Tanner crab, and 98% of the male snow crab mortality. The crab fishery has a relatively smaller impact on females. For females, crab fisheries accounted for 68% of the female red king crab, 47% of the Tanner crab, and 6% of the snow crab mortality. Most of the remaining removals are due to the trawl and other groundfish fisheries. In all cases examined, the scallop fishery had relatively little impact on crab stocks as measured by observed bycatch. These data indicate that reductions in crab quotas for crab fisheries may have relatively more impact on rebuilding than reductions in crab bycatch in trawl or dredge fisheries.

Average adult equivalent crab removals by groundfish, scallop, and crab fisheries as a percentage of total crab abundance, 1993.

	Bristol Bay Red king		EBS Tanner		EBS Snow	
Fishery	male	female	male	female	male	female
Groundfish	0.82 %	0.98 %	4.24 %	1.73 %	1.06 %	0.12 %
Scallop	0.00 %	0.00 %	0.09 %	0.19 %	0.00 %	0.00 %
Crab	35.23 %	2.04 %	29.73 %	1.79 %	80.39 %	0.01 %

The second insight provided by this exercise is a measurement of adult equivalent removals relative to population size. As indicated by the adjacent table, bycatch in groundfish fisheries has relatively small impacts on crab populations. Of these crab species, groundfish fisheries impact Tanner crab the most, killing almost 5% of the adult male stock as bycatch. The impact on female Tanner crab was less, as fewer females are taken as bycatch. Smaller impacts on red king crab and snow crab were estimated. Additionally, impacts due to the 1995 groundfish fisheries on these crab species were generally lower than in previous years.

Average adult equivalent crab bycatch in groundfish fisheries as a percentage of total crab abundance, 1993-1995.

	Bristol Bay Red king		EBS Tanner		EBS Snow	
Year	male	female	male	female	male	female
1993	0.82 %	0.98 %	4.24 %	1.73 %	1.06 %	0.12 %
1994	0.88 %	1.47 %	4.25 %	1.87 %	2.27 %	0.12 %
1995	0.22 %	0.24 %	5.69 %	0.91 %	1.09 %	0.03 %
Average	0.64 %	0.90 %	4.73 %	1.50 %	1.47 %	0.09 %

From these data, one can also estimate what a reduction in trawl PSC limits means in terms of female spawning biomass. For example, an 82.5% reduction in allowable bycatch of red king crab to 35,000 (the most conservative alternative) would result in about a 0.75 % increase in female spawner abundance [Calculation = 0.825*0.90% = 0.743%]. In other words, for 1994, abundance of Bristol Bay red king crab females may have been increased from an estimated 8.746 million mature females (LBA estimate) to about 8.811 million mature females if such a reduced PSC limit had been in place. Such an increase (65,000 crabs) would be almost unmeasurable, as the trawl survey estimated the 1994 mature female abundance to be within the range of 4.2 million to 10.9 million (Stevens et al. 1994). The impacts of a 25% reduction in Tanner crab PSC limits proposed under Alternative 2 would result in about a 0.38% increase in female spawner abundance. In other words, Tanner crab female spawner may have increased from 37.2 million mature females to 37.3 million mature females in 1995. A limit on the take of snow crab could serve to maintain minimal impacts of bycatch on spawning biomass.

This analysis indicates that reducing the PSC limits may not drastically improve or rebuild crab stocks. Because bycatch mortality caused by trawl fisheries is very small relative to other sources of removals due to natural and fishing mortality, reductions in bycatch limits may not result in measurable improvements to crab stock abundance. Potential "savings" of crab through PSC reductions proposed under Alternative 2 and 3 will increase crab available for harvest or spawning only slightly. This was also the conclusion of Stevens (1990) who stated that "Removals of this magnitude (0.5% of the population as trawl bycatch) are well below the ability of the NMFS crab survey to detect, and probably have no significant biological impact". However, as noted in Section 5.1.1, the cumulative effect of natural and man-induced mortalities has exceeded the ability of the red king crab population to replace itself. Any reduction in mortality would slow the decline of the Bristol Bay red king crab stock. Adult equivalent removals of about 65,000 female spawners likely has more impact on the red king crab stock when abundance is low than when the stock is at higher levels.

Although concern has been raised about the unknown mortality of crabs caused by trawling, reducing PSC limits may exacerbate these unobservable impacts. In an attempt to catch less crabs (via reduced bycatch limits, VIP regulations, or proposed measures such as IBQ's, Harvest Priority, etc.), trawl fishermen may modify their gear. Modifications to footrope design, roller size, and mesh size can result in fewer crabs being retained and counted by observers (NRC 1988). For trawl fisheries historically limited by bycatch limits, reduced bycatch rates of PSC species may result in increased effort (at least until limited by TAC of targets). In turn, increased trawl effort could result in increased unobservable impacts on crab resources. This possibility was also raised during the Council's 1993 deliberations over trawl codend mesh size, but the benefits of reduced bycatch were felt to outweigh the possible costs of unobserved mortality due to non-retention.

Alternative 3 as currently drafted (PSC limits based on "total" crab abundance) may have biological impacts on crab stocks. The biggest drawback of using abundance indices for population totals as opposed to those for larger crabs is that there is considerable doubt as to what fraction of the total areal distribution of the population is being sampled by the NMFS summer survey. The survey area is largely determined by the distribution of commercially exploitable stocks which generally corresponds to that of mature animals of various species but not to the general range of a stock or species. This is true for both crabs and various fishes.

Small changes in the distribution of juveniles can cause large changes in survey abundance indices because nursery areas are often found at the edges of the survey area. Relative to the annual survey area, many juvenile Tanner crabs are found in deeper water, many juvenile snow crab are found to the north and small juvenile red king crab are found inshore. Obviously small changes in survey area that occur from year to year may have similar effects. For example, when adverse budgets or weather cause a shrinkage in the survey area, the tendency is to contract into areas on known commercial abundance at the sacrifice of peripheral areas where juveniles are frequently dominate catches.

The statistical distribution of small crabs tends to show a greater degree of dispersion than for larger crabs. This is especially so for red king crab. For example, over the last 5 years (1991-1995) the coefficient of variation (here 100 * std. err./ mean) for juvenile female red king crabs (<90 mm CL) averaged 44.1 and ranged from 28.4 to 82.4. For mature females (>89 mm CL) the average was 19.1 and the range was from 15.9 to 22.6. The above problems lead to imprecision, bias and year to year instability that can occur quite apart from actual changes in the population. Since changes in total abundance indices are frequently dominated by those of juveniles it may be better to use a multi-year index and or one that is based on the abundance of mature crabs, rather than keying the bycatch cap to the total population index in a given year.

5.1.4 Potential Impacts of a Nearshore Trawl Closure on Bycatch and Groundfish Catch

The primary fisheries with directed effort in the proposed Bristol Bay closure area (east of 162° West Longitude) are the bottom trawl fisheries for yellowfin sole, flatfish, other flatfish and rocksole. The percentages of observed catch and the bycatch of several species in these fisheries during the period 1986 - 1994 are provided in **Table 5.14** and **Figures 5.3 and 5.4**. There has historically been very limited observed fishing in Area 508 (**Table 5.14** and **Figure 5.4**).

Of the four fisheries examined, the directed fishery for yellowfin sole has historically taken the highest percentage of catch within the Bristol Bay area. The percentage of catch in the JV fisheries ranged between 11% and 45% between 1986 and 1988. There was no directed fishing in Bristol Bay in 1989. Since the domestic fisheries began in 1990, the yellowfin sole fishery took approximately 11%, 50%, 25%, 11% and 2% of its catch in Bristol Bay in the 5 years 1990 to 1994, respectively. The highest percentages of directed catch from the Bristol Bay area by the other fisheries were 9% and 7% by the flatfish fishery in 1991 and 1992, respectively; 33% by the other flatfish fishery in 1994; and 11% by the rock sole fishery in 1987. Otherwise, a relatively small percentage of the total directed catch was taken in Bristol Bay by these fisheries (**Figure 5.3**).

Trawl fishing activity in the Bristol Bay area is generally concentrated in the vicinity of Togiak Bay, and is primarily for yellowfin sole (**Figures 5.5 - 5.7**). **Figures 5.8-5.13** also show the hauls with bycatch of herring and crab in 1992, 1993 and 1994. Because of the intense fishing effort in a relatively small portion of Bristol Bay, the bycatch of crab and herring also overlap with the directed catch in Togiak Bay. Additional plots of herring, Tanner crab, and halibut bycatch are provided in **Appendix 10**.

Among the bycatch species, virtually no Tanner crab have been bycaught in the Bristol Bay area. In contrast, a very high percentage of the herring bycatch taken by the four fisheries under discussion was taken in the Bristol Bay area. It should be pointed out, however, that although a high percentage of herring bycatch by these fisheries occurs within Bristol Bay, there is also significant bycatch of herring by the pollock fisheries in areas 514 and 517. The flatfish bycatch does not generally constitute the major bycatch of herring. The yellowfin sole fishery took 85%, 98%, 100%, 91% and 89% of its herring bycatch in the Bristol Bay during the years 1987 - 1992, respectively. In 1993, this percentage dropped to 46%, and in 1994 it dropped further to 17%.

Because a higher percentage of directed catch is taken in Bristol Bay by the yellowfin sole fishery, the percent of bycatch species taken in Bristol Bay also tends to be higher than in the other fisheries. The percentage of observed halibut bycaught by the yellowfin sole fishery in the Bristol Bay area is generally lower than the percentage of directed catch taken in the area, and varies between 10% and 30%. A high of 41% of yellowfin sole bycaught halibut were taken in the Bristol Bay area in 1991. Similarly, the bycatch of red king crab by the yellowfin sole fishery has ranged between 0% and 20% of the fishery total bycatch between 1986 and 1994. The exception to this was the 1991 domestic yellowfin sole fishery which bycaught 45% of its red king crab in the combined northern Bristol Bay and 508 areas.

In summary, the fishery with the highest percentage of directed catch taken within the Bristol Bay area is the yellowfin sole fishery. A high of 50% of the yellowfin sole observed catch was taken in 1991, however, this percentage has declined annually until only 2% of the directed catch was taken in Bristol Bay in 1994. The percentages of prohibited species bycatch taken in the Bristol Bay area are generally similar to the catch percentages with the exception of herring which generally constitutes a very high percentage of the total yellowfin sole bycatch of herring.

Option A under Alternatives 2 and 3

During the April Crab Rebuilding Committee meeting, and in the April Council meeting, it was suggested that the area between 159° and 160° W longitude and 58° and 59° N latitude be considered as a possible section of northern Bristol Bay to remain open (Option A), given a general closure of the Northern Bristol Bay area to trawling. This is an area of intense fishing effort by the yellowfin sole fleet, but is also an area of relatively low bycatch rates, and a large portion of the area is protected by the Walrus Islands 12 mile buffer, and the 3 mile State territorial limit. During public testimony at the April Council meeting, a request was also made that the northern boundary of this option extend to 58° 43' rather than 59° N latitude.

The percentage of total catch, and the percentages of red king crab, Tanner crab, halibut, and herring bycatch from observed hauls in this area are provided in **Table 5.15**. The total numbers or weights from which these percentages were derived are presented in **Table 5.14** for the entire Bering Sea, as are the percentages of catch and bycatch in the entire Northern Bristol Bay area.

The percentages of directed catch taken by the yellowfin sole fishery within the two blocks in Northern Bristol Bay were similar to the percentages reported in **Table 5.14** for the entire Northern Bristol Bay area, indicating that most of the catch is taken within these blocks. The largest difference in percentage between the two blocks and the entire Northern Bristol Bay area was in 1988 when approximately 30% of the directed catch was taken in the two blocks, and approximately 38% of the directed catch was taken in all of Northern Bristol Bay.

The highest percentages of total observed king crab bycaught in the yellowfin sole fishery within the two blocks in northern Bristol Bay under this option were 13% in 1991 and 12% in 1993. The comparable percentages for the entire Northern Bristol Bay area were 45% and 15% in 1991 and 1993, respectively (**Table 5.14**). In 1991, the percentage of total catch taken in the two blocks was 47% of the yellowfin sole catch that year, and the total taken in the entire Northern Bristol Bay area was 50%. So 3% of the directed catch and 32% of the king crab bycatch was taken in Northern Bristol Bay outside of the two blocks under consideration in 1991. This would indicate that the area of secondary fishing activity, along the northern border of Area 512, can account a disproportionately large portion of the king crab bycatch within northern Bristol Bay. In other years this percentage has been substantially lower.

The percentages of halibut bycaught within the two blocks are similar to those from all of Northern Bristol Bay. Essentially no Tanner crab are encountered in trawls within the two blocks. As with the analysis of the impacts of the Northern Bristol Bay closure, the percentages of herring bycaught by the yellowfin sole fishery are much higher than the percentage of directed catch from the area. In the domestic fisheries since 1990, all of the herring taken in the Northern Bristol Bay area were taken in the two blocks under this option.

The percentages of catch and bycatch within the area bounded by 159° and 160° W longitude and 58° and 58° 43' N latitude are provided in **Table 5.15** as well. In most years, the percentages are nearly identical to the above Option A with a northern boundary of 59° N latitude. This would indicate that the majority of catch and bycatch taken in the area described under the above option have been taken south of 58° 43' N latitude, and a maximum of approximately 5% of the total catch was taken north of this boundary in 1991. The only bycatch species for which the percentages are not similar regardless of the northern boundary are Pacific herring. In 1988, an additional 35% of the total herring bycaught by the yellowfin sole fishery was taken north of 58° 43' N latitude, and in 1992 an additional 25% of the total herring bycatch was taken north of the boundary. Additionally, although little effort is expended by other directed fisheries in the area, an additional 40% of the herring bycaught in the flatfish fishery during 1993 was taken north of 58° 43' N latitude, and 100% of the other flatfish bycatch of herring was taken north of the proposed boundary in 1994.

5.1.5 Potential Impacts of a Nearshore Trawl Closure on Red King Crab

The effectiveness of a trawl closure area to protect juvenile red king crab, proposed under Alternatives 2 and 3, Management Measure 3, hinges on recruitment dynamics and the distribution of juveniles and their habitat. A review of year-class strength formation and survival of red king crabs is provided by Tyler and Kruse (1995b). It has been hypothesized that red king crab encounter a critical intersection at the settlement and juvenile stage, when the availability of appropriate habitat may constrain the abundance of juveniles, in turn affecting the year class strength and recruitment (Cassano et al. 1995, Tyler and Kruse 1995). Larval crabs drift with the current before they settle on the sea floor. Larval settlement and survival patterns vary according to ocean currents and availability of appropriate substrate. If the current transports the larvae to an area without suitable habitat, the chances of survival are slim (McMurray et al. 1984, Jewett & Onuf 1988). Larval crab settle in late July and August in areas with biotic assemblages and rocky substrate, where they stay as juvenile crab for the first two years before they move to deeper waters. Juvenile red king crab are solitary, cannibalistic, and require habitat that provides protection. Therefore, during this time they are mainly found among biotic assemblages, such as tube building polychaete worms, sea onion, erect bryozoans, mussels, kelp, and ascidians (McMurray et al. 1984, Stevens et al. 1992, Armstrong et al. 1993). If no epifaunal community exists, juveniles can be found on rocky or gravel substrate (McMurray et al. 1984).

In the Bering Sea, juvenile red king crab inhabit depths less than 50 m, and have been found along the Alaska Peninsula, and around Kvichak and Togiak Bays. Within this area juveniles live among epifaunal communities, which are associated with gravel/cobble substrate. Juvenile distribution in Bristol Bay can be interpreted from the distribution of gravel/cobble substrate (Hood and Calder 1981, McMurray et al. 1984) and areas sampled for young crab (McMurray et al. 1984, Stevens et al. 1992, Armstrong et al. 1993). Suitable juvenile habitat is "extremely patchy" in Bristol Bay (McMurray et al. 1984, Jewett & Onuf 1988). Areas shown by surveys to contain age 0-2 juvenile crab likely underestimate their actual distribution because the entire area has not been sampled, and young crab are difficult to catch with sampling gear, particularly in cobble habitats (Stevens et al. 1992). Furthermore, distribution of juvenile red king crab may be affected by year class strength. Juvenile surveys were conducted in years of low stock abundance, 1984 and 1991. The abundance and distribution of juveniles might have been more encompassing and conclusive had the surveys occurred in the early 1970's. Sample areas with low abundance could be viable habitat in times of high abundance. From the existing survey data it is not possible to determine the exact distribution of juveniles in any given year. However, by combining the survey data of where juveniles have been sampled with substrate information, a general distribution of juvenile red king crab habitat can be inferred.

Potential benefits of a trawl closure area for red king crab habitat depend on the alternative and option chosen. Alternative 4 provides protection for most of the year, but would still allow trawling to potentially occur in habitat areas from April 1 to June 15, as well as in Area 508. The addition of Option A for this alternative provides additional protection of habitat. Although the Alternative 2 closure area in northern Bristol Bay would protect some juvenile red king crab habitat, more comprehensive nearshore area closure of Alternative 3 may provide additional protection of juvenile red king crab habitat. Due to the depressed state of the stock and the existing knowledge that trawling may potentially damage juvenile habitat, a modified trawl closure might be warranted. More extensive trawl closures than encompassed by Alternative 2 have been proposed (Armstrong et al. 1993, Cassano et al. 1995, and Witherell and Harrington 1995). The lack of suitable habitat could be a population constraint, and habitat protection should be considered as a means to increase red king crab populations (Armstrong 1993, Cassano et al. 1995). A more extensive trawl closure would also protect migrating juveniles. After age 2, juvenile crabs begin podding, forming into large clusters of crab for protection from predators as they move into deeper waters (>50 m) (Jewett & Onuf 1988,). These pods are vulnerable to trawling, which could cause direct mortality or break up pods and expose crabs to predation. Maximum protection of red king crab and juvenile habitat is thus provided by Alternative 3.

In September 1995, the Council's Scientific and Statistical Committee concluded that refuges to protect juvenile king crab can assist with stock rebuilding, but quantitative analysis of these effects could not be made. They state:

> "In general, area closures to protect species and their habitat can contribute to successful recruitment and population rebuilding. Witherell & Harrington (1995) review evidence that specific early-life history stages of red king crab require rocky bottom with living substrate for settling, and then gravel sediments in the early juvenile stages. These bottom types are limited in extent and lie towards the shore in Bristol Bay. There is sufficient evidence of the importance of these sediments, and consequently proposals for the protection of these areas from trawling activities have to be taken seriously. It was proposed that the effects of closures be evaluated against their effects on brood strength of the king crab stocks. It must be realized, however, that the life history of red-king crab is extremely complex, much more so than many groundfish species. There are several critical control points in the life history that have to be factored into any evaluation of the development of king crab brood strength. This means a multivariate study of factors, only one of which is improved survival while they are on rocky and cobble bottom. Some of the needed time-series of data are not being collected at the present time. Because of these deficiencies it would not be possible to quantify the effects of protecting benthic habitat on year-class strength."

Based on analysis of life history and spawning migrations of major stocks of red king crab around the world, Rodin (1989) established 4 major habitat factors that must be present for red king crab populations to persist:

1. The conditions and period of massive hatching of larvae in the coastal zone must be combined with transport of larvae to favorable habitats for survival of young,
2. A well developed sessile community (dense concentration and large areas of hydroids, bryozoans, and sponges) and a food base is necessary where settlement occurs,
3. A broad continental shelf is necessary with fish food base for adult crab,
4. No physical barriers to juvenile and adult migrations.

In evaluating these factors, Rodin asserts that "The most important, judging from everything, is the presence of favorable habitat conditions for the post-larval stages". As detailed in Section 5.1.1, increased survival of young crab to recruitment will be necessary to maintain the red king crab population. Hence, a trawl closure area designed to protect juvenile red king crab habitat may be a significant action managers can take to increase recruitment of red king crab.

5.1.6 <u>Potential Impacts of a Nearshore Trawl Closure on Pacific Herring</u>

Trawl closure areas proposed under Alternatives 2, 3 and 4 would not be likely to provide substantial benefits to herring recruitment. This conclusion is based on herring life history and trawl fishery interactions. Herring spawn primarily in the intertidal areas, which are already closed to trawling under State regulations. No spawning is known to occur outside State waters in the Togiak area (K. Rowell, ADF&G, pers. comm.). The

State water trawl closure may provide some protection to herring spawn, which could be impacted by trawls. It has been noted that "various towed gears in contact with the bottom may damage fish eggs attached to the seabed (e.g., herring). Some spawning beds are closed to fishing during the spawning season." (ICES 1992). Herring spawning will not be impacted by any of the Alternatives.

On the other hand, a trawl closure area may reduce bycatch of herring. Herring tend to aggregate offshore prior to spawning, and are thus subject to incidental catch by trawl fisheries. Because herring are a prohibited species under the FMP (meaning that they cannot be retained), all trawl caught herring is considered regulatory bycatch. Bycatch of herring in trawl fisheries is limited to 1% of projected spawning biomass. In 1995, about 950 mt of herring were taken as bycatch in BSAI trawl fisheries (NMFS bulletin board data). This was well below the 1% cap which equaled 1,861 mt in 1995.

5.1.7 Potential Impacts of a Nearshore Trawl Closure on Pacific Halibut

The proposed nearshore trawl closure area encompasses a portion of the known distribution of juvenile halibut. Closure of this area to trawling will reduce the bycatch mortality on juvenile halibut within the boundaries, and thus provide maximum protection for juvenile halibut in nearshore areas. However, for that portion of the resource outside the closed area, this alternative provides no protection and in fact may increase bycatch mortality. This is because vessels may have to fish harder to catch their desired groundfish catches and in the process may drag their nets longer or fish in areas where juvenile halibut are more abundant than average, or more abundant than inside the closure area. The majority of juvenile halibut habitat is outside the boundaries of the proposed closed area. Given that halibut bycatch is managed by bycatch limits, total halibut bycatch will be constrained within the limit with or without the closure. However, the groundfish catch may be reduced if halibut bycatch rates increase.

It is very difficult to make precise estimates of the effects of bycatch on commercial-sized component of the halibut stocks because bycatch is largely made up of younger migrating halibut. Growth, mortality, and migration greatly complicate the estimation procedures. If the same age composition occurred in both fisheries one could consider the bycatch removals as merely increasing the directed removals. Migration rates of juvenile halibut are not well known, so the impact of bycatch of juvenile halibut from specific areas on adult populations in those or other areas must be estimated indirectly.

Bycaught halibut are generally smaller than those harvested by the directed fishery. Consequently, factors such as maturity, reproductive capacity, survivorship, and growth substantially affect stock productivity. By allowing small halibut to remain at large for a longer period of time, a net gain in stock biomass occurs due to the greater cumulative gain in individual weight relative to losses incurred due to mortality. Smaller fish are less likely to be reproductively mature, and have less reproductive capacity. Those harvested earlier in their life history not only contribute less in terms of short term yield, but they also contribute less to the maintenance of future stock biomass or to future yields. Bycatch losses affect recruitment, future catch, and future reproductive potential of the stock.

The current approach for bycatch compensation is to reduce harvest in the directed fishery such that the reproductive potential of the exploitable component of the stock would be the same after bycatch as it would have been if bycatch had not occurred. The compensation factor was determined to be one pound of catch limit reduction for each pound of bycatch mortality.

Impact on the directed halibut fishery consists of two parts: (1) the catch limit reduction to maintain reproduction, and (2) reduced recruitment to the directed halibut fishery from bycatch of pre-recruits.

(1) Reproductive compensation for bycatch immediately deprives the directed fishery of one pound of yield for each pound of bycatch the previous year. But this amounts to leaving fish in the stock rather than catching them right away, and some are caught later. On the average, about 0.6 pounds of the one pound bycatch compensation is eventually caught, so the net impact of reproductive compensation is 0.4 pounds per pound of bycatch.

(2) Bycatch eventually reduces recruitment to the directed fishery, and amounts to 1.2 pound of lost yield for each pound of bycatch.

The combined effects of reproductive compensation and lost recruitment show a net loss to the directed fishery of 1.6 pounds for each pound of bycatch: 0.4 pounds from reproduction compensation and 1.2 pounds from reduced recruitment.

If the reproductive compensation is done correctly and if the bycatch is estimated correctly, the halibut spawning stock size will remain in the same condition whether bycatch occurs or not. The directed halibut fishery pays for maintenance of the resource through lower catches. Therefore, changes of ± 50 percent in juvenile halibut bycatch will be felt in the directed halibut fishery, but should not affect the condition of the resource (G. Williams, IPHC, personal communication).

5.2 Impacts on Endangered, Threatened or Candidate Species

Listed and candidate species under the Endangered Species Act (ESA) that may be present in the GOA and BSAI include:

Endangered

Northern right whale	Balaena glacialis
Sei whale	Balaenoptera borealis
Blue whale	Balaenoptera musculus
Fin whale	Baleanoptera physalus
Humpback whale	Megaptera novaeangliae
Sperm whale	Physeter macrocephalus
Snake River sockeye salmon	Oncorhynchus nerka
Snake R. fall chinook salmon	Oncorhynchus tshawytscha
Short-tailed albatross	Diomedea albatrus

Threatened

Steller sea lion	Eumetopias jubatus
Snake River spring and summer chinook salmon	Oncorhynchus tshawytscha
Spectacled eider	Somateria fischeri

The impact of BSAI and GOA groundfish fisheries on Steller sea lions was addressed in a formal consultation on April 19, 1991. NMFS concluded that the BSAI groundfish fisheries were not likely to adversely affect listed cetaceans or to jeopardize the continued existence or recovery of Steller sea lions. NMFS determined that section 7 consultation should be reinitiated for Steller sea lions if any proposed change in the BSAI fishery was likely to adversely affect them, if new information regarding the effects of the fishery on Steller sea lions was obtained, or if there was a change in the status of sea lions. Since April 1991, NMFS has reinitiated section 7 consultation for several regulatory amendments and for the annual total allowable catch specifications.

Formal consultation conducted on effects of the GOA and BSAI groundfish fisheries concluded that the continued operation of these fisheries would not adversely affect listed species of salmon as long as current observer coverage levels continued and salmon bycatch was monitored on a weekly basis. Consultation must be reinitiated if chinook salmon bycatch exceeds 40,000 fish in either the BSAI or GOA or sockeye salmon bycatch exceeds 200 fish in the BSAI or 100 fish in the GOA.

Endangered, threatened, proposed and candidate species of seabirds that may be found within the regions of the GOA and BSAI where the groundfish fisheries operate, and potential impacts of the groundfish fisheries on these species are discussed in the EA prepared for the TAC specifications. The U.S. Fish and Wildlife Service (USFWS), in consultation on the 1995 specifications, concluded that groundfish operations will not jeopardize the continued existence of the short-tailed albatross (letter, Rappoport to Pennoyer, February 7, 1995). This action is not expected to affect threatened or endangered seabird species in any manner or extent not already addressed under previous consultations.

None of the alternatives is expected to impact endangered, threatened, or candidate species of listed whales. Steller sea lions using the Round Island haulout may benefit from reduced habitat disturbance under Management Measure 3, Alternatives 2 and 3. However, one possible negative effect of Alternatives 2 and 3 (in conjunction with other existing trawl closures) on Steller sea lions may be to concentrate trawling effort to other areas. If trawl effort increased to the area immediately west of 162°W, near Cape Newenham, increased interaction with fishing vessels and Steller sea lions could occur. The two haulout sites are not routinely surveyed during Steller sea lion population censuses and may, like other haulouts, be most important during the non-breeding season (for which there are few survey data).

5.3 Impacts on Marine Mammals

Marine mammals not listed under the Endangered Species Act that may be present in the GOA and BSAI include cetaceans, [minke whale (Balaenoptera acutorostrata), killer whale (Orcinus orca), Dall's porpoise (Phocoenoides dalli), harbor porpoise (Phocoena phocoena), Pacific white-sided dolphin (Lagenorhynchus obliquidens), and the beaked whales (e.g., Berardius bairdii and Mesoplodon spp.)] as well as pinnipeds [northern fur seals (Callorhinus ursinus), and Pacific harbor seals (Phoca vitulina)] and the sea otter (Enhydra lutris).

A trawl closure could have local benefits for marine mammals not listed under the ESA, since fishery interactions and habitat disturbance would be reduced within the closure area.

5.4 Coastal Zone Management Act

Implementation of any of the alternatives would be conducted in a manner consistent, to the maximum extent practicable, with the Alaska Coastal Management Program within the meaning of Section 30(c)(1) of the Coastal Zone Management Act of 1972 and its implementing regulations.

5.5 Conclusions or Finding of No Significant Impact

None of the alternatives is likely to significantly affect the quality of the human environment, and the preparation of an environmental impact statement for the proposed action is not required by Section 102(2)(C) of the National Environmental Policy Act or its implementing regulations.

____________________________ __________________________
DATE

6.0 REGULATORY IMPACT REVIEW: ECONOMIC AND SOCIOECONOMIC IMPACTS OF THE ALTERNATIVES

This section provides information about the economic and socioeconomic impacts of the alternatives including identification of the individuals or groups that may be affected by the action, the nature of these impacts, quantification of the economic impacts if possible, and discussion of the trade offs between qualitative and quantitative benefits and costs.

The requirements for all regulatory actions specified in E.O. 12866 are summarized in the following statement from the order:

> In deciding whether and how to regulate, agencies should assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits (including potential economic, environment, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires another regulatory approach.

This section also addresses the requirements of both E.O. 12866 and the Regulatory Flexibility Act to provide adequate information to determine whether an action is "significant" under E.O. 12866 or will result in "significant" impacts on small entities under the RFA.

E. O. 12866 requires that the Office of Management and Budget review proposed regulatory programs that are considered to be "significant". A "significant regulatory action" is one that is likely to:

(1) Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities;

(2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

(3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or

(4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order.

A regulatory program is "economically significant" if it is likely to result in the effects described above. The RIR is designed to provide information to determine whether the proposed regulation is likely to be "economically significant."

6.1 Background Economic Information on Bering Sea Crab and Groundfish Fisheries

The most recent description of the groundfish fishery is contained in the Economic Status of the Groundfish Fisheries Off Alaska, 1995 (Kinoshita et al. 1995). The report includes information on the catch and value of the fisheries, the numbers and sizes of fishing vessels and processing plants, and other economic variables that describe or affect the performance of the fisheries. Catch of groundfish in the Bering Sea has remained relatively stable over the past 10 years, averaging about 1.8 million metric tons, consisting primarily of pollock (**Figure 6.1**). About 2,000 vessels fish for groundfish in the BSAI and GOA each year. Preliminary data for 1995 indicate that in the BSAI area, 112 vessels fished with hook and line, 105 vessels fished with groundfish pot gear, and 156 vessels fished with trawls. Catch in the domestic groundfish fisheries off Alaska totaled over 2 million metric tons in 1994, worth $439 million in ex-vessel value. The value of resulting products was over $1.1 billion (**Table 6.1**).

The economics of BSAI crab fisheries are summarized in ADF&G's Annual Area Management Reports (e.g., Morrison 1996). **Tables 6.2-6.4** list economic data for the three major Bering Sea crab fisheries, 1975-1995. Total value of these crab fisheries in recent years is about $180 million to $260 million per year. Most vessels that participate in Tanner crab fisheries also participate in the Snow crab and Bristol Bay red king crab fisheries. Since 1982, the snow crab fishery has generated much higher values than the other crab fisheries. Although snow crab landings had dropped drastically since the peak in 1991 (325 million lbs.), price increased such that average gross ex-vessel value increased to over $710,000 per vessel in the 1995 snow crab fishery. In the Tanner crab fishery, price did not keep up with reduced landings since 1992, and gross ex-vessel value was only $60,000 per vessel in 1995. Assuming that all vessels in the snow crab fishery also fished for Tanner crab in 1995, vessels averaged about $770,000 in ex-vessel value. The Bristol Bay red king crab fishery did not open in 1995. Ex-vessel values had averaged about $175,000 per vessel per year in that fishery.

Gross revenues from crab fisheries are expected to be lower in 1996 than in previous years. The 1996 snow crab fishery produced only about 50.7 million pounds. At an exvessel price of $1.25 per pound, this fishery generated a total of approximately $63 million. This represents a 65% decline over the 1995 fishery gross revenues ($180 million). In addition, the 1996 fisheries for Bristol Bay red king crab and Bering Sea Tanner crab may occur at very low levels. Red king crab stocks remain at low level, but a reduced exploitation rate for red king crab has allowed a directed fishery to occur for 1996 (K. Griffin, ADF&G, personal communication). As a consequence of low stock sizes and low prices, the crab fleet is expected to experience major changes in revenues in 1996.

6.2 Potential Impacts of Extending Duration of the Bristol Bay Red King Crab Savings Area

6.2.1 Alternative 1: Status quo, no action. Amendment 37 would be submitted to the Secretary based on the closure period adopted by the Council in September 1995. The Bristol Bay Red King Crab Savings Area (162° to 164° W longitude, 56° to 57° N latitude) would be closed to non-pelagic trawling from January 1 through March 31. The area bounded by 56° to 56°10' N latitude would remain open during the years in which a guideline harvest level for Bristol Bay red king crab is established.

As with the final analysis (Amendment 37), the model runs predicted no substantial change in net benefits to the nation due to the closure from a no-closure status. Under the initial runs with an annual closure, the net benefits to the nations were estimated to increase from a no-closure status by 1.4% under Alternative Area 3 (the preferred area alternative; known as the Red King Crab Savings Area) based on the 1993 data. The net benefits to the nation were estimated to decrease from status quo by 2.3% under Alternative Area 3 using the 1994 data.

6.2.2 Alternative 2: Extend closure period for the Bristol Bay Red King Crab Savings Area to provide increased protection for red king crab. Amendment 37 would be submitted to the Secretary based on one of the closure period options considered.

The estimated net benefits to the nation under a three month closure increased by only approximately $10,000 over an annual closure, and the six month closure caused a $4,000 decrease in net benefits to the nation. Given the scale of revenues generated by BSAI fisheries, there is essentially no difference between these closure periods. Similarly, model runs with the 1994 data estimated the seasonal closures under Alternative Area 3 (the Red King Crab Savings Area) changed the net benefits to the nation by a negligible amount of less than $1,000 from an annual closure. There were no estimated differences in net benefits to the nation between a 3 month closure and a six month closure using the 1994 data which indicates no fishing activity in the area between March and July in 1994.

6.2.3 Alternative 3: Close the area based on a modified version of the old pot sanctuary. Boundaries of the closure would close all waters in the Bering Sea east of a line originating at Cape Constantine, extending to 58°10' N, 160°W to 57°10'N, 163°W to 56°30'N, 163°W to 56°30'N, 164°W, then south to 56°N. After April 1, this closure would extend south to the Alaska Peninsula. This option would require 100% observer coverage for fishing north of 58° and east of 162° and would be limited to May and June. Further, the area between 163° and 164° between 56°30' and 57°00' would not open until April 1 and would be closed upon reaching a red king crab cap in a range of 5,000 to 15,000 red king crab. (Note this alternative deals with both Bristol Bay Red King Crab Savings Area and nearshore Bristol Bay Trawl Closure Area.)

Alternative 3 may provide benefits to the trawl fleet targeting yellowfin sole and rock sole. According to public testimony, and previous analysis, the northwest corner of the red king crab savings area has been a productive area for flatfish fishing. Additional opportunities for flatfish trawling will be provided by allowing the fleet to follow yellowfin sole during their migration to the east towards Cape Constantine. Areas of 516 and 512 that have been closed to trawling since 1987 would be open to allow fishing on yellowfin sole concentrations. Fisheries would continue to be constrained by PSC caps within Zone 1, however, fishing on large aggregations of flatfish may provide higher catches per unit of PSC. Increased catches of flatfish may be possible.

6.3 Potential Impacts of Modifying Crab Bycatch Limits

6.3.1 Alternative 1: Status quo, no action. PSC limits would remain at 200,000 red king crab and 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

In general, crab PSC limits have not constrained most groundfish trawl fisheries. Rather, these fisheries close either upon reaching the total allowable catch quota (TAC) or attainment of halibut PSC limits (**Tables 6.5-6.8**). The one notable exception is the rock sole/other flatfish trawl fishery, which was limited in 1993 and 1994 despite relatively high levels of crab PSC apportioned to that fishery (**Figures 6.2-6.5**). For example, in 1994 Zone 1 was closed on February 28 due to attainment of red king crab PSC limit (110,000 crabs) and Zone 2 closed on May 7 due to the Tanner crab PSC limit (260,000 crabs). In 1995, the red king crab PSC was not reached, in part due to emergency implementation of the red king crab savings area (NPFMC 1995). The yellowfin sole fishery was closed out of Zone 1 due to Tanner crab bycatch on April 14, 1995.

A review of historic bycatch data suggests that the amount of red king crab and Tanner crab taken as bycatch is not directly related to landings of flatfish. **Figure 6.6** shows the landings of flatfish by foreign, joint venture, and domestic fisheries and the number of crab taken as bycatch, 1978-1995. Bycatch data prior to implementation of the domestic observer program in 1991 may be less precise than in following years and should be viewed with caution. It is likely that many things have changed during the time series to affect catch and bycatch including, changes in crab and fish stock sizes, changes in groundfish targets, the change from foreign to domestic fisheries, as well as regulatory changes (see **Appendix 4**).

Even under status quo, halibut and crab PSC limits may become more constraining to groundfish trawl fisheries if pollock TAC's are reduced in the future. Total annual BSAI groundfish harvest is limited by an optimum yield (OY) cap of two million metric tons. Pollock accounts for about 1.1 to 1.3 million mt of the total OY cap. The rest is apportioned among other fisheries. This OY cap generally results in TAC allocations to higher valued species and fisheries with lower halibut bycatch (such as the pollock fishery) than to flatfish fisheries (Witherell 1994). For example, in 1996, pollock TAC was set at the ABC level, whereas TACs for flatfish were 665,000 mt below ABC (**Table 6.9**). Hence, if pollock TAC is reduced in the future, fisheries will have higher TAC of flatfish to harvest. However, fisheries may be unable to harvest this additional flatfish TAC even under existing PSC limits. Reduced PSC limits would make achieving a two million mt OY even more challenging.

In evaluating the status quo, or proposed reductions, it is informative to know what crab bycatch in groundfish fisheries costs the directed crab fisheries. The answer to this question can be derived from the adult equivalent exercise made in the previous section. If groundfish fisheries caught no crab incidentally, the crab fishery may increase total ex-vessel revenues by about $10.5 million. This represents an estimate of opportunity costs. Assuming there are about 275 crab vessels, these crab would equate to about $38,000 per vessel in gross ex-vessel value. Potential costs of proposed alternative crab PSC limits for trawl fisheries can be measured against potential benefits to crab fisheries.

Value of crab bycatch in groundfish fisheries to directed crab fisheries, based on 1993-1995 average bycatch and price.

	Adult male Equivalents	Adult weight	Average price/lb	Total value ($)
Red king crab	33,231	6.5	3.80	820,800
Tanner crab	920,060	2.3	2.80	5,925,000
Snow crab	1,958,138	1.3	1.50	3,818,000
Total				**$10,563,800**

6.3.2 Alternative 2: Reduce PSC limits of red king crab and Tanner crab.

RED KING CRAB: PSC limits would be reduced to a fixed level at 180,000 red king crab based on a three year average (1992-1994)

Option A: Further reduce the red king crab PSC limit in Zone 1 to 35,000 crab, which was the number of red king crab bycaught in 1995 within Zone 1.

TANNER CRAB: PSC limits would be reduced to a fixed level of 900,000 Tanner crab in Zone 1, and within the range of 1,500,000 to 2,100,000 Tanner crab in Zone 2.

SNOW CRAB: Based on a three year average (1992-1994), a PSC limit would be established at a fixed level of 11,000,000 snow crab in Zone 2. No snow crab PSC limit would be established for Zone 1, as bycatch in this area has been minuscule by comparison.

Option A: Establish PSC limit at 6 million snow crab in Zone 2.

Recent data indicate that the current PSC limits for crab could be reduced from existing levels, yet not impact groundfish fisheries if the available PSC is optimally allocated among target fisheries and seasons. On average, bycatch taken each year has been less than the PSC limit. For example, bycatch of red king crab in Zone 1 was 187,067 crabs (average 1992-94, all gears). Bycatch of Tanner crab was 902,724 crabs in Zone 1 and 2,033,057 crabs in Zone 2 (average 1993-94, all gears). Hence, based on average bycatch needs, PSC limits could be reduced by about 20,000 red king crab and 1,000,000 Tanner crab (Zones 1 and 2 combined). This is essentially what is proposed by Alternative 2. Optimal allocation will be difficult to achieve because these apportionments are made pre-season. However, the Council will be considering an FMP amendment in the future that would allow individual vessel bycatch accountability, a tool that has potential to reduce bycatch and better allocate available PSC.

Red king crab Alternative 2, Option A, would limit red king crab bycatch in Zone 1 to the 1995 level of 35,000 crab. The 1995 bycatch of red king crab in trawl fisheries was about the lowest ever recorded (tied with 1991 estimate). Reduced bycatch was a result of reduced stock size, implementation of trawl closure areas in Bristol Bay and around the Pribilofs, as well as active avoidance of red king crab concentrations by the trawl fleet (J. Gauvin, AFTA, personal communication). Because crab are mobile, an area closure cannot completely eliminate bycatch. Therefore, if and when the Bristol Bay red king crab stock recovers, a PSC limit based on this alternative could potentially be very constraining to the trawl fleet and limit harvest of groundfish, particularly rock sole.

Snow crab Alternative 2 would essentially limit snow crab bycatch in Zone 2 to levels taken in 1992-1994, but would be in excess of what was taken in 1995. Bycatch of snow crab in BSAI groundfish fisheries totaled 17.7 million in 1992, 14.8 million in 1993, and 12.5 million in 1994, but was drastically reduced to only 5.4 million in 1995. To some extent, reduced bycatch is a function of stock abundance. Option A (6 million snow crab) reflects the 1995 bycatch needs. A Zone 2 PSC limit of snow crab would be seasonally apportioned among trawl fisheries during the annual specification process. Based on previous bycatch use, most (about 60-70%) would likely be apportioned to the yellowfin sole fishery.

As with all PSC limits proposed under this alternative, trawl fisheries may be negatively impacted if PSC limits are not optimally allocated pre-season. In particular, the yellowfin sole fishery stands to be the most impacted fishery. Recent implementation of trawl closure areas in Bristol Bay by emergency rule and around the Pribilof Islands (Amendment 21a) have limited grounds available to this fishery. Further, the proposed trawl closure area in Northern Bristol Bay may increase trawl effort for yellowfin sole in Zone 2, which may cause snow crab bycatch in Zone 2 to increase. A limit proposed under snow crab Alternative 2, could result in reduced catch of yellowfin sole.

The major assumption regarding assessment of impacts for Alternative 2 is that crab stock abundance will remain relatively stable, or that the trawl fishery will adapt to changes in crab abundance. As crab stocks increase, bycatch will further constrain trawl fisheries if fixed PSC limits are established. This may be expected for snow crab PSC limits, in particular, as abundance of large snow crab is projected to increase in the near future. On the other hand, if crab stocks continue to decline, bycatch will account for a higher proportion of the total annual mortality.

6.3.3 Alternative 3: Establish PSC limits for crab that fluctuate with crab abundance. This section also applies to Alternative 4 for red king crab.

RED KING CRAB: Annual red king crab PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey. Limits would be established based on a rate specified, within the range 0.1-1.0% of red king crab in the Bristol Bay District.

Alternative 3 Option A: Set a fixed upper limit for crab PSC at 200,000 red king crab in Zone 1.

Alternative 4 (**Preferred**): Establish a stairstep based PSC limit for red king crab in Zone 1, based on abundance of Bristol Bay red king crab as follows:

(A) When the number of mature female red king is equal to or below the threshold number of 8.4 million crab, or the effective spawning biomass (ESB) is less than 14.5 million pounds, the Zone 1 red king crab PSC limit would be 35,000 crabs;

(B) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 14.5 but less than 55 million pounds, the Zone 1 red king crab PSC limit would be 100,000 crabs; and

(C) when the number of mature female red king crab is above threshold, and the ESB is equal to or greater than 55 million pounds, the Zone 1 red king crab PSC limit would be 200,000 crabs.

TANNER CRAB: Annual Tanner crab PSC limits would be set as a percentage of the total population indexed by the NMFS bottom trawl survey. Limits would be established based on a rate specified, within the range 0.10-2.0% of Tanner crab in the Eastern District, as indexed by the survey.

Option A: Set a fixed upper limit for crab PSC at 1,000,000 Tanner crab in Zone 1, and 3,000,000 Tanner crab in Zone 2.

Option B: Establish PSC limits for Tanner crab based on abundance thresholds. Limits would be set as a percentage of population when abundance is less than 100 million crab. In years when Tanner crab abundance is more than 100 million, but less than 250 million, PSC limits would be established at 850,000 Tanner crab in Zone 1, and 1,500,000 in Zone 2. In years when Tanner crab abundance is more than 250 million, but less than 500 million, PSC limits would be established at 900,000 Tanner crab in Zone 1, and 2,300,000 in Zone 2. In years when Tanner crab abundance exceeds 500 million, PSC limits would be established at 1,000,000 Tanner crab in Zone 1, and 3,000,000 in Zone 2.

SNOW CRAB: Annual snow crab PSC limits would be set as a percentage of the NMFS bottom trawl survey index. Limits for Zone 2 would be set at a percentage within the range 0.005 to 0.25% of the snow crab total population index (all districts combined). No snow crab PSC limit would be established for Zone 1.

Option A: Set fixed upper limit for PSC at 12 million snow crab in Zone 2.

Alternative 3 specifies a PSC limit that varies with crab abundance. This is similar to the way PSC limits are set for Pacific herring in BSAI trawl fisheries and crab in BSAI scallop fisheries. The measures are frameworked such that they are established during the annual specification process. Herring PSC limits are set at 1% of the projected adult herring biomass (Amendment 16a). For the BSAI scallop fishery, the Council adopted floating crab PSC limits as part of the Amendment 1 package. Crab PSC limits for the scallop fishery will be set annually as a percentage of the NMFS survey abundance for Tanner crab (0.13542%) and snow crab (0.003176%), but a fixed limit for red king crab within the range of 500 to 3,000 crab. Amendment 1 to the Scallop FMP was implemented on August 29, 1995 (60 FR 42070, August 15, 1995).

A comparison of trawl fisheries crab bycatch with other bycatch levels provides insights into the appropriateness of PSC rates from an allocation standpoint. It appears that current crab bycatch limits are somewhat lower than the range of acceptable bycatch limits set for other species and fisheries. Current crab bycatch due to groundfish fisheries amount to about 0.49 % of the adult red king crab stock and 1.19 % of the adult Tanner crab stock and 0.14 % of the adult snow crab stock. These numbers can be compared to rates for halibut and crab PSC limits. For BSAI halibut PSC, bycatch *mortality* is limited to 4,675 mt (3,775 mt trawl, 900 mt non-trawl), or 6.6 % of total exploitable halibut biomass (1995). For BSAI herring PSC, bycatch is limited to 1% of projected adult biomass. For salmon, BSI trawl bycatch levels that trigger area closures represent about 15 % of BSAI chinook adult chinook harvest, and 1.1% of the BSAI adult chum harvest (1995). For marine mammals, the level of human caused mortality is termed Potential Biological Removals, or PBRs, defined by the Marine Mammal Protection Act. For example, for western US Steller Sea Lions (a threatened species), the PBR is 766 animals from a population estimate of 42,536. This equates to a removal rate of 1.8%, below which the species will become a non-strategic stock.

Snow crab Option A sets fixed upper limits for snow crab PSC to levels of recent bycatch. All impacts discussed for Alternative 2 apply when crab bycatch is limited at high crab abundance. Below the upper limits, bycatch is reduced based on biomass, and impacts discussed under Alternative 3 apply at low stock sizes. It should be remembered, however, that the abundance of Bering Sea snow crab is currently relatively high.

Impacts of Alternative 3 to the trawl fishery depend on the percentage or rate chosen. A PSC limit established based on a higher percentage of crab abundance will cause the least negative impacts to trawl fisheries. Alternatively, a lower rate that equates to smaller PSC limits than set under the status quo may result in negative impacts to the trawl fleet (via increased costs, shorter seasons, less fish harvested, etc.). **Tables 6.10-6.12** illustrate PSC limits within the range proposed under Alternative 3 for red king crab in Zone 1 and Tanner crab in Zone 1 and Zone 2. Note that in these tables, the Tanner crab PSC limits generated by this Alternative assume a 25:75 split among Zones 1 and 2. A 25:75 apportionment approximates recent distribution of the Eastern Bering Sea Tanner crab stock (**Table 6.13)**. It should be noted from this table, however, that 52.4% of the adult males and 41.3% of the adult females are found in Zone 1. PSC limits for snow crab within the range proposed under Alternative 3 are listed in **Table 6.14**.

Another possible way to base PSC caps on abundance of the size of crab taken as bycatch in trawl fisheries, rather than based on the total survey index of all size groups. A shortcoming of Alternative 3 is due to the fact that minor changes in survey station or crab distribution can create major changes in the survey population estimate. This is because the population index is dominated by small animals (true for all 3 species) and survey estimates of small crab and their distribution are highly variable from year to year. Alternative 3 creates problems because annual PSC limits could be set disproportional to the abundance of the size of crab taken in trawl fisheries (which consists primarily of large crab). Of concern is the potential for a high PSC limit generated by large numbers of juveniles. A similar concern occurs at the opposite extreme where an artificially low PSC limit could needlessly constrain trawl fisheries. In reviewing the draft EA/RIR, the Council's Crab Rebuilding Committee concluded that Alternative 3 would have less problems if PSC limits were based on the survey abundance of large crab, but noted that there would still be annual variability. At its April 1996 meeting, the Council's Scientific and Statistical Committee recommended that this approach be considered, but as a separate amendment. The following is an excerpt from their minutes:

> "*In examining the alternatives for PSC limits that fluctuate with abundance (Measure 2: Alternative 3), the SSC discussed the recommendation made by the Crab Rebuilding Committee that a different "currency" be used in establishing caps (e.g., the use of a cap in terms of "large" crab rather than total number of crab may be more stable over time than the total number of crab due to recruitment fluctuation). The SSC believes that a change to a new "currency" system should be done carefully with requisite analyses, because the effects of using different measures may be complicated (nonlinear, highly variable). If the Council wishes to move in this direction, the SSC suggests it be done as a separate amendment to avoid confusion*."

Due to time limitations, a comprehensive analysis of PSC limits based on abundance of large crab was not undertaken for this amendment package. If the Council's preferred option is Alternative 3, then a follow up amendment analysis to modify the index may be prepared. Such an analysis would examine the effects of using a different "currency" for establishing the PSC limits, rather than based on total population index. For example, PSC limits of red king crab could be based on the combined abundance of large males (>134 mm) and mature females (>89 mm) from the LBA estimates of Bristol Bay red king crab

Red king crab bycatch as a percentage of large males and females combined, 1992-1995.

Year	Bycatch (millions)	Adults (millions)	Bycatch Rate (%)	Bycatch % (lagged 1 yr)
1992	0.17	20.0	0.85	1.25
1993	0.25	17.5	1.43	1.60
1994	0.28	13.4	2.09	0.37
1995	0.05	13.8	0.36	-
Average	0.19	16.2	1.18	1.08

stock. The adjacent table shows the relationship of the bycatch and abundance of large crab for 1992-1995. Because bycatch occurs prior to the survey, and PSC limits would be set in the year prior to the fishery, data are lagged one year. Based on this information, bycatch has accounted for 0.37 to 1.60% of the adult red king crab stock, averaging 1.1%. Hence, PSC limits could be set as a similar percentage. Additional analysis is required to determine appropriate "currency", and potential biological impacts if one portion of the index (say for example, females) declines in abundance relative to the other portion.

Examination of recent bycatch as a percent of the total NMFS population index (all sizes of crab) provides some guidance on bycatch needs of the groundfish fisheries. **Table 6.15** lists annual crab bycatch, 1992 through 1995, as a percentage of the total index for each applicable bycatch limitation zone. Bycatch of Zone 1 red king crab has ranged from 0.09% to 0.72% of the survey index. Bycatch of Tanner crab has ranged from 0.26% to 0.49% in Zone 1 and 0.62% to 0.91% in Zone 2. Snow crab bycatch in Zone 2 has ranged from 0.05% to 0.15% of the survey index. Average bycatch rates, 1992-1995, based on survey percentages are shown in the adjacent table. If PSC limits were established at these rates, impacts would depend on the speed and magnitude of changes in crab stock abundance.

Crab PSC rates based on average bycatch, 1992-1995, and annual crab abundance index of all sizes.

	(Zone 1)	(Zone 2)
Red king crab	0.40%	-
Tanner crab	0.39%	0.79%
Snow crab	-	0.10%

The threshold limits proposed under Tanner crab Alternative 3, Option B were developed from historical bycatch data, and therefore may not substantially impact fisheries if PSC can be optimally allocated among trawl fisheries. The lower threshold "steps" were based on average levels of bycatch observed when Tanner crab abundance was at that level. For Step 1 (100-250 million crab), the proposed PSC limit (850,000 Tanner crab in Zone 1, and 1,500,000 in Zone 2) would be established at approximately the average bycatch observed for 1994 and 1995, which was 835,000 Tanner crab in Zone 1, and 1,515,000 in Zone 2. Average abundance in 1994/1995 was 191 million crab of all sizes. Abundance of Tanner crab was also in this range in 1986. For Step 2 (250-500 million crab), the proposed PSC limit (900,000 Tanner crab in Zone 1, and 2,300,000 in Zone 2) would be established at levels intermediate between Steps 1 and 3. These levels for Step 2 are slightly lower levels than the average bycatch observed for 1992 and 1993. Average abundance of Tanner crab in 1992/1993 was 347 million crabs of all sizes. Tanner crab abundance at this step was also observed in 1978, 1979, 1982, 1983, 1984, and 1987. For Step 3 (years when Tanner crab abundance exceeds 500 million), PSC limits would be established at 1,000,000 Tanner crab in Zone 1, and 3,000,000 in Zone 2. Tanner crab abundance at this step was occurred in 1976, 1977, 1980, 1981, 1988, 1989, 1990, and 1991. The current PSC limits were adopted by the Council in 1989 based on an estimated abundance of Tanner crabs in 1988. In 1988, it was estimated there were 176.1 million Tanner crabs in Zone 1 and 412.8 million Tanner crabs in Zone 2 (NPFMC 1989). Abundance has fallen below 100 million animals only once in the time-series (1985, 84.7 million). Based on past bycatch performance, and historic Tanner crab abundance, impacts on trawl fisheries under this option may be only somewhat constraining to trawl fisheries as long as PSC limits can be efficiently allocated among various trawl fisheries. The potential benefit of threshold limits is that while it allows bycatch levels to fluctuate with crab abundance, it would temper year-to-year variability in PSC limits caused by trawl survey abundance estimates. Some stability may also be beneficial to long-term financial planning for trawl companies.

Bering Sea fishery simulation model results for various crab caps

The Bering Sea fishery simulation model was employed to estimate the economic impacts of reducing crab caps in the Bering Sea. A general discussion of the model follows in the next section, and a detailed discussion can be found in Amendments 21a and 21b, as well as in the Bristol Bay Red King crab Savings Area analysis (NPFMC 1995) and **Appendix 8**. Detailed output from the model was not provided for this section in order to conserve space, and because the output is similar to other model runs in this amendment.

The Bering Sea fishery simulation model was modified to include the bycatch of *Chionoecetes opilio* crab and assign caps for this species. The value data for C. bairdi, C. opilio and red king crab were updated for this analysis as well. The model was run with the most constraining options in place to examine the greatest expected changes from Status Quo. Model runs using both the 1993 and 1994 data sets included the following options: (1) Status Quo which included a three month closure of the Red King Crab Savings Area; (2) a Zone 1 cap for bairdi crab of 850,000 and a Zone 2 bairdi crab cap of 1.5 million crab; (3) a Zone 1 cap of 35,000 red king crab; (4) a Zone 2 cap of 11 million opilio crab; (5) a run with all of the above caps in place (850,000 Zone 1 bairdi, 1.5 million Zone 2 bairdi, 11 million Zone 2 opilio, and 35,000 Zone 1 red king crab) as well as the closure of the Red King Crab Savings Area; (6) a run with all of the above caps, the Red

King Crab Savings Area closure, and the Northern Bristol Bay closure; and (7) the caps and closures as above in (6) with the additional constraint of a 6 million opilio crab cap in Zone 2.

The model runs which examined the impacts of various area alternatives for the Red King Crab Savings Area were presented in NPFMC 1995. The impacts of the Northern Bristol Bay Closure were estimated by model runs and presented in sections 4.0 and 6.0 of this document. The results of the cap analysis runs presented here can be compared with the previous runs with the caution that splitting Tanner crab into bairdi and opilio separately may have changed the bycatch rates of areas, and that the crab values have been updated.

Opilio crab has not previously been constrained by a cap. To assign portions of the cap to individual fisheries, the bycatch of opilio crab in each of the directed fishing groups was averaged over three years, and that average was used to assign a portion of the 11 million crab cap to each group (**Table 6.16**). The Zone 2 caps used for the opilio crab option were as follows: 2,313,651 opilio crab to the flatfish/rock sole group (21%); 1,413,464 to the "other" group which includes bottom trawl for pollock (13%); 136,904 to the Pacific cod target (1%); and 7,135,981 to the yellowfin sole fishery (65%).

The valuation of bycaught crab was modified somewhat, to take into account the average size of bycaught crab in each species, and the size at which the crab are available to the directed crab fishery for harvest. The steps for estimating gross values of bycaught crab are provided in **Table 6.17**. Red king crab are, on average, about legal size (135 mm cl) when bycaught in trawls, and were therefore not discounted by natural mortality. Bairdi crab were estimated to be one year away from legal size (140 mm cw), and opilio crab were estimated to be 3 years away from marketable size (102 mm cw). The average harvest weight of the crab species at legal size were estimated to be 2.5 lbs, 1 lb, and 5 lbs for bairdi, opilio and red king crab, respectively. Product recovery rates were estimated to be 65% for bairdi, 61% for opilio crab, and 100% for red king crab, and the prices per pound were estimated to be $7.00, $3.50, and $6.00 for each of the species, respectively. The estimated per crab gross values to the directed crab fisheries were $6.83 for bairdi crab, $.72 for opilio, and $24.00 for red king crab. Net values were estimated by the same ratio of net value to gross value used in previous model runs.

The bycatch of the crab species in 1993 and 1994, largely because of existing caps, were not generally in excess of the most restrictive options used in the model runs, and often were below the more restrictive caps. For instance, under Status Quo in the 1993 data, 7.5 million opilio crab were estimated to be bycaught in Zone 2 in the absence of a cap, and in 1994 approximately 10 million opilio crab were estimated to be bycaught in Zone 2. The cap used for opilio crab was 11 million, so that only specific fisheries might be affected by the opilio cap, since the overall cap of 11 million exceeded the bycatch from all fisheries in each year. Thus the model does not capture the impacts of years in which the bycatch rates for any of the species might be higher. Similarly, the impacts of a cap might be less than the model predicts if crab were caught at a higher rate in 1993 or 1994 than would happen in future fisheries, as was the case in 1994. The bycatch of red king crab predicted by the model from 1994 data was approximately 90,000 red king crab with the 3 month Red King Crab Savings Area closure in place, while in 1995 the actual number bycaught was approximately at the most restrictive cap of 35,000 crab.

The constraints on the fishing fleet by the more restrictive crab caps resulted in changes in net benefits to the Nation from Status Quo of less than approximately $500,000 under the 1993 data set (**Table 6.18**). This is because the bycatch of each crab species available to the model was similar to the caps in that year. The model runs based on the 1994 data estimated decrements to the net benefits to the Nation of from approximately $1 million to $4.8 million. The reduction of the red king crab cap to 35,000 resulted in the greatest change from Status Quo under both the 1993 and 1994 data.

Model runs to estimate the impacts of all three management measures in place concurrently were also made using the 1993 and 1994 data. These runs simulated a closure of the Red King Crab Savings Area for the first three months of the year, a closure of the Northern Bristol Bay area, and caps of 850,000 bairdi crab in Zone 1, 1.5 million bairdi crab in Zone 2, 11 million opilio crab in Zone 2, and 35,000 red king crab in Zone 1 (indicated as RKC, Caps, N.B.B. in **Table 6.18**). With these constraints in place, the estimated net benefits to the Nation decreased by approximately $1.4 million using the 1993 data set and by approximately $3.9 million using the 1994 data set.

Reducing the opilio cap to 6 million crab in addition to all of the proposed closures and caps above reduced the estimated net benefits to the action from status quo by approximately $1.4 million using the 1993 data and by approximately $11.1 million using the 1994 data. The reason there was no change from all proposed closures and caps in place using the 1993 data and decreasing the opilio cap by 5 million crab was that the bairdi caps closed the Zone 2 fisheries which would have been impacted by the reduced caps. Using the 1994 data, it was the opilio cap rather than the bairdi cap which was more constraining. The overall bycatch of opilio crab was not greatly reduced in 1993 from status quo because the bairdi crab closure caused fishing to occur outside of Zone 2 where opilio crab bycatch is still substantial.

6.4 Potential Impacts of Implementing a Nearshore Trawl Closure in Bristol Bay

A brief summary of the Bering Sea fishery simulation model is provided below. This model was used to examine the impacts of implementing a nearshore trawl closure in Bristol Bay. A more detailed explanation is provided in **Appendix 8**.

The Bering Sea fishery simulation model was developed as a quantitative means of estimating the impacts of management actions contemplated by the Council. The model uses the most recent information available and attempts to estimate the changes in catch and bycatch which occur by "stepping through" the data in an iterative process - comparing the catch or bycatch "to date" with TAC and PSC restrictions. However, the actual fisheries are not static but change with weather, fish biomass, market conditions, management actions, and individual expectations among a host of factors. The Bering Sea fishery simulation model utilizes data which, to some extent, reflect the dynamics of the particular year in which they were collected, in this case 1993 and 1994. The regimes anticipated to be in place in the near future are then applied to those data. The results of the model reflect a static state, and are somewhat useful in providing an answer to "what if?". The model cannot currently capture more of reality than is inherent in the data and in prescribed management actions. The model is unable to anticipate any other changes, and results of the model, when compared with the actual fishing year it was meant to predict, also contain the inaccuracies which occur when actual situations differ from what had occurred when the data was collected.

Background

Amendments to Fishery Management Plans (FMPs) require an estimation of the net benefits to the Nation which might occur due to the alternatives being considered. Thus, as a section of Environmental Assessment/Regulatory Impact Review (EA/RIR) documents for amendments to the FMP for the Groundfish Fishery of the Bering Sea and Aleutian Islands, an examination of the economic impacts from alternatives to the *status quo* must be included. A fishery simulation model developed by Smith (1989) and Funk (1990) has been used to analyze the impacts of several amendments involving area closures and catch or bycatch allocations. This Bering Sea fishery simulation model estimates the changes in catch and bycatch resulting from alternative management actions, and assigns values to the catch (positive benefits) and bycatch (negative benefits) to arrive at an estimate of the total net benefit to the Nation.

Funk (1990) converted the original spreadsheet model into a SAS program to estimate benefits or costs resulting from proposed trawl closures to protect herring. This program was later modified and used by the Alaska Department of Fish and Game to make quantitative estimates of the likely consequences of alternatives for chinook salmon bycatch in Amendment 21b (Anon. 1994). The Bering Sea fishery simulation model, as modified, was also used to analyze options in the Pribilof Islands trawl closure Amendment 21a (NPFMC 1994), to examine impacts of halibut bycatch allocations, and to estimate Inshore/Offshore allocation impacts. The model was further modified for the analysis of the Red King Crab Savings Area in 1995.

All of the data, assumptions and caveats are as described in the previous analysis (NPFMC 1995), with the exception that updated 1993 and 1994 datasets containing some revised product values were received from NMFS and used in this analysis. This may cause slight variations from the model runs presented in the previous analysis (NPFMC 1995). That analysis should be consulted for a more detailed explanation of the model and the data used in this analysis.

Results of the model

The economic impacts of the closure alternatives are estimated in terms of the foregone gross wholesale value and foregone wholesale value net of variable costs[2] in both the groundfish fisheries and the directed fisheries for bycatch species. Estimated net benefits from the various alternatives, including the status quo, are calculated by the difference between the estimated net wholesale value of the groundfish fisheries and the estimated foregone net wholesale value of the bycatch species. The difference between the estimated net benefits under status quo and under the two closure alternatives is used as a measure

In the remainder of this section, the term "net wholesale value" refers to the estimated gross wholesale value net of variable costs only.

of the potential change in net benefits as a result of the alternatives. Data were available from 1993 and 1994. Because the data from each year incorporate management and fisheries decisions specific to each year, the model runs are discussed separately below. Output from the various model runs from both years is available in **Appendix 11**.

1993 data-based runs

The base-line runs of the model represent Alternative 1, status quo, with no northern Bristol Bay closure, and with a 3-month red king crab closure in place (as adopted by the NPFMC in September, 1995). As can be seen in **Table 6.19**, status quo based on 1993 data resulted in a total catch of 1,809,778 mt of groundfish from all fisheries with 1,552,688 mt retained. The estimated total gross value from the retained catch was $847 million and the total net value was $315 million (See economic assumptions in the previous analysis (NPFMC 1995). Subtracting the total gross value of the bycaught species, $24 million, from the gross value of the groundfish catch resulted in an estimated gross value of the difference of $823 million. The total estimated net benefit to the Nation resulting when the total net value of the groundfish catch is reduced by the total net value of the bycatch species ($12 million) was $303 million.

The model simulated the prosecution of the fisheries under the baseline run of 1993 data which included the 3-month closure of the Red King Crab Savings Area. This baseline run was virtually identical to the run with the Red King Crab Savings Area (Alternative 3) in the previous analysis (NPFMC 1995), with the exception that the values differed somewhat due to updates of product value information. Otherwise, catch and bycatch amounts and timing of closures were the same.

Under Alternative 2 (the closure of Bristol Bay east of 162° W. longitude and north of 58° N. latitude), the total predicted catch of groundfish was 1,802,256 mt with 1,547,898 mt of retained catch. The total gross and net values of the retained catch were $844 million and $314 million, respectively. The estimated gross and net values of retained catch minus the gross and net values of bycatch species were $820 million and $302 million, respectively. The bycatch model predicted that the net benefits to the nation would decrease by approximately $1.1 million under status quo ($303 million minus $302 million). The factors which contributed to this decrease in net benefits under Alternative 2 were a reduction in total retained catch (4,790 mt) and an increase in the bycatch of Tanner crab (31,317 crab). Herring bycatch was predicted to be reduced by 115 mt.

The times and causes of predicted closures were similar between Alternative 2 and the status quo with the exception that the yellowfin sole fishery was closed one week earlier due to halibut bycatch in week 24 rather than week 25.

Alternative 3 (the additional closure of Area 508) resulted in no change in total groundfish catch over Alternative 2, and a small increase in retained catch over Alternative 2 (1,547,961 mt vs. 1,547,898 under Alternative 2). The total gross value and total net value of the retained groundfish catch thus increased somewhat under Alternative 3 when compared with Alternative 2 to $843.7 million gross value and $314.1 million net value. The slight increase in the net value of groundfish catch under Alternative 3 coupled with the slight increase in the net value of the bycatch, due to increased Tanner crab bycatches, resulted in the total net benefits to the nation of $302 million which was approximately the same as under Alternative 2.

Between the two alternatives, king crab bycatch was reduced somewhat under Alternative 3, and Tanner crab and halibut bycatch increased somewhat under this alternative. Compared with status quo, Tanner crab bycatch increased under both alternatives, and the bycatches of halibut, red king crab, and herring were reduced.

1994 data-based runs

As can be seen in **Table 6.19**, status quo based on 1994 data resulted in a total catch of 1,803,803 mt of groundfish from all fisheries with 1,536,805 mt retained. The estimated total gross value from the retained catch was $828 million and the total net value was $305 million (See economic assumptions in the previous analysis (NPFMC 1995)). Subtracting the total gross value of the bycaught species, $30 million, from that of the groundfish catch, resulted in an estimated gross value of the difference of $798 million. The total estimated net benefit to the Nation resulting when the total net value of the groundfish catch is reduced by the total net value of the bycatch species ($15 million) was $290 million.

As with the 1993 data, the model simulated the prosecution of the fisheries under the baseline run of 1994 data which included the 3-month closure of the Red King Crab Savings Area. This baseline run was virtually identical to the run with the Red King Crab Savings Area (Alternative 3) in the previous analysis (NPFMC 1995), with the exception that the values differed somewhat due to updates of product value information. Otherwise, catch and bycatch amounts were the same. Because of slight variations in bycatch amounts, the yellowfin sole fishery was not closed to second quarter halibut in week 28 as had occurred in the Red King Crab Savings Area closure (Alternative 3 in the previous analysis (NPFMC 1995), a comparable base run).

Under Alternative 2 (the closure of Bristol Bay east of 162° W. longitude and north of 58° N. latitude), the total predicted catch of groundfish was 1,797,306 mt with 1,531,428 mt of retained catch. The total gross and net values of the retained catch were $824 million and $304 million, respectively. The estimated gross and net values of retained catch minus the gross and net values of bycatch species were $794 million and $289 million, respectively. The bycatch model predicted that the net benefits to the nation would decrease by approximately $1.3 million under status quo ($290 million minus $289 million). The principal factors which contributed to this decrease in net benefits under Alternative 2 were a decrease in retained catch of 5,377 mt, an increase in Tanner crab bycatch of 29,271 crab, and the earlier attainment of halibut PSC in week 26 by the yellowfin sole fishery. Herring bycatch was reduced by 24 mt.

Alternative 3 (the additional closure of Area 508) resulted in no change in total groundfish catch, retained catch, net value or gross value of groundfish over Alternative 2. The net value of the bycatch, however, did decrease somewhat under Alternative 3 due to slightly increased Tanner crab bycatch. The total net benefits to the nation, $289 million, were approximately the same as under Alternative 2.

Summary of Alternatives

Estimates based on the Bering Sea fishery simulation model indicate that adoption of any of the Alternatives would lead to a slight decrease in the net benefits to the Nation over status quo based on both the 1993 and 1994 data. The approximately $1.1 million decrease in net benefits (1993 data) and $1.3 million decrease in net benefits (1994 data) result in approximately a 0.4% and a 0.5% decrease of the net benefits to the Nation under status quo from 1993 and 1994 data, respectively. Given the accuracy inherent in the data, and in the model procedures, these predicted changes in net benefits to the nation are probably not great enough to indicate an actual change from status quo. As with any closure, the tradeoff's between foregone groundfish catch, and savings in bycatch species are apparent in the model results. A closure of northern Bristol Bay would result in a slight decrease in retained catch and herring bycatch and an increase in Tanner crab bycatch. The minimal directed fishing activity in Area 508 during 1993 and 1994 resulted in minute changes in the model results due to the closure of this area.

6.5 Potential Cumulative Impacts and Interactions of the Three Management Measures Considered

Implementation of the three management measures may have cumulative effects on groundfish trawl fisheries. As noted by the Scientific and Statistical Committee, time-area closures cause area shifts in groundfish fishery effort. With each additional bycatch restriction, options for the groundfish trawl fleets are reduced and these effort shift could increase the bycatch of other prohibited species. To some extent, this situation occurred in the rock sole trawl fishery as a result of implementing the Bristol Bay Red King Crab Savings Area (Management Measure 1) by inseason action in 1995 and 1996. The 1996 directed rock sole fishery was apparently closed early due to increased halibut bycatch per metric ton of groundfish. Bycatch rates for Tanner crab also increased (note that about the same amount of Tanner crab bycatch was taken, and less rock sole was caught), but bycatch of red king crab was much reduced due to the closure. These types of tradeoffs will occur with any area closure alternative considered.

The impacts of trawl closure areas on the trawl fleet may be further exacerbated by reduced crab PSC limits. As discussed in the previous paragraph, implementation of the Red King Crab Savings Area may cause higher bycatch rates for Tanner crab in the rock sole fishery. Hence, to maintain the rock sole fishery in Zone 1 at current harvest levels, a relatively high proportion of Tanner crab PSC (requiring ~300,000 crab) could be allocated to the early season rock sole fishery. An additional trawl closure area proposed under Management Measure 3 (nearshore Bristol Bay) may similarly shift effort of the yellowfin sole trawl fishery into Zones 1 and 2, which may have higher bycatch rates of Tanner crab and halibut. Hence, the yellowfin sole fishery may require increased allocation of Tanner crabs and halibut to maintain harvest levels. Allocations of crab PSC among trawl fisheries will become much more contentious, even at current halibut and crab PSC limits. With reduced crab PSC limits, all trawl fisheries could be affected, as fisheries may be shut out of better fishing areas sooner. Flatfish fisheries may be "forced" to shift effort into Area 514 (west of 162° W. longitude), which typically has moderately high bycatch rates of halibut (Narita et al. 1994). Because attainment of the halibut cap shuts down fishing in the entire Bering Sea for the affected fishery, the combination of closure areas and reduced PSC limits may have significant negative effects on certain

Catch and bycatch in the rock sole trawl fishery through the first PSC closure, 1993-1995.

Year	Date Closed	Reason for closure	Harvest (mt) of rock sole	Zone 1 Tanner crab	Zone 1 red king crab	halibut mortality (mt)
1993	Feb 16	RKC, Zone 1	38,000	420,000	181,000	667
1994	Feb 28	RKC, Zone 1	37,000	259,000	154,000	281
1995	Feb 21	Halibut	32,000	320,000	19,000	428
1996	Feb 26	Halibut	19,000	290,000	9,000	436

trawl fisheries, particularly those targeting flatfish.

6.6 Administrative, Enforcement and Information Costs

No additional costs for administration, enforcement, or information requirements are expected under any of the alternatives for the three management measures considered. It should be noted that NMFS enforcement and U.S. Coast Guard have generally favored closure areas that affect all trawling rather than just non-pelagic trawling.

7.0 FINAL REGULATORY FLEXIBILITY ANALYSIS

The objective of the Final Regulatory Flexibility Act is to require consideration of the capacity of those affected by regulations to bear the direct and indirect costs of regulation. If an action will have a significant impact on a substantial number of small entities an Initial Regulatory Flexibility Analysis (FRFA) must be prepared to identify the need for the action, alternatives, potential costs and benefits of the action, the distribution of these impacts, and a determination of net benefits.

NMFS has defined all fish-harvesting or hatchery businesses that are independently owned and operated, not dominant in their field of operation, with annual receipts not in excess of $2,000,000 as small businesses. In addition, seafood processors with 500 employees or fewer, wholesale industry members with 100 employees or fewer, not-for-profit enterprises, and government jurisdictions with a population of 50,000 or less are considered small entities. A "substantial number" of small entities would generally be 20% of the total universe of small entities affected by the regulation. A regulation would have a "significant impact" on these small entities if it reduced annual gross revenues by more than 5 percent, increased total costs of production by more than 5 percent, or resulted in compliance costs for small entities that are at least 10 percent higher than compliance costs as a percent of sales for large entities.

If an action is determined to affect a substantial number of small entities, the analysis must include:

(1) a description and estimate of the number of small entities and total number of entities in a particular affected sector, and total number of small entities affected; and

(2) analysis of economic impact on small entities, including direct and indirect compliance costs, burden of completing paperwork or recordkeeping requirements, effect on the competitive position of small entities, effect on the small entity's cashflow and liquidity, and ability of small entities to remain in the market.

7.1 Economic Impact on Small Entities

Most trawl vessels and processor participating in the BSAI groundfish fishery would be affected by the management measures proposed under all alternatives to the Status quo for the three management measures under consideration.

Most catcher vessels harvesting groundfish off Alaska meet the definition of a small entity under the RFA. In 1993, 132 trawl catcher vessels landed groundfish from the BSAI. Many of these vessels would be affected by time/area closures considered under Management Measures 1 and 3, as well as by PSC limits considered under Management Measure 2. The economic impact on small entities that would result from some of the time/area closures and PSC limits considered could result in a reduction in annual gross revenues by more than 5 percent and could, therefore, potentially have a significant economic impact on a substantial number of small entities. Refer to analysis presented in section 6.0 for details.

NMFS received five letters of comment in response to the request for comments in the proposed rule implementing Amendment 37 (September 12, 1996; 61 FR 48113). Most comments centered on the biological and conservation aspects of red king crab in the specified closure areas. Respondants, in part, supported the closure area and asked NMFS to explain the basis for the specific closure area and the PSC limit. NMFS's response outlines the rationale and the data that justify the specific closure areas the stair-step approach to the PSC limit. One comment states that the EA/RIR/IRFA estimates a net loss to the nation and indicates that the management measures may have a negative impact on small entities. NMFS's response summarizes the information in the EA/RIR/IRFA that based on the Bering Sea simulation model, the proposed management measures would lead to a decrease in net benefits of 0.4 and 0.5 percent, from 1993 and 1994 data respectively. Given a certain level of uncertainty inherent in the data and in the model procedures, these predicted changes in net benefits are probably not great enough to indicate an actual change from the status quo. The analysis indicates that a significant effect on a substantial number of small entities could occur through displacement from the closed areas. However, Amendment 37 would allow the lower ten minute portion of the Red King Crab Savings Area to be opened in a year when a guideline harvest level of red king crab was established for the previous year. As well, the measures retained an open area in northern Bristol Bay. These open areas will help to minimize the impact that the proposed management measures may have on small entities.

8.0 REFERENCES

Armstrong, D.A., T.C. Wainwright, G.C. Jensen, P.A. Dinnel, and H.B. Andersen. 1993. Taking refuge from bycatch issues: red king crab (Paralithodes camtschaticus) and trawl fisheries in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences 50: 1993-1999.

Aschan, M.M. 1991. Effects of Iceland scallop dredging on benthic communities in the Northeast Atlantic. Special international workshop on the effects of physical disturbance on the sea floor on benthic and epibenthic ecosystems. Conseil International pour L'Exploration de la Mer, Benthos Working Group.

Bakkala, R.G., V.G. Wespestad, and L-L. Low. 1982. The yellowfin sole (Limanda aspera) resource of the eastern Bering Sea - its current and future potential for commercial fisheries. NOAA Technical Memorandum NMFS F/NWC-33.

Blackburn, J. and D. Schmidt. 1988. Injury and apparent mortality rates from incidental trawl catches of halibut, king crab, and Tanner crab in the Kodiak area, 1977-81. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-21.

Best, E.A. 1977. Distribution and abundance of juvenile halibut in the Southern Bering Sea. International Pacific Halibut Commission Scientific Report No. 62:23p.

Best, E.A., and W.H. Hardman. 1982. Juvenile halibut surveys, 1973-1980. International Pacific Halibut Commission, Technical Report No. 20, 38 p.

Byersdorfer, S., and L.J. Watson. 1992. A summary of biological data collected during the 1991 Bristol Bay red king crab tagging study. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-14.

Byersdorfer, S., and L.J. Watson. 1993. A summary of biological data collected during the 1992 Bristol Bay red king crab test fishery. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-14.

Breen, P.A. 1987. Mortality of Dungeness crabs caused by lost traps in the Fraser River estuary, British Columbia. North American Journal of fisheries Management 7:429-435.

Caddy, J.F. 1968. Underwater observations on scallop *(Placopecten magellanicus)* behavior and drag efficiency. Journal of the Fisheries Research Board of Canada 25: 2123-2141.

Caddy, J.F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada 30: 173-180.

Carls, M.G., and C.E. O'Clair. 1989. Influence of cold air exposures on ovigerous red king crabs (Paralithodes camtschatica) and Tanner crabs (Chionoecetes bairdi) and their offspring. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant College Program Report No. 90-04.

Cassano, E., G. Harrington, P.S. Hill, and T. Loher. 1995. Management of Bristol Bay red king crab: a critical intersections approach to fisheries management. University of Washington. Contemporary Issues in Fisheries Management SMA/FISH 582.

Donaldson, W.E. 1990. Determination of experimentally induced non-observable mortality on red king crab. Alaska Department of Fish and Game Regional Information Report 4K90-13.

Donaldson, W.E., R.T. Cooney, and J.R. Hilsinger. 1981. Growth, age and size at maturity of Tanner crab, Chionoecetes bairdi, in the northern Gulf of Alaska. J. Crustacean Biology 9:37-53.

Dew, C.B. 1990. Behavioral ecology of podding red king crab, Paralithodes camtschatica. Canadian Journal of Fisheries and Aquatic Science 47:1944-1958.

Eleftheriou, A., and M.R. Robertson. 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. Netherlands Journal of Sea Research 30:289-299.

Fisher, R.B. 1980. The joint-venture fishery for yellowfin sole. The Bering Sea, summer 1980: A case study in fishery development. 89p.

Fredin, R.A. 1987. History of regulation of Alaskan groundfish fisheries. NOAA/NMFS NWAFC Processed Report 87-07.

Fukuhara, F.M., and D. Worlund. 1973. Incidence of halibut and Tanner crab in catches by the eastern Bering Sea mothership trawl fishery and independent trawlers. NOAA/NMFS/NAFC Report to the International North Pacific Fisheries Commission.

Funk, F. 1994. Preliminary summary of 1994 Alaska herring roe fisheries. Alaska Department of Fish and Game, Regional Information Report No. 5J94-20.

Gilmer, T. 1978. Cape Romanzof herring project, May 22 - June 20, 1978. Alaska Department of Fish and Game, Preliminary Report.

Gilroy, H.L., and S.H. Hoag. 1993. The 1987 Bristol Bay survey and the Bristol Bay halibut fishery, 1990-1992. International Pacific Halibut Commission Technical Report No. 28.

Guttormsen, M.R., R. Narita, and J. Berger. 1990. Summary of U.S. observer sampling of foreign and joint venture fisheries in the Northeast Pacific Ocean and eastern Bering Sea, 1989. NOAA Tech. Memo NMFS F/NWC-189.

Haegele, C.W., and J.F. Schweigert. 1990. Egg loss in herring spawn in Georgia Strait, British Columbia. Proceedings of the International Herring Symposium, Anchorage, Alaska.

Haflinger, K.E., C.P. McRoy. 1983. Yellowfin sole (Limanda aspera) predation on three commercial crab species (Chionoecetes opilio, C. bairdi, and Paralithodes camtschaticus) in the Southeastern Bering Sea. Institute of Marine Science, UAF, Fairbanks, AK.

Hammerstrom, L.F., and M.F. Merritt. 1985. A survey of Pacific weathervane scallops (Patinopecten caurinus) in Kamishak Bay, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 252.

Hayes, M.L. 1973. Survival of Tanner crab (Chionoecetes bairdi) after capture in trawls and subsequent handling and storage aboard fishing boats. NOAA/NMFS report to the International North Pacific Fisheries Commission.

Hare, S.R. 1988. Report on the Port Moller Pacific Cod Trawl Fishery, Summer 1988. NOAA/NMFS --NWAFC Processed Report 88-25.

Hart, J.L., 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180.

Hennick, D.P. 1973. Sea scallop, Patinopecten caurinus, investigations in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report 5-23-R.

High, W.L. 1976. Escape of Dungeness crabs from pots. Marine fisheries review 38(4):19-23.

High, W.L. 1985. Some consequences of lost fishing gear. Pages 430-437 in R.S. Shomura and H.O. Yoshida, editors. Proceedings of the workshop on the fate and impact of marine debris. NOAA/NMFS/SWFC Technical Memorandum 54.

High, W.L. , and D.D. Worlund. 1979. Escape of king crab (Paralithodes camtschaticus) , from derelict pots. NOAA/NMFS/SSRS Technical Report 734.

Hood, D.W., and J. A. Calder. 1981. The eastern Bering Sea shelf: oceanography and resources, Volume 2. NOAA/Office of Marine Pollution Assessment.

Hood, D.W., and E.J. Kelly. 1974. Oceanography of the Bering Sea. Institute of Marine Science, University of Alaska.

Hughes, S.E., and N. Bourne. 1981. Stock assessment and life history of a newly discovered Alaska surf clam (Spisula polynyma) resource in the southeastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences 10:1173-1181.

Hutchings, P. 1990. Review of the effects of trawling on macrobenthic epifaunal communities. Australian Journal of Marine and Freshwater Research (41)111-120.

ICES (International Council for the Exploration of the Sea). 1992. Report of the study group on ecosystem effects of fishing activities. ICES C.M. 1992/G11.

Jackson, D. 1996. Commercial king and Tanner crab fisheries in Kodiak and Alaska Peninsula areas. Alaska Department of Fish and Game Regional Information Report No. 4K96-8.

Jewett, S.C., and C.P. Onuf. 1988. Habitat suitability index models: red king crab. U.S. Fish and Wildlife Service Biological Report 82(10.153).

Jones, J.B. 1992. Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research 26: 59-67.

Kaiser, R.J. 1986. Characteristics of the Pacific weathervane scallop (Patinopecten caurinus) fishery in Alaska 1967-1981. Alaska Department of Fish and Game, Division of Commercial Fisheries (Unpublished Report, Catalog RUR-5J86-01).

Kimker, A. 1994. Tanner crab survival in closed pots. Alaska Fishery Research Bulletin 1(2):179-183.

Kruse, G.H. 1993. Biological perspectives on crab management in Alaska. Proceedings of the International Symposium on Management Strategies for Exploited Populations. 1993: 357-384.

Kruse, G.H., and A. Kimker. 1993. Degradable escape mechanisms for pot gear: a summary report to the Alaska Board of Fisheries. Alaska Department of Fish and Game Regional Information Report 5J93-01.

Livingston, P.A. 1989. Interannual trends in Pacific cod, Gadus macrocephalus, predation on three commercially important crab species in the eastern Bering Sea. Fishery Bulletin 87:807-827.

Livingston, P.A. 1993. Importance of predation by groundfish, marine mammals and birds on walleye pollock (Theragra chalcogramma) and Pacific herring (Clupea pallasi) in the eastern Bering Sea. Marine Ecology Progress Series 102:205-215.

Livingston, P.A. L-L Low, and R.J. Marasco. 1994. Eastern Bering sea ecosystem trends. Unpublished paper presented at the Symposium on Large Marine Ecosystems of the Pacific. October 11, 1994. Qingdao, China.

MacIntosh, R.A., B.G. Stevens, and J.A. Haaga. 1995. Effects of handling and discarding on mortality of Tanner crabs, Chionoecetes bairdi. Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant College Program Report (in press).

Matsuura, S., and K. Takeshita. 1989. Longevity of red king crab , Paralithodes camtschatica,, revealed by long-term rearing study. Proceedings of the International Symposium on king and Tanner Crabs. Alaska Sea Grant College Program Report.

Mayer, L.M., D.F. Schick, R.H. Findlay, and D.L. Rice. 1991. Effects of commercial dragging on sedimentary organic matter. Marine Environmental Research 31:249-261.

McCaughran, D.A., and G.C. Powell. 1977. Growth model for Alaska king crab (Paralithodes camtschatica). Journal of the Fisheries Research Board of Canada 34:989-995.

McLellan, G.L., and J.K. Leong. 1981. Summer food of Pacific cod, Gadus macrocephalus, in coastal waters of Southeastern Alaska. Fishery Bulletin 78(4):968-973.

McMurray, G., A.H. Vogel, P.A. Fishman, D.A. Armstrong, and S.C. Jewett. 1984. Distributional of larval and juvenile red king crabs (Paralithodes camtschatica) in Bristol Bay. U.S. Department of Commerce, NOAA OCSEAP Final Report 53(1986):267-477.

Messieh, S.N., T.W. Rowell, D.L. Peer, P.J. Cranford. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research II: 1237-1263.

Meyer, R.M. 1971. A study concerning the problem of derelict pots in the king crab fishery. NOAA/NMFS unpublished manuscript.

Morrison, R. 1996. Bering Sea and Aleutian Islands King and Tanner Crab Management: Historic Overview and Preliminary Summary of the 1995/96 Fisheries. January 9, 1996.

Morrison, R., and R.K. Gish. 1995. Annual management report for the shellfish fisheries of the Bering Sea area, 1993. Alaska Department of Fish and Game, Commercial Fisheries Management and Development.

Murphy, M.C., and G. H. Kruse. 1995. An annotated bibliography of capture and handling effects on crabs and lobsters. Alaska Fishery Research Bulletin 2(1):23-75.

Narita, R., M. Guttormsen, J. Gharrett, G. Tromble, and J. Berger. 1994. Summary of observer sampling of domestic groundfish fisheries in the Northeast Pacific Ocean and Eastern Bering Sea, 1991. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-48.

Natural Resource Consultants. 1988. Minimization of king and Tanner crab by-catch in trawl fisheries directed at demersal groundfish in the Bering Sea. Report of NOAA Award 86-ABH-0042. Seattle.

NEFMC (New England Fishery Management Council). 1982. Fishery management plan, final environmental impact statement, regulatory impact review for Atlantic sea scallops *(Placopecten magellanicus)*. New England Fishery Management Council, Saugus, Massachusetts.

Nichol, D., T. Sample, and T. Crawford. 1995. Cruise results of the 1995 Togiak nearshore beam-trawl survey. NOAA/NMFS Alaska Fisheries Science Center Cruise 95-1 Crawdad.

NMFS (National Marine Fisheries Service). 1995. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Amendment 36 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area and Amendment 39 to the Fishery Management Plan for groundfish of the Gulf of Alaska. September 1995.

NPFMC (North Pacific Fishery Management Council). 1986. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Amendment 10 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area. November 1986.

NPFMC (North Pacific Fishery Management Council). 1990. Environmental Assessment for Amendment 1 to the fishery management plan for the commercial king and Tanner crab fisheries in the Bering Sea and Aleutian Islands. November 1990.

NPFMC (North Pacific Fishery Management Council). 1992. Supplemental Information for the proposed eastern Gulf trawl closure and future management of rockfish in the Gulf of Alaska. September +9, 1992. 46 p.

NPFMC (North Pacific Fishery Management Council). 1993. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility Analysis alternatives to allocate the Pacific cod total allowable catch by gear and/or directly change the seasonality of the cod fisheries: Amendment 24 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area. October 1993.

NPFMC (North Pacific Fishery Management Council). 1994. Ecosystems Considerations chapter to the stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea / Aleutian Islands Regions as projected for 1995. December 1994. 88 p.

NPFMC (North Pacific Fishery Management Council). 1994a. Discussion Paper: Snow crab (C. opilio) Bycatch in the Groundfish Trawl Fisheries.

NPFMC (North Pacific Fishery Management Council). 1994b. Faces of the Fisheries.

NPFMC (North Pacific Fishery Management Council). 1995. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for red king crab bycatch in the Bering Sea trawl fisheries and alternatives for closure areas.

NPFMC (North Pacific Fishery Management Council). 1995b. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Alternative 1 to the Fishery Management Plan for the Scallop Fishery of the Bering Sea and Aleutian Islands area.

NRC (Natural Resources Consultants). 1988. Minimization of King and Tanner crab by-catch in trawl fisheries directed at demersal groundfish in the Bering Sea. February 1988.

Owen D. 1988. A bottom trawl survey on the west side of Kodiak Island: Viekoda Bay, Spiridon Bay, and Kupreanof Strait. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-28.

Otto, R.S., R.A. MacIntosh, and P.A. Cummiskey. 1990. Fecundity and other reproductive parameters of female red king crab in Bristol Bay and Norton Sound, Alaska. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant Report 90-04:65-90.

Paul, A.J. 1984. Mating frequency and viability of stored sperm in the Tanner crab Chionoecetes bairdi (Decapoda, Majidae). J. Crustacean Biology. 4:375-381.

Paul, J.M., A.J. Paul, and A. Kimker. 1993. Starvation resistance in Alaska crabs: interim report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A93-03.

Pengilly, D., and D. Schmidt. 1995. Harvest strategy for Kodiak and Bristol Bay red king crab and St. Matthew Island and Pribilof blue king crab. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division Special Publication Number 7.

Queirolo, L.E., L.W. Frita, P.A. Livingston, M.R. Loefflad, D.A. Colpo, and Y.L. deReynier. 1995. Bycatch, Utilization, and Discards in the Commercial Groundfish Fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. NOAA Technical Memorandum NMFS-AFSC-58.

Rodin, V.E. 1989. Population biology of the king crab *Paralithodes camtschatica* Tilesius in the North Pacific Ocean. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant Report 90-04:133-144.

Rounds, P.M., C. Brodersen, and M.M. Babcock. 1989. Effects of cohort density and habitat on survival and growth of juvenile red king crab Paralithodes camtschaticus. Proceedings of the International King and Tanner Crab Symposium. Alaska Sea Grant College Program Report No. 90-04.

Schmidt, D.C., and D. Pengilly. 1990. Alternative red king crab fishery management practices: Modeling the effects of varying size-sex restrictions and harvest rates. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant Report 90-04:551-566.

Schmidt, D.C., and D. Pengilly. 1993. Review of harvest strategies used in the management of Lithodid crab in Alaska. Proceedings of the International Symposium on Management Strategies for Exploited Populations. 1993: 385-407.

Sharma, D. 1979. The Alaska Shelf. Springer-Verlag, New York. 498 p.

Smith, T.P. 1992. Management of the groundfish fisheries off Alaska: The race for bycatch. Arctic Research of the United States, Volume 6.

Smith, T.P. 1993. Allocating the incidental catch of crab, halibut, herring, and salmon in the groundfish fisheries off Alaska. Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. 93: 745-760.

Smith, EM., and P.T. Howell. 1987. The effects of bottom trawling on American lobsters, Homerus americanus, in Long Island Sound. Fishery Bulletin 85:737-744.

Stevens, B.G. 1990. Survival of king and Tanner crabs captured by commercial sole trawls. Fishery Bulletin 88:731-744.

Stevens, B.G., and R.A. MacIntosh. 1993. Preliminary results of the 1992 survival experiment for crabs discarded from commercial pot fisheries. NOAA/NMFS unpublished manuscript.

Stevens, B.G., and R.A. MacIntosh. 1993. Survival of crabs discarded from commercial pot fisheries. Cited in Queirolo et al. 1995. Bycatch, Utilization, and Discards in the Commercial Groundfish fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. NOAA Technical Memorandum NMFS-AFSC-58.

Stevens, B.G., J.A. Haaga, and R.A. MacIntosh. 1994. Report to the industry on the 1994 Eastern Bering Sea crab survey. NOAA/NMFS-AFSC Processed Report 94-07.

Stevens, B.G. 1995 Crab bycatch in pot fisheries: causes and solutions. Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant Program Report (in press).

Stevens, B.G., J.A. Haaga, and R.A. MacIntosh. 1996. Report to the industry on the 1995 Eastern Bering Sea crab survey. NOAA/NMFS-AFSC Processed Report 96-01.

Stone, R.P., C.E. O'Clair, and T.C. Shirley. 1993. Aggregating behavior of ovigerous female red king crab (Paralithodes camtschaticus), in Auke Bay, Alaska. Canadian Journal of Fisheries and Aquatic Science 50:750-758.

Sumerton, D.A., and L.L. Low. 1977. Determination of minimum size and yield limitations for Tanner crabs in the eastern Bering Sea. NOAA/NMFS/NAFC Processed Report. April 1977.

Taylor, F.H.C. 1964. Life history and present status of British Columbia herring stocks. Fisheries Research Board of Canada, Bulletin 143.

Thompson, G. 1993. Impacts of trawling on the seabed and benthic community. Appendix F to the EA/RIR for Amendment 24 to the Fishery Management Plan for Groundfish Fisheries in the Bering Sea and Aleutian Islands Area. 5 p.

Thomson, A. 1989. An industry perspective on problems facing the rebuilding of king and Tanner (bairdi) crab stocks of the Eastern Bering Sea. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant College Program Report 90-04:533-545.

Tracy, D.A. 1994. Biological summary of the 1992 mandatory shellfish observer program database. Alaska Department of Fish and Game. Regional Information Report 4K94-10.

Tyler, A. L., G.H. Kruse. 1995. Report of the modeling workshop on year-class strength formation of red king crab. ADF&G, Juneau, AK.

Tyler, A. L., G.H. Kruse. 1995b. Conceptual modeling of brood strength of red king crab in the Bristol Bay region of the Bering Sea. Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant Program Report (in press).

Urban, D. 1996. Bottom trawl survey of crab and groundfish: Kodiak Island, Alaska Peninsula, and Eastern Aleutian Islands, 1994. Alaska Department of Fish and Game, Regional Information Report No. 4K96-3.

Urban, D., D. Pengilly, and I. Vining. 1994. The scallop observer program and statewide data analysis summary to the Board of Fisheries. Alaska Department of Fish and Game Report 4K94-28.

Watson, L.J., and D. Pengilly. 1994. Effects of release method on recovery rates of tagged red king crabs (Paralithodes camtschaticus in the 1993 Bristol Bay commercial fishery. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-40.

Witherell, D. 1994. Management of flatfish fisheries in the North Pacific. Proceedings of the International Symposium on North Pacific Flatfish. Alaska Sea Grant College Program Report No. 95-04:573-590.

Witherell, D. 1995. Crab Rebuilding Committee Report. North Pacific Fishery Management Council Report. April 1995.

Witherell, D., and G. Harrington. 1995. Evaluation of Alternative Management Measures to Reduce the Impacts of Trawling and Dredging on Bering Sea Crab Stocks. Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant Program Report (in press).

Witherell, D., and L. Roberts. 1995. Regulatory and closure areas for the groundfish fisheries in the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council. 17 p.

Zheng, J. M.C. Murphy, and G.H. Kruse. 1994. A length-based population model and stock-recruitment relationships for red king crab, Paralithodes camtschaticus, in Bristol Bay, Alaska. Canadian Journal of Fisheries and Aquatic Science. (in press).

Zheng, J. M.C. Murphy, and G.H. Kruse. 1995a. Overview of population estimation methods and robust long-term harvest strategy for red king crabs in Bristol Bay. Alaska Department of Fish and Game Regional Information Report No. 5J95-21.

Zheng, J. M.C. Murphy, and G.H. Kruse. 1995b. A length-based approach to estimate population abundance of Tanner crab, Chionoecetes bairdi, in Bristol Bay, Alaska. North Pacific Symposium on Invertebrate Stock Assessment and Management.

Zheng, J. M.C. Murphy, and G.H. Kruse. 1996. Overview of population estimation methods and recommended harvest strategy for red king crabs in Bristol Bay. Alaska Department of Fish and Game Regional Information Report No. 5J96-04.

Zhou, S. and T.C. Shirley. 1995a. Is handling responsible for the decline of the red king crab fishery? Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant Program Report (in press).

Zhou, S. and T.C. Shirley. 1995b. Effects of handling on feeding, activity, and survival of red king crabs, Paralithodes camtschaticus (Tilesius, 1815). Journal of Shellfish Research 14:173-177.

9.0 AGENCIES AND INDIVIDUALS CONSULTED

Ron Berg, Mary Furuness
NMFS/Fish Management Division
Alaska Region Office, Juneau

Sue Mello
NMFS/Protected Species Management Division
Alaska Region Office, Juneau

Bob McConnaughey, Lowell Fritz, Craig Rose, Martin Loefflad
NMFS/Alaska Fisheries Science Center
Seattle, Washington

Bob Otto
NMFS/AFSC Kodiak Laboratory

Arni Thomson
Alaska Crab Coalition

Dave Fraser
F/V Muir Milach

Gregg Williams
International Pacific Halibut Commission
Seattle, Washington

Kathy Rowell
Alaska Department of Fish and Game
Anchorage, Alaska

Ken Griffin, Gordon Kruse, Earl Krygier,
Peggy Murphy
Alaska Department of Fish and Game
Juneau, Alaska

NPFMC Crab Rebuilding Committee

NPFMC BSAI Crab Plan Team

NPFMC Scientific and Statistical Committee

NPFMC Advisory Panel

10.0 LIST OF PREPARERS

David Witherell
North Pacific Fishery Management Council
605 West 4th Avenue, Suite 306
Anchorage, Alaska 99501

David Ackley
Alaska Department of Fish and Game
P.O. Box 25526
Juneau, Alaska 99802

11.0 LIST OF FIGURES

12.0 LIST OF TABLES

13.0 APPENDICES

Appendix 1: Executive Summary of EA/RIR for Amendment 37, dated August 24, 1995

Results from the 1994 NMFS summer trawl survey indicated that red king crab stocks in the Bristol Bay area were at continuing low levels, and that the estimated abundance of mature female king crab of 7.5 million individuals was below the threshold level set in the State of Alaska management plan for king crabs in the Bering Sea and Aleutian Islands of 8.4 million crab. Because of this low abundance of mature female crab, the 1994 directed fishery for red king crab was closed in Bristol Bay, and the directed fishery for Tanner crab was closed in Zone 1 east of 163° W. longitude due to bycatch concerns. Because trawl fisheries had experienced high king crab bycatch, especially in the first months of the rock sole fishery in the same area, the Council took emergency action to close a designated four block area to trawling for the duration of the emergency order (120 days). During the January 1995 meeting, the Council directed staff to analyze 6 alternatives for closure to bottom trawling and to present the results for initial Council review at the April Council meeting. The initial review was presented to the SSC and AP in April, and to the Council in June. Due to the possible economic impact any closure might have on the rock sole fishery in particular, the Council, AP and SSC all recommended that the analysis include output from the Bering Sea bycatch model as a means of weighing alternatives in light of the myriad of existing and potential closures that impact fisheries. This economic analysis had not been completed for the initial reviews, but has been included in the present document. During the June meeting, the Council requested that the economic portion of the analysis be presented to the SSC prior to release for public review.

The six alternatives in addition to status quo are in an area which has experienced high king crab bycatch but has also sustained a roe fishery for rock sole. The alternatives represent closures of varying size, all with an eastern border along Area 512, permanently closed to all trawling. The alternatives are indicated in **(Appendix) Figure 1**. All six alternatives have longitudinal boundaries of 162° West longitude and 164° West longitude and have northern and southern boundaries as follows:

1) Status Quo - no new closure;

2) Northern boundary of 57° North latitude and southern boundary of 56° 10' North latitude;

3) Northern boundary of 57° North latitude and southern boundary of 56° North latitude;

4) Northern boundary of 57° North latitude and southern boundary of 55° 45 ' North latitude;

5) Northern boundary of 58° North latitude and southern boundary of 56° 10' North latitude;

6) Northern boundary of 58° North latitude and southern boundary of 56° North latitude;

7) Northern boundary of 58° North latitude and southern boundary of 55° 45 ' North latitude.

The alternative recommended by the Council during a teleconference in November 1994 was Alternative 4, and the alternative subsequently enacted by NMFS was Alternative 3. The closure had a dramatic effect on reductions in king crab bycatch. In 1992, this fishery bycaught approximately 59,000 red king crab, in 1993 the rock sole fishery took 166,154 red king crab and in 1994 the fishery took 216,821 crab. **The rock sole fishery exceeded the red king crab cap in both 1993 and 1994.** In 1995 through the month of March, the rock sole fishery took only 19,000 red king crab. It is unlikely that crab bycatch numbers in the rock sole fishery will increase substantially in the coming months because red king crab have primarily been taken during the first few months of the year.

The success of this closure in protecting red king crab is however diminished by the impacts it had on the rock sole fishery. Data from the 1995 fishery were unavailable for this document, but since the fishery has had a high reliance on the closed area for obtaining spawning rock sole for roe, the closure is expected to have had economic consequences. Whereas the majority (in 1990, 89%; in 1991, 65%; in 1992 95%; in 1993, 90%; and in 1994 84% of the fishery total Zone 1 bycatch of red king crab) of the red king crab historically taken in the rock sole fishery were within the area (Alternative 3) designated for emergency closure, this area has also provided a significant percentage of groundfish catch (in 1990, 40%; in 1991, 28%; in 1992, 54%; in 1993, 50%; and in 1994, 58% of the fishery Zone 1 groundfish catch). The impacts of the closure are made more significant because of the recent Pribilof Islands closure which had historically been important to the rock sole fishery as well. **However, much of the rock sole effort in the Pribilof Islands area does not occur at the same time as the rock sole roe fishery along the Alaska Peninsula in the first few months of the year.**

In summary, the rock sole fishery has bycaught the majority of red king crab during the January -March fishery for rock sole roe. The major savings to red king crab are found in Alternative 3 with a southern boundary of 56° North latitude. **A subsection of this** area between 56° North latitude and 56° 10' North latitude is productive to the rocksole fishery. In 1990, 15%; in 1991, 13%; in 1992, 35%; in 1993, 26%; and in 1994, 18% of the fishery's Zone 1 groundfish catch came from this area. However, this area has also had high king crab bycatch rates, and in 1990, 12%; in 1991, 32%; in 1992, 47%; in 1993, 31% and in 1994, 20% of the Zone 1 bycatch of king crab came from this area.

The bycatch and economic tradeoffs and implications that such a closure will have on various fisheries require that a model-based economic analysis be performed. The results of the Bering Sea bycatch model are based on data from two separate years. The results under one data set indicate that some net economic benefits to the nation occur due to any of the Alternatives selected, and under the other data set indicate that the opposite, or that some reduction in economic benefits occurs due to the selection of Alternatives. The model predicted that the rock sole fishery would not be closed prematurely due to red king crab bycatch in Zone 1, but would later be closed in the Bering Sea due to halibut bycatch. The rock sole fishery was able to take a comparable amount of rock sole outside of the closure as it had with no closure in place, and red king crab was reduced significantly. The model based on 1993 data estimated that the reduction in red king crab bycatch and slightly better retention of rock sole in the rock sole fishery lead to an increase in net economic benefits to the nation of approximately $3 million, or an increase of approximately 1% over status quo. In contrast, the model based on 1994 data estimated the increased catch of rock sole and reductions in red king crab bycatch, but also estimated a loss in net economic benefits to the nation of approximately $6-8 million, or a decrease of approximately 2%-3% over status quo. Given the accuracy inherent in the data, and in the model procedures, these predicted changes in net benefits to the nation are probably not great enough to indicate an actual change from status quo. Among the Alternatives, Alternatives 2 and 3 are very similar with greater king crab savings realized under Alternative 3. The low amount of catch in the additional area represented by Alternatives 5 - 7 made the impacts of these alternatives difficult to assess as they appear similar to the first three alternatives.

As a caveat, the Bering Sea fishery simulation model uses the most recent information available and attempts to estimate the changes in catch and bycatch anticipated to occur in the future. However, actual fisheries are not static but exist in a dynamic state which changes with weather, fish biomass, market conditions, management actions, and individual expectations among a host of factors. The model utilizes data which, to some extent, reflects the dynamics of the particular year in which it was collected, in this case 1993 and 1994. The regimes anticipated to be in place in the near future are then applied to that data. The results of the model reflect a static state, and are somewhat useful in providing an answer to "what if?". The model is unable to anticipate any other changes which might happen in the real world.

Appendix 2: Excerpts from the January 1995 Council Meeting: Development of the Alternatives

D-2(b) Crab Bycatch Issues

The Council received a review of recent actions to protect crab stocks and an overview of crab bycatch in the groundfish, crab and scallop fisheries.

Report of the Scientific and Statistical Committee

Because the impacts of multiple closures are not well evaluated at this time, and because Council harvest objectives may be precluded, the SSC believes that the cumulative effects of bycatch measures must be analyzed in a comprehensive manner, looking at costs and benefits of present and proposed fishery restrictions. As a means of initiating the development of a more comprehensive bycatch amendment, the SSC recommends that the Bering Sea Groundfish and Crab Plan Teams meet jointly to review available data and alternatives to define amendment objectives. The SSC believes that an industry working group, representing both crab and groundfish interests, would also be helpful in developing acceptable alternatives.

Report of the Advisory Panel

The following is a summary of extensive comments and recommendations from the Advisory Panel. The entire set of recommendations can be found in the AP Minutes, Appendix III to these minutes.

1. The AP recommends that the Council address the current problems resulting from low king and bairdi crab abundance in a comprehensive way; the AP endorses the SSC recommendations, particularly the recommendation that the crab and groundfish plan teams meet jointly. The AP requests that the joint plan teams, under the direction of a Council member, begin to develop a problem statement, objectives and a rebuilding plan for king and bairdi crab.

2. The AP recommends that the Council initiate analysis for a trawl closure with three options: 56ºN 56º10"N; 55º45"N. (More parameters for the analysis are found in the full AP Minutes.)

3. The AP recommends additional amendment alternatives for the analysis package developed by the State of Alaska (see AP Minutes).

4. The AP recommends that the Council draft a proposal to the Alaska Board of Fisheries repealing the 3-mile trawl closure in Bristol Bay. The AP believes that the loss of this area, which had few bycatch problems, may have exacerbated king crab bycatch in other areas of Bristol Bay.

COUNCIL DISCUSSION/ACTION

Wally Pereyra moved to adopt the following AP recommendations:

I. That the Council address the current problems resulting from low king and bairdi crab abundance in a comprehensive way.

Endorse the SSC recommendations, particularly the recommendation that the crab and groundfish plan teams begin meeting jointly, under the direction of a Council member, to develop a problem statement, objectives and finally a rebuilding plan for king and bairdi crab, with a status report at the April meeting.
Realizing that the Alaska Board of Fisheries and the State of Alaska are an integral part of crab management, the AP recommended that the State begin examining:
[Robin Samuelsen suggested that this should read ". . .State continue examining:" because in his opinion the State is already doing those things identified by the AP]:

- **a. multi-species retention,**
- **b. season changes,**
- **c. crab gear modifications and enforcement of current gear restrictions,**
- **d. changing harvest strategies, including harvest of females, size limits, etc., and**
- **e. improved data on all sources of mortality.**

Recognizing that ecological changes (i.e., oceanic conditions, habitat, predator/prey relationships) as well as fisheries have impacted crab stocks and that such ecological impacts are not well understood, it is imperative to the development of an effective rebuilding program that these changes be examined.

An evaluation of the effectiveness of past and present trawl closures in contributing to crab stock rebuilding should be undertaken.

Individual vessel accountability for bycatch is, as always, a key to the success of bycatch management.

~~**The AP recommends that the Council ask the Alaska Board of Fisheries to waive the April 10, 1995 proposal deadline, so that any proposals arising from Council activities between this meeting and the April meeting can be submitted.**~~

The motion was seconded by Bob Mace and used as a framework motion for revision and amendment before the final vote.

Regarding the joint meeting of the Crab and Groundfish Plan Teams, it was clarified that they should meet as soon as practicable, and that the joint meeting is for the purpose of this task, not an ongoing requirement that they meet jointly.

The last paragraph under Item I, regarding the Alaska Board of Fisheries proposal deadline, was deleted from the motion by friendly amendment.

II. Initiate analysis of the following options for a trawl closure:

56° 58ºN
56° 10"-58ºN
55° 45"-58ºN

[Ron Berg offered a friendly amendment to **include the longitudes of 162ºW and 164ºW** as they are in the current emergency rule. The amendment was accepted. Additionally, Mr. Berg pointed out that for the northern boundary, the emergency rule is currently 57ºN and he wished to amend the motion to **include up to 58ºN.** This was also accepted as a friendly amendment.]

Using the methodology of the BSAI bycatch simulation model originally developed by Terry Smith after it has been appropriately updated, the analysis should examine:

1. **Bycatch consequences:**
   - **a. impact on halibut**
   - **b. impact on opilio**
   - **c. impact on bairdi**

2. **Target species impacts:**
   - **a. CPUE**
   - **b. Catch composition of groundfish (retention)**

3. **Effort redistribution impacts on other fisheries**

4. **Seasonality of the closure**

5. **Application of the closure on a target fishery specific basis**

6. **Size and sex of red king crab**

7. **The analysis should also examine the effects of bycatch rates being calculated on overall catch versus retained, how the current method of calculating bycatch affects fishing techniques, strategies, restricts gear modification and achieving caps.**

~~**The AP believes a 2-year sunset should be analyzed.**~~
[Dave Benton recommended that the **sunset clause should be deleted** in light of earlier discussions on "sunset clauses" and timeframes for analysis and implementation. Mr. Pereyra accepted this as a friendly amendment.]

III. Crab bycatch amendment alternatives developed by the State of Alaska as a package for analysis should also include:

1. **analysis of a floating cap with no upward limit,**
2. **deleting all references to scallop caps,** and**

3. change variable caps as follows:

	Variable caps indexed between:
red king crab	**0.25 - 1.0%**
bairdi	**0.25 - 2.0%**
opilio	**.005 - .25%**

The AP believes a rigorous analysis of these options is critical.

Mr. Benton wished to clarify that the AP's recommendation includes analysis of the alternatives proposed by the State of Alaska, in addition to those listed above. Those items recommended by the State are attached to these Minutes as Appendix IV. With reference to item III.2. above, deletion of reference to scallop caps, the Council substituted the following:

****2. The analysis will consider two alternatives: (1) including scallop caps, or (2) excluding scallop caps.**

Robin Samuelsen moved to amend to the motion to close all waters east of 162ºW and north to 58ºN to bottom trawling in the Bering Sea, with the analysis to be prepared for Council review in December. The motion was seconded.

During discussion, Council members expressed concern that staff time is limited for new analyses. It was suggested that the joint plan teams, working with Council member Fluharty, could address this in the overall review of crab rebuilding alternatives. Mr. Samuelsen said that the committee could address it, but he still wished the Council to take up the closure in December.

The amendment carried, 10 to 1, with Pereyra voting against.
The main motion carried, as revised and amended, without objection.

Mr. Benton pointed out that the State will begin analysis of the alternatives suggested in items II and III of the AP motion because some of these issues cannot be delayed. Other, longer-term aspects of the motion, i.e., those in item I, will be more appropriately addressed by Dr. Fluharty's committee.

Appendix 3: History of Season Opening Dates for the BSAI Yellowfin Sole Fishery

Season opening changed to May 1

In 1991, the season opening date for the BSAI yellowfin sole and "other flatfish" trawl fisheries was delayed from January 1 to May 1. This was also the opening date for the arrowtooth and Greenland turbot trawl fisheries. The opening date for the rock sole fishery remained at January 1. The original purpose for delaying directed fishing for yellowfin sole and other flatfish until May 1 was to prevent the joint venture and domestic fisheries from taking a disproportionate share of their respective Zone 1 red king crab bycatch allowances before available amounts of yellowfin sole and other groundfish could be harvested.

This action was taken primarily to reduce the bycatch of crab. It was thought that fishermen would fish in Area 514 with a May 1 opening date. Bycatch in area 514 was much lower than in Zone 1 areas 511 and 516. For example, data indicated that red king crab and Tanner crab bycatch rates would be reduced by over 90%. Zone 1 bycatch rates of 4.069 red king crab and 1.703 Tanner crab would be reduced to 0.085 red king crab and 0.100 Tanner crab by fishing in area 514.

The May 1 date was also thought to be superior in terms of safer working conditions and lower operating costs. Spring and summer offer better weather and longer daylight than a winter opening. Additionally, fishermen found that catch rates of flatfish were higher in the second quarter.

Season opening changed to January 20

Beginning in 1994, the season opening date for the yellowfin sole trawl fishery was moved back to January 20 to account for changes in fisheries and management. Joint venture fisheries no longer operated, and domestic fisheries had developed new markets for the other flatfish complex (such as other flatfish markets). In addition, the yellowfin sole and rock sole/other flatfish fisheries were allocated separate PSC allowances which could be seasonally allocated.

Essentially, domestic fisheries had grown to the point where they no longer could harvest the TAC quota with a May 1 opening date. Fishermen simply needed more fishing time. For example, in 1991, only 47 percent of the other flatfish TAC was harvested; this figure dropped to 38% in 1992 and 32% in 1993.

An additional factor that contributed to this change was that vessels were switching back and forth between the GOA and BSAI to take advantage of the differential opening dates. It was felt that moving the opening date back to January would reduce the pressure on available halibut bycatch in the GOA, thus diminishing the likelihood of an early closure of GOA trawl fisheries.

Appendix 4: History of Groundfish Management Relative to BSAI Crab Stocks

1959 - The Bristol Bay Pot Sanctuary was established. This area remained closed to trawling until 1984, when implementation of Amendment 1 allowed domestic trawling within the area.

1981 - FMP implemented: Established trawl closure areas for foreign fisheries. Petrel Banks closed January 1-June 30. Territorial Sea (3 to 12 miles) closed January 1 - April 30.

1983 - Amendment 3: Established a bycatch reduction schedule of 25% over 5 years for king and Tanner crab bycatch in foreign fisheries.

1987 - Amendment 10: PSC zones and limits (Zone 1 = 135,000 red king crab and 80,000 Tanner crab; Zone 2 = 326,000 Tanner crab in Zone 2) established for yellowfin sole/other flatfish trawl fisheries. Crab Protection Area 512 closed to all trawling year-round.

1989 - Amendment 12a: PSC limits established at current levels (Zone 1 = 200,000 red king crab and 1,000,000 Tanner crab; Zone 2 = 3,000,000 Tanner crab in Zone 2) to include all trawl fisheries. Crab Protection Area 516 closed to all trawling from March 15-June 15.

1991 - Amendment 16: Authorized seasonal apportionment of PSC limits into allowances for specific trawl fisheries. Established Vessel Incentive Program (VIP), which was designed to reduce PSC bycatch rates in trawl fisheries. Also in 1991, the season opening date for the BSAI yellowfin sole and "other flatfish" trawl fisheries was delayed from January 1 to May 1 by regulatory amendment.

1992 - Amendment 19: Revised time/area (hotspot) authority to reduce PSC bycatch. Amendment also expanded VIP program to cover all trawl fisheries.

1995 - Amendment 21a: No trawling allowed in Pribilof Islands Habitat Conservation Area.

1995 - Emergency Rule: Prohibited non-pelagic trawling in Bristol Bay Red King Crab Savings Area from January 20 through April 19, 1995.

1995 - In September, Council adopted Amendment 37 with preferred alternative to prohibit non-pelagic trawling in Bristol Bay Red King Crab Savings Area from January 1 through March 31.

1996 - Inseason Management Action: Prohibited all trawling in Bristol Bay Red King Crab Savings Area from January 20 through March 31.

1996 - Inseason Management Action: Extended inseason action to prohibit all trawling in Bristol Bay Red King Crab Savings Area from March 31 - June 15.

Appendix 5: Status of Alaska King and Tanner Crab Stocks and Trawl Closure Areas

In January 1995, the Council's Advisory Panel requested that an evaluation of the effectiveness of past and present trawl closures in contributing to crab stock rebuilding be undertaken. This appendix provides information on the status of Alaska's king and Tanner crab stocks and the presence or absence of trawl closure areas.

King and Tanner crab stocks in Alaska are in poor shape; of the 28 stocks, all but 5 are classified as in a depressed condition (**Appendix Table 5.1**). About one-half of these stocks no longer support active fisheries. Those stocks that do support fisheries generally have much reduced landings compared to earlier years. Additionally, for stocks where trends are able to be estimated, all stocks except Norton Sound red king crab are considered stable or declining. Red king crab stocks in the Gulf of Alaska are particularly poor condition. For example, the 1995 population estimate in Kodiak is 27,000 red king crabs, or about 2% of the population observed in the early 1980's (Jackson 1996). Along the south side of the Alaska Peninsula, the red king crab stock has declined to the point where only 96 red king crabs were captured in 155 hauls during the 1994 trawl survey (all but 4 crab were taken in Cold Bay) (Urban 1996). Red king crab stocks in Cook Inlet and Prince William Sound are also at extremely low levels (A. Kimker, ADF&G, personal communication). Jackson (1996) concluded that red king crab stocks in the Gulf of Alaska will only rebound when oceanographic conditions become favorable for recruitment.

Most trawl closure areas were implemented after crab stocks have collapsed, and the potential benefits of these closures have not yet materialized. State waters have been closed to trawling in most areas. Trawling has been restricted or prohibited in the bays and inside waters of Southeast Alaska, Prince William Sound, and Cook Inlet as well as much of the coast out to 3 nautical miles. Over 20,000 square nautical miles of waters in the EEZ off Alaska have been closed to protect crab resources (**Appendix Figure 5.1**). Crab stocks in the major EEZ closure areas of Kodiak, Bristol Bay, and Pribilof Islands remain in depressed condition. These closure areas, and affect on crab rebuilding are discussed below.

Kodiak Island: Trawl closure areas were implemented around Kodiak Island in 1987 under Amendment 15 to the GOA Groundfish FMP. Three types of areas are closed to non-pelagic trawl gear (**Appendix Figure 5.2**). Type 1 areas have high concentrations of red king crab and are closed year-round to promote stock rebuilding. Type 2 areas have lower crab abundance and are closed seasonally from February 15 to June 15 to protect molting king crab. Type 3 areas close seasonally or year-round if female red king crab increase to threshold levels. The Type 1 and 2 areas encompass 80-90% of the female stock distribution. Since implementation of these closure areas, the king crab stock has further declined to historically low levels.

Bristol Bay: Trawl closure areas were first implemented in Bristol Bay in 1959. This trawl closure zone (termed the Bristol Bay Pot Sanctuary) was established mainly to prevent conflicts between mobile gear and concentrations of crab pots. The areas boundaries were modified several times, but large portions remained closed until 1984, when Amendment 1 allowed year-round domestic trawling within the Pot Sanctuary. The eastern portion of the Pot Sanctuary (Area 512) was again closed to trawling in 1987, and was further expanded in 1989. These trawl closures did not prevent stock collapses of red king crab which occurred in 1981 and 1994.

Pribilof Islands: The Pribilof Islands red king crab and blue king crab stocks have increased slightly since 1986. From 1987 to 1993, the fishery for king crab was closed. The apparent increase in king crab abundance since 1986 cannot be attributable to the Pribilof Islands Habitat Conservation Area, as this trawl closure area was not established until 1995.

Appendix 6: Board of Fisheries Actions on BSAI Crab Managment, March 1996

At their March 1996 meeting, the Alaska Board of Fisheries (BOF) made policy decisions that affect the conservation and management of king and Tanner crab stocks in the Bering Sea and Aleutian Islands area. A brief summary of these actions is provided below.

Rebuilding and Long-Term Harvest Strategy for Bristol Bay Red King Crab
The BOF adopted a new harvest strategy for Bristol Bay red king crab. The strategy chosen balances short-term economic gains from the fishery against risks to the long-term maintenance and productivity of the stock. In adopting the new harvest strategy, the Board considered the stocks ability to rebuild the stock to a productive level since its abundance is presently depressed. To evaluate the current harvest strategy against alternative strategies, ADF&G developed a new method to estimate the population abundance based on the best available information, and two models were constructed to simulate the population over time (Zheng et al. 1996). Performance of the current harvest strategy, a suite of long-term harvest strategies and a rebuilding strategy were evaluated relative to their effectiveness in meeting the constraints and achieving the benefits that serve as guidelines in the Board of Fisheries policy on king and Tanner crab resource management. Results of the modeling efforts indicate:

(1) the current threshold should be maintained at 8.4 million mature females which equates to an effective spawning biomass of 14.5 million pounds with the additional constraint that both number of mature female crabs and weight of effective spawners define threshold;
(2) the mature male harvest rate should be lowered from 20% to 10% when the population is above threshold and when effective spawning biomass is below 55 million pounds and to 15% when the population is above threshold and the effective spawning biomass is at or above 55 million pounds; and
(3) the maximum harvest rate on legal-sized male crabs should be lowered from 60% to 50%.

The BOF adopted these three points as the new policy for management of the Bristol Bay red king crab fishery. The threshold minimizes the risks of irreversible effects on reproductive potential. Reducing the mature male harvest rate to 10% at low stock sizes provides for fishing opportunity while promoting stock rebuilding. Once the stock .is rebuilt reducing the mature harvest rate to 15% and reducing the maximum legal harvest rate to 50% provides for relatively high yield, greater stability in yield, fewer fishery closures, and healthier stocks over the long-term.

Gear Restrictions for BSAI Crab Fisheries
The BOF adopted regulations to require escape rings in pots to reduce the capture and handling mortality of non-target crab. A minimum of 4 escape rings per pot will be required, each ring meeting a minimum diameter for specified BSAI fisheries. Minimum escape ring diameters are 5.5" for brown king crab fisheries, 5.0" for the bairdi fishery, and 3.75" for opilio fishery. In addition, only longline pots will be allowed in the Adak/Dutch Harbor brown king crab fishery.

Other Management Changes
The Board also made changes to the way fisheries are managed. Although many of these measures do not impact rebuilding efforts, they do affect fishermen as well as how fisheries are conducted. Changes were made in the registration areas (Adak and Dutch Harbor brown king crab area combined), seasons (Adak/Dutch brown king crab fishery to open September 1), tank inspection and delivery times, pot storage time and area (35 f around Pribilof Islands 14 days before and after snow crab fishery), as well as adjustments to the State observer program.

Appendix 7: Management of Red King Crab Fisheries and Crab Bycatch in Russia

Large stocks of red king crab are found in Russian waters, and these stocks have provided large yields since the 1920's. A summary of Russian red king crab stock status and management measures provides some insight for managers of other stocks and fisheries.

There are two major stocks of red king crab in the Okotsk Sea: the West Kamchatka and the Ayano-Shantarskiy stock. The West Kamchatka stock is the largest red king crab stock in the world (Rodin 1989), and has provided the bulk of landings from Russian waters. Data supplied in public testimony by Gordon Blue (F/V Zolotoi) indicated that landings from the West Kamchatka stock have undergone two major cycles since 1924, when data were first reported (**Appendix Figure 7.1**). Landings first peaked in 1929 during the fishing up period, when 32.4 million crabs were landed. High landings were maintained through the 1930's, then ~~dropped off with the~~ advent of WWII. Apparently, during the war, very little fishing effort was expended, and landings remained under 3 million animals until 1949. During the 1950's and 1960's, landings were sustained at over 20 million red king crab. Reduced landings, ranging from 7.0 to 14.0 million animals were taken during the 1970's and early 1980's. Average size of crab landed ranged from 1.2 to 2.0 kg (about 2.5-4.5 pounds per crab).

Our knowledge of current management strategies for red king crab fisheries in Russian waters is derived from information supplied by Russian scientists to Gordon Blue (F/V Zolotoi), and Rodin (1989). Overall harvest is limited by catch quotas. Management measures include restrictions on size, sex, and season. Only males over 13 cm (5.1 inches) carapace width are legally harvested, and seasons are established to avoid the molting period. Only pots are allowed in the directed crab fishery, although incidental catch (and possibly retention) of crab is apparently allowed in longline and trawl fisheries, as long as the crab catch doesn't exceed 2% of allowed finfish catch. Extensive trawl closure areas have been established in areas of adult and juvenile concentrations and migration routes for juveniles and spawners in the West Kamchatka region (Rodin 1989). **Appendix Figure 7.2** illustrates the distribution of West Kamchatka red king crab at various life stages and **Appendix Figure 7.3** shows the location of trawl closure areas in this region.

Appendix 9: Location of highest CPUE in the Yellowfin Sole Fishery

At the request of the Council's Advisory Panel (AP), the 1/2° latitude by 1° longitude blocks with the highest catch per unit effort (CPUE) in the yellowfin sole fishery by month and year were identified. NMFS observer data at the individual haul level were used to determine highest CPUE blocks. The average catch per tow within each block for a given month and year was calculated and the resulting highest blocks are indicated in **Appendix Figures 9.1 -9.7**.

Because blocks with a few hauls frequently were ranked as having the highest average catch per tow and may not be indicative of the fishing patterns of the yellowfin sole fleet, the highest CPUE blocks were chosen only if at least 10 hauls were included in calculating the average. If the average catch per tow of a given block was similar to that of the block with the highest catch per tow (e.g. within three tons), that block has been indicated in **Appendix Figures 9.1 - 9.7** as well. The blocks with the highest number of tows in each month are provided in **Appendix Figures 9.8 - 9.14** for comparison.

In 1987, the blocks with the highest effort (**Appendix Figure 9.8**) corresponded to the blocks with the highest CPUE (**Appendix Figure 9.1**), and were located in the vicinity of the Red King Crab Savings Area during the months of February through April, and located in the vicinity of Cape Constantine in May and June. The pattern was similar in 1988 for the first six months of the year, however, even though in the same general area, the blocks with the highest catch per tow (**Appendix Figure 9.2**) did not always correspond to the blocks with the highest number of tows (**Appendix Figure 9.9**). For instance, the block which includes Kulukak Bay (north of Cape Constantine) had the highest number of tows in May of 1988, but the highest CPUE blocks were in Togiak Bay and to the south of 58°. In the second half of 1988, the blocks with the highest average catch per tow and the highest number of tows were distributed along the shelf east and north of the Pribilof Islands, as was the case in 1989. Note that there was no fishing activity for Yellowfin sole in May and June of 1989, and thus the high number of tow blocks do not appear in northern Bristol Bay in 1989 (**Appendix Figures 9.3 and 9.10**).

In the 1991 domestic fishery for Yellowfin sole, there was correspondence between the blocks with the highest number of tows and highest average catch per tow in only one block in one month (**Appendix Figures 9.4 and 9.11**). In June, the block which includes Kulukak Bay had both the highest number of tows and was one of three blocks with the highest average catch per tow for June. The blocks with the highest catch per tow were to the south and east of the block with the highest number of tows in May. Otherwise there was little correspondence between the blocks with the highest number of tows and those with the highest average catch per tow, especially in July and August where the block with the highest number of tows was near Cape Constantine, but where the blocks with the highest average catch per tow were located between the Pribilof Islands and Nelson Island.

Similarly, the data from 1992 - 1994 indicated that the blocks with the greatest number of observed tows in May and June were in the vicinity of Kulukak Bay and Cape Constantine, but the blocks with the highest average catch per tow were to the north and east of the Pribilof Islands or in the vicinity of Nelson Island (**Appendix Figures 9.5-9.7 and 9.12-9.14**). Although the blocks with the highest catch per tow were located near Nelson Island in May and June of 1993 and 1994, this area can produce high halibut bycatch in some years, and may be less desirable to the fleet for that reason.

In many months, the blocks with the highest number of tows for yellowfin sole do not correspond to the blocks with the highest average catch per tow. This could be due to the gradual decline in CPUE in an area due to fishing or fish movement over time, and the decisions by the fleet of when to move based on CPUE. Fleet decisions are also influenced by costs of movement, expectations or reports of catch elsewhere, and bycatch concerns among a host of factors.

Appendix Figure 9.1. Yellowfin sole blocks with highest average catch per tow by month - 1987.

Appendix Figure 9.2. Yellowfin sole blocks with highest average catch per tow by month - 1988.

Appendix Figure 9.3. Yellowfin sole blocks with highest average catch per tow by month - 1989.

Appendix Figure 9.4. Yellowfin sole blocks with highest average catch per tow by month - 1991.

Appendix Figure 9.5. Yellowfin sole blocks with highest average catch per tow by month - 1992.

Appendix Figure 9.6. Yellowfin sole blocks with highest average catch per tow by month - 1993.

Appendix Figure 9.7. Yellowfin sole blocks with highest average catch per tow by month - 1994.

Appendix Figure 9.8. Yellowfin sole blocks with highest number of tows by month - 1987.

Appendix Figure 9.9. Yellowfin sole blocks with highest number of tows by month - 1988.

Appendix Figure 9.10 Yellowfin sole blocks with highest number of tows by month - 1989.

Appendix Figure 9.11 Yellowfin sole blocks with highest number of tows by month - 1991.

Appendix Figure 9.12 Yellowfin sole blocks with highest number of tows by month - 1992.

Appendix Figure 9.13 Yellowfin sole blocks with highest number of tows by month - 1993.

Appendix Figure 9.14 Yellowfin sole blocks with highest number of tows by month - 1994.

Appendix 10: Additional Plots of Fishing Effort and Bycatch in the Northern Bristol Bay Area.

List of Figures

Appendix 11: Additional Data and Model Results for Analysis of Management Measure 3

<u>List of Tables</u>