UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of the Chief Scientist
Washington, D.C. 20230

To All Interested Government Agencies and Public Groups:

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

TITLE: Environmental Assessment for Revised Amendments 16 and 21 to the Fishery Management Plans for the Groundfish Fishery of the Bering Sea and Aleutian Islands and Groundfish of the Gulf of Alaska

LOCATION: Exclusive Economic Zone of the Gulf of Alaska and the Bering Sea and Aleutian Islands

SUMMARY: These amendments authorize a vessel incentive program to reduce bycatch rates of prohibited species in the Alaskan groundfish trawl fisheries.

RESPONSIBLE OFFICIAL: William W. Fox, Jr.
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for Fisheries
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The environmental review process led us to conclude that this action will not have a significant impact on the environment. Therefore, an environmental impact statement was not prepared. A copy of the finding of no significant impact, including the environmental assessment, is enclosed for your information. Also, please send a copy of your comments to me in Room 6222, CS/ES, U.S. Department of Commerce, Washington, D.C. 20230.

Sincerely,

David Cottingham

David Cottingham
Director, Office of Ecology
and Environmental Conservation

ENVIRONMENTAL ASSESSMENT/REGULATORY IMPACT REVIEWS/

INITIAL REGULATORY FLEXIBILITY ANALYSIS (EA/RIR/IRFA)

FOR REVISED AMENDMENT 21

TO THE FISHERY MANAGEMENT PLAN FOR

GROUNDFISH OF THE GULF OF ALASKA

AND REVISED AMENDMENT 16

TO THE FISHERY MANAGEMENT PLAN FOR

GROUNDFISH OF THE BERING SEA/ALEUTIAN ISLANDS

Prepared by staff of the National Marine Fisheries Service

November 26, 1990

EA/RIR/IRFA FOR REVISIONS TO AMENDMENTS 16 AND 21 TO THE GROUNDFISH FISHERY MANAGEMENT PLANS FOR THE BERING SEA/ALEUTIAN ISLANDS AND THE GULF OF ALASKA

1.0 INTRODUCTION

Revisions to Amendments 21/16 are being considered because a critical component of the bycatch management measures contained in the amendments was disapproved by the Secretary.

1.1 Overview of the Need for Action and the Alternatives

Because trawl, hook and line, and pot fisheries use non-selective harvesting techniques, incidental catches (bycatch) including crab, halibut, and herring are taken in addition to targeted species. A conflict occurs when bycatch measurably impacts the resources available to another fishery. Bycatch management attempts to balance the effects of various fisheries on each other. This is particularly contentious because fishermen value the use of crab, halibut, or herring very differently, depending on the fishery they pursue.

Amendment 21/16 was approved by the Council in June 1990, except for the vessel incentive program, it was approved by the Secretary. The Secretary disapproved the measures that held each bottom trawl fishing operation individually accountable for its bycatch of crab and halibut in the BSAI and halibut in the GOA.

The Secretary determined that the vessel incentive program in Amendments 21/16 is inconsistent with the Magnuson Act and the Administrative Procedure Act. The proposed rule required vessels in each fishery to maintain a 4-week average bycatch rate less than two times the concurrent fleet average in each of the fisheries and for each of three bycatch species. Failure of a vessel to meet such bycatch standards would result in a suspension of the vessel from the Alaskan groundfish fishery for a period ranging from five days to six weeks.

Subsequent to Council approval of the incentive program, NMFS analysis of the 1990 observer database indicated that substantial revisions to the observer database occur after observers are debriefed and their data are analyzed and corrected. Corrected data for a fishery may not be available for up to six months after a fishing week. Because enforcement of the incentive program could only be based upon corrected data, inseason action against vessels that fail to meet acceptable bycatch standards cannot be taken.

The incentive program also failed to conform to requirements of other applicable law, including the Administrative Procedure Act. This Act requires that regulations be reasonable and effective. The observer data are insufficient to determine whether variability of bycatch rates permit the use of four-week fleet averages as a basis for legally acceptable standards.

Although NOAA cannot promulgate regulations to implement this incentive program, it believes an incentive program is a feasible and critical element of the 1991 bycatch management regime. Such a program is the topic of this amendment revision package.

The Council may submit a revised amendment accompanied by proposed regulations to the Secretary. After the Secretary receives the revised amendment, he must approve, partially disapprove, or disapprove the amendment within 60 days. Implementing regulations also must be promulgated within this time frame. A revised incentive program could be implemented in early February, 1991.

The two alternatives being considered are:

1. The status quo (no action).

2. A vessel incentive program that provides civil penalties as sanctions for vessels that exceed published bycatch rate standards for halibut in the BSAI and GOA Pacific cod trawl fisheries and the GOA rockfish trawl fishery or for red king crab in the BSAI rock sole and yellowfin sole/other flatfish fisheries. The halibut program will be extended to the BSAI rock sole and yellowfin sole/other flatfish fisheries if sufficient resources are available without detracting from the effectiveness of the program for other fisheries.

The alternatives are more fully described in Section 3.

2.0 NATURE AND SOURCE OF THE PROBLEM

The groundfish fishery results in incidental fishing mortality for crab, halibut, herring and other prohibited species. These resources can also be used as current or future target catch in the crab, halibut, or herring fisheries.

The Council has established prohibited species catch (PSC) limits to control the take of crab, halibut, and herring in the groundfish trawl fisheries in the BSAI and halibut in the GOA. In 1990, the attainment of these limits resulted in closures of trawl fisheries prior to taking their allowable catch. The failure to harvest fully the available resources represents a real cost to the trawl fishery. This cost was only partially offset by increased catch and benefits for the fixed gear groundfish fisheries.

For each PSC limit, the amount of groundfish that can be harvested is determined by the average bycatch rate of the fishery. It has been argued that a PSC limit provides fishermen an incentive to reduce bycatch rates. This argument fails to recognize that, although it is in the best interest of the fleet as a whole to decrease bycatch rates, it is in the best interest of individual operators to ignore bycatch and harvest groundfish as fast as possible prior to the closure of the fishery.

This results in inequities and unnecessarily high bycatch rates. The latter will cause a given PSC limit to impose a much higher cost on the fishery it closes. An operation that reduces its bycatch rate bears the costs of doing so generally by decreased catch or increased operating costs, but it does not receive benefits proportional to its success in reducing bycatch or to the cost of doing so. Operations that take no actions to control bycatch rates do not bear such costs but may receive a disproportionately large share of the benefit from the actions taken by others to reduce the fishery's average bycatch rate. The problems are that: (1) there are external costs and benefits that provide each operation with incentives to do what is counter to the best interests of the fishery as a whole and (2) the actions of a few operations can impose substantial costs on the rest of the fleet.

The vessel incentive program approved by the Council as part of Amendments 21/16 was intended to provide a partial solution to these problems by reducing the magnitude of the external benefits and costs. The replacement vessel incentive program discussed below is intended to do the same. This incentive program is similar to the program that was disapproved in that it is primarily intended to decrease the costs that the PSC limits will impose on the trawl fisheries in 1991 and secondarily intended to provide guidance for future development of a comprehensive, effective, equitable, and efficient long-term bycatch management regime.

3.0 DETAILED DESCRIPTIONS OF THE ALTERNATIVES

The preceding introduction to the revision of Amendments 21/16 presented an overview of the revised alternatives being considered. They are more fully described in this section.

3.1 Alternative 1: Status Quo

If Alternative 1 is chosen, the existing bycatch control management measures and those that have been or will be approved under Amendments 21/16 and 16a will be in place. These do not include a vessel incentive program. The measures that are expected to be in place include those outlined below.

1. Crab and halibut are prohibited species in the groundfish fisheries and cannot be retained.

2. The aggregate BSAI trawl fishery PSC limits for C. bairdi Tanner crab, red king crab, and Pacific halibut are as follows:

C. bairdi Tanner crab:	1,000,000 crabs in Zone 1 for Zone 1 closure 3,000,000 crabs in Zone 2 for Zone 2 closure
Red king crab:	200,000 crabs in Zone 1 for Zone 1 closure
Halibut:	4,400 mt catch in BSAI for Zones 1 and 2H closure 5,333 mt catch in BSAI for BSAI closure

   Figure 1.1 presents bycatch protection zones in relation to statistical areas. Zone 1 consists of statistical areas 511, 512, and 516, and Zone 2H is area 517.

3. Apportionments of PSC limits in the BSAI listed for the above species into bycatch allowances to DAP and JVP trawl fisheries, subject to review and revision by the Secretary of Commerce, after consultation with the Council, are authorized. For the 1991 fishing year, fishery categories are: DAP trawl fisheries for turbot, rock sole, yellowfin sole/other flatfish, and all others combined; and the JVP trawl flatfish fishery. The bycatch in each of these three flatfish fisheries counts against its PSC apportionments and when its apportionment is taken the fishery closes. The bycatch in all other trawl fisheries counts against the other fishery PSC apportionments; however, when one of its apportionments is taken, only the bottom trawl Pacific cod and pollock fisheries are closed.

4. In the GOA, the PSC limit for halibut can be set annually and apportioned by season and among the trawl, hook-and-line, and pot gear types.

5. Fishing gear restrictions in both the BSAI and GOA include a new definition of a pelagic trawl and requirements for biodegradable panels and halibut exclusion devises on groundfish pots.

6. For the BSAI, the Regional Director will be able to set a limit on the amount of the pollock TACs that can be taken in other than the mid-water pollock fisheries (16a).

7. For the BSAI, the Regional Director will have the authority to temporarily close limited areas in-season due to high bycatch rates (16a).

8. With the exception of the rock sole and arrowtooth flounder fisheries, the 1991 BSAI flatfish and Greenland turbot fisheries will not open until May 1.

3.2 Alternative 2: Revised Vessel Incentive Program

The following outlines the elements of a revised bycatch incentive program for implementation in 1991 which has been proposed to correct the deficiencies of the vessel incentive "penalty box" provisions proposed under Amendments 21/16 to the groundfish FMPs. Under the revised program, penalties would be imposed after observers have been fully debriefed and their data analyzed and corrected. In most cases, this would result in post-season action against vessels that have exhibited bycatch rates in excess of established bycatch rate standards.

If the Council adopts a revised bycatch incentive program, the program would be subject to public review and comment as part of the Secretarial review process.

I. Scope of 1991 incentive program.

   A. Option 1 (as recommended by the Bycatch Committee):

      The 1991 incentive program would encompass:

   (1) halibut bycatch in the BSAI and GOA Pacific cod trawl fisheries and the GOA "bottom rockfish" trawl fishery; and

   (2) red king crab bycatch in the BSAI flatfish fisheries.

   (3) All catcher/processor vessels and catcher vessels (including those that deliver unsorted codends to mothership processors) that participate in these fisheries and for which observer data are collected would be participants in the incentive program.

   B. Option 2. The incentive program will be expanded to include halibut bycatch in the BSAI flatfish fisheries if there are sufficient resources to do this without detracting from the program included under Option 1.

II. Fishery Definitions.

A. Each week a bottom trawl vessel's observed BSAI groundfish catch of the TAC species would be used to place it into one of five fisheries for that week. The first of the five rules that is met determines the fishery assignment of a vessel.

1. Greenland turbot fishery if Greenland turbot is at least 35% of its groundfish catch.

2. Pacific cod fishery if Pacific cod is at least 45% of its groundfish catch.

3. Rock sole fishery if rock sole is at least 40% of its groundfish catch.

4. Yellowfin sole/other flatfish fishery if yellowfin sole/other flatfish is at least 40% of its groundfish catch.

5. Other bottom trawl fishery if pollock is less than 95% of its groundfish catch.

The distinction between the rock sole and yellowfin sole/other flatfish fisheries would be used for monitoring the PSC limit apportionments between these fisheries. However, for the purposes of the vessel incentive program, they would both be part of the flatfish fishery. Similarly, the definition of the turbot fishery will be used to monitor the apportionments of PSC limits to the turbot fishery. Neither the turbot fishery nor the other bottom trawl fishery will be included in the vessel incentive program for the BSAI.

B. Each week a bottom trawl vessel's observed GOA groundfish catch of the TAC species excluding arrowtooth flounder will be used to place it into one of three fisheries for that week. The first of the three rules that is met determines the fishery assignment of a vessel.

1. Pacific cod fishery if Pacific cod is at least 45% of its groundfish catch.

2. Rockfish fishery if rockfish (slope rockfish, demersal shelf rockfish, and thornyhead rockfish,

in the aggregate) is at least 30% of its groundfish catch.

3. Other bottom trawl fishery if pollock is less than 95% of its groundfish catch.

The other bottom trawl fishery will not be included in the vessel incentive program for the GOA.

III. Bycatch Standards.

A. Red king crab and halibut bycatch performance standards for vessels in the monitored fisheries will be based on seasonal fixed rates. The red king crab bycatch rate standard will be for Zone 1 and compliance with the standards will be for flatfish fisheries in Zone 1. The halibut standards will be for the BSAI or GOA as a whole and compliance with the halibut standards will be for the BSAI or GOA as a whole. Prior to January 1 and July 1 of each year, bycatch rate standards will be published in the Federal Register that would be in effect for specified seasons within the six-month periods of January 1 - June 30 and July 1 through December 31, respectively. Such rates would remain in effect until revised by a subsequent notice in the Federal Register. Revisions to bycatch rate standards may be made as often as appropriate. Seasonal rates will be based on prior seasonal bycatch rates and other relevant criteria.

B. Separate halibut bycatch standards will be established for the BSAI Pacific cod and flatfish fisheries.

C. A single halibut bycatch standard will be established for the GOA Pacific cod and bottom rockfish fisheries that will be weighted in favor of the bottom rockfish fishery.

IV. Fishery Checkpoints and Penalties.

A. At the end of each fishing month, the average observed bycatch rate of red king crab and\or halibut for each vessel assigned to the BSAI flatfish fishery, the BSAI/GOA Pacific cod fisheries or the GOA bottom rockfish fishery during that month will be judged against the fixed seasonal standard established for those fisheries. If the vessel's average bycatch rate for a fishing month exceeded a seasonal standard, a separate violation could be considered for each week during the month that the standard was exceeded. If the Magnuson Act amendments as passed by the House and Senate are signed by the President, each violation will carry a maximum civil penalty of $100,000, so total civil penalties for a monthly period could total a maximum of $400,000. Possible sanctions in addition to the civil penalties include permit restrictions and vessel seizure.

B. Observer sampling procedures will be standardized, to the extent possible, to remove discretionary sampling procedures by observers. Standardized procedures will be used to determine vessel bycatch rates and fishery assignments.

C. General Counsel, Alaska Region, will have discretion to determine whether to prorate vessel penalties, taking into account a number of factors, including resource or economic damage to the groundfish trawl fishery, relevant participation in voluntary programs designed to reduce prohibited species bycatch, and culpability of the vessel operator/owner.

D. NMFS will institute an enforcement policy to expedite citation and penalty procedures for vessels with the most flagrant apparent violations (excessive bycatch rates) which are identified inseason. Once such a vessel is preliminarily identified through weekly observer reports, the vessel could be placed on a priority list for observer debriefing, citation, and GCAK legal proceedings.

V. Public Release of Vessel Bycatch Rates.

A. Under a proposed regulatory amendment to the observer plan, NMFS will have the authority to publicize observed bycatch rates of individual vessels. If such authority is approved, NMFS will have the option of posting weekly observed bycatch rates that could be used by vessel operators as guidance on whether or not changes in fishing practices are necessary to meet bycatch performance standards. At a minimum, NMFS will continue to release a vessel's observed bycatch rate to the vessel's operator or owner upon request. Whether or not NMFS exercises authority for public release of observed bycatch rates, inseason weekly rates available to the industry will continue to be based on unverified observer data and subject to revision as observers are debriefed and their data are analyzed and corrected.

4.0 Analysis of the Alternatives

4.1 Alternative 1: The Status Quo

The bycatch management regime that will be in place for the 1991 fishing year with Alternative 1 is more flexible than that which has been in effect during 1990. It is expected to make the PSC limits less costly to the groundfish trawl fishery by postponing the yellowfin sole/other flatfish and turbot fisheries in the BSAI, by providing more flexibility in apportioning the PSC limits among fisheries and seasons in the BSAI and GOA, and by providing the Regional Director with inseason authority to close BSAI fisheries or areas with exceptionally high bycatch rates. Had these measures been in effect in 1990, some of the closures that occurred could have been delayed or prevented and the cost imposed on the trawl fishery as a result of the PSC limits could have been substantially reduced.

These measures are expected to reduce the costs the PSC limits will impose on the trawl fishery in 1991; however, potential changes in the 1991 fishery may result in the limits imposing higher costs. These changes include an earlier and more intensive fishery cod fishery and new entrants into the cod fishery if the first period apportionment of the pollock TACs results in an early switch from the pollock fishery to the cod fishery. They could also include a more extensive bottom trawl fishery for pollock due to increases in pollock fillet prices relative to surimi prices. The potential increase in halibut bycatch early in the year as a result of increased bottom trawl effort for Pacific cod and pollock may be offset to some extent by relatively lower halibut bycatch rates early in the year before halibut move into more shallow waters and become more vulnerable to these fisheries.

Although it is not known whether the PSC limits will be more burdensome to the trawl fishery in 1991 than they were in 1990, it is clear that in the absence of a vessel incentive system that decreases both the external costs of high bycatch rates and the external benefits of taking actions to reduce bycatch rates, fishing operations will continue to have an incentive to have bycatch rates that are not in the best interest of the trawl fisheries. Based on projections from the bycatch model that was used to evaluate Amendment 16a, it is estimated that gross trawl fishery revenue and gross revenue net of variable cost will be, respectively, $130 million and $48 million less without the vessel incentive program assumed to be in place for the purposes of the analysis of Amendment 16a. Similar estimates are not available for the Gulf.

Despite the speculative nature of these estimates, the cost imposed on the trawl fishery by the PSC limits in the BSAI and GOA are expected to be substantially greater if there is no vessel incentive program. A significant part of the higher costs will be due to exceptionally high bycatch rates associated with a relatively small percentage of both the total number of fishing operations and total groundfish catch. For example, the observer data that are available for 67 fishing operations that participated in the 1990 BSAI Pacific cod fishery indicate that the 13 operations with the highest halibut bycatch rates for the year as a whole: (1) accounted for 38.8% of the observed halibut bycatch but only 16.7% of the observed catch in the cod fishery; and (2) increased the fishery's halibut bycatch rate from 1.1% to 1.5% of its groundfish catch. Similar comparisons are made for other fisheries in the following section in which the effects of the revised vessel incentive program are discussed.

4.2 Alternative 2: Revised Vessel Incentive Program

The proposed elements of the revised vessel incentive program are evaluated with respect to whether they are expected to result in a program that is effective and equitable, that can be implemented early in 1991 given the time and resources that are expected to be available, and that provides a cost effective solution to the problems caused by the externalities associated with reductions in bycatch rates.

4.2.1 Scope of the Program

The program will be limited to the BSAI cod and flatfish fisheries and the GOA cod and rockfish fisheries for several reasons. The time and resources necessary to develop and implement similar programs for additional fisheries are not expected to be available. Expanding the program beyond the level that can be affectively supported would result in a more costly but less effective program.

The program that was initially designed for the BSAI was extended to the GOA to prevent the possibility that fishing operations would practice in the Gulf or fish in the Gulf after not being able to meet the bycatch rate standards in the BSAI. Either would result in higher bycatch rates in the Gulf and corresponding decreases in the amount of groundfish that could be harvested in the Gulf prior to PSC limit induced closures.
The fisheries and bycatch species to be included are based on priorities established by industry representatives for the BSAI and GOA trawl fisheries. The closures of the BSAI cod and flatfish fisheries in 1990 posed the most significant costs to the trawl fishery as a result of the BSAI PSC limits. In the Gulf, the cod and rockfish fisheries are expected to account for much of the bottom trawl catch and halibut bycatch. Therefore, these fisheries are thought to be the most critical fisheries for an incentive program.

The vessel incentive program will increase some of the inequities of the current bycatch management regime. For vessels in BSAI cod and flatfish fisheries and the GOA cod and rockfish fisheries, it will increase the disparity in costs between vessels with 100%, 30%, and no observer coverage. It will also increase the inequity associated with the fact that, in the BSAI, all bycatch except that of the flatfish and turbot fisheries counts against the other bottom trawl PSC bycatch allowances, but that only the bottom trawl cod and pollock fisheries are closed when the apportionment is taken. This situation will be less equitable because even though the cod fishery will be subject to the costs of the vessel incentive program and is expected to have lower bycatch rates as a result of the program, it can still be shut down by high bycatch in other fisheries. The limited scope of the program will also introduce new inequities. Specifically, the fisheries that are not included in the program are not provided as much of an opportunity to reduce their bycatch rates.

The decision to include catcher vessels delivering codends to processing vessels in the incentive program and to exclude processing vessels was based on comments by industry representatives for the trawl fisheries. This will require observers on these processing vessels to identify the catcher vessels associated with each codend delivery. The observer program has indicated that this will require a change in observer reporting that can be accomplished at a relatively small cost. This will prevent a disparity in the accountability of bycatch by catcher vessels that deliver to at-sea and shore based processors.

The addition of halibut to the vessel incentive program for the BSAI flatfish fisheries (i.e, Option 2) will assist in delaying a halibut closure that will close Zones 1 and 2H. Such a closure could substantially reduce the benefits to the flatfish fishery gained by the vessel incentive program for red king crab in Zone 1. If halibut is not included in the program, fishing operations that cannot meet the red king crab bycatch rate standard in Zone 1 may elect to fish in Zone 2. This could result in higher halibut bycatch and an earlier closure of Zones 1 and 2H. It is not known if the time and resources necessary to add halibut to the BSAI flatfish fishery vessel incentive program will be available without detracting from the other programs.

4.2.2 Fishery Definitions

The proposed fishery definitions are based on at-sea observer data for the 1990 DAP fisheries in the BSAI and GOA. Catch and bycatch data by vessel and reporting week (i.e., vessel week observations) were sorted on the basis of the percentage of the groundfish catch of TAC species that was accounted for by the species for which a fishery definition was needed. This was done separately for flatfish, Greenland turbot, and Pacific cod in the BSAI and separately for Pacific cod and rockfish (i.e., slope rockfish, demersal shelf rockfish, and thornyhead rockfish, in the aggregate) in the GOA. For the Gulf, arrowtooth flounder catch was deducted from groundfish catch prior to calculating species composition by vessel week. The data that were sorted to define a fishery for each species or species group excluded vessel week observations for which the species did not account for at least 20% of the groundfish catch. The exception was that for Greenland turbot, only vessel week observations with Greenland turbot accounting for less than 5% of the catch were excluded. An explanation for each of the definitions in terms of the corresponding sorted data is presented below.

BSAI Cod Fishery The halibut bycatch rate was relatively stable for a cod fishery defined in terms of a minimum catch composition rule of 45% to 60% but fell for a rule of 40%. At or above a 45% rule, cod was the dominant species, below the 45% rule it was not. About 78.4% of the cod catch in the sorted data set was accounted for by vessel week observations in which cod was at least 45% of the groundfish catch.

BSAI Flatfish Fishery The halibut bycatch rate increased sharply when flatfish accounted for less than 40% of the catch and red king crab bycatch rates were subject to large fluctuations over a wide range of rules. At or above a 40% rule, flatfish was the dominant species, below the 40% rule it was not. About 89% of the flatfish catch in the sorted data set was accounted for by vessel week observations in which flatfish was at least 40% of the groundfish catch.

BSAI Greenland Turbot Fishery The halibut bycatch rate was relatively unstable for a Greenland turbot fishery defined in terms of a minimum catch composition rule; however, there was a pronounced decrease in the bycatch rate when Greenland turbot accounts for less than 35% of the catch. Above a 35% rule, Greenland turbot was the dominant species; at the 35% rule, it was the dominant species if arrowtooth flounder is ignored; and below the 35% rule, it was not the dominant species. Over 88% of the Greenland Turbot catch in the sorted data set was accounted for by vessel week observations in which Greenland turbot was at least 35% of the groundfish catch.

GOA Cod Fishery The halibut bycatch rate was unstable for a large range of rules. At or above a 45% rule, cod was the dominant species, below the 45% rule it was not. About 90% of the cod catch in the sorted data set was accounted for by vessel week observations in which cod was at least 45% of the groundfish catch.

GOA Rockfish Fishery The halibut bycatch rate was unstable for a large range of rules. At or above a 35% rule, rockfish was the dominant species, below the 35% rule it was not. Almost 97% of the rockfish catch in the sorted data set was accounted for by vessel week observations in which rockfish was at least 30% of the groundfish catch.

4.2.3 Bycatch Rate Standards

The use of seasonal bycatch rate standards is intended to allow for seasonality in the factors that affect bycatch rates. The seasonal rates will be established semi-annually to reduce the costs of establishing the rates. For purposes of this analysis, seasonal rates based on calendar quarters were examined, although additional data collected from the groundfish fisheries may indicate that seasonal rates based on other than calendar quarters may be more appropriate.

The red king crab standard will be based on historical bycatch rates in Zone 1 and compliance with the standard will be monitored only for Zone 1. There are two primary reasons for this. First, the red king crab PSC limit is only for Zone 1. Second, if a flatfish fishing operation's monthly catch and bycatch from the BSAI as a whole is used to determine its monthly bycatch rate, the operation may be provided with an incentive that will increase the probability of a halibut closure of Zones 1 and 2H without increasing the amount of flatfish that can be harvested in Zone 1. Specifically, a fishing operation could take part of its catch each month in Zone 2 in an attempt to reduce its BSAI king crab bycatch rate. However, to the extent that halibut bycatch rates are higher outside of Zone 1, the halibut PSC limit induced closure of Zones 1 and 2H will occur sooner. The incentive for a fishing operation to do this would of course be greater if halibut is not included in the incentive program for the flatfish fisheries.

Based on comments from industry representatives, the same set of bycatch rate standards were proposed to be used for the GOA Pacific cod and bottom trawl rockfish fisheries to reduce the cost of establishing, administering, and enforcing the standards. The bycatch rates in the rockfish fishery were not expected to be sufficiently greater than those in the cod fishery to prevent standards based on historical halibut bycatch rates for the rockfish fishery from being appropriate for the cod fishery. Initial analyses of 1990 data, however, indicates that bycatch rates in the rockfish and Pacific cod fisheries may differ significantly for some seasons. This difference may require that separate rates be established for the GOA rockfish and Pacific cod fisheries if the additional administrative and enforcement costs can be accommodated by NMFS.

4.2.3.1 Tentative bycatch rate standards

The fishery definitions presented above were used to place each 1990 vessel week observation into one of the vessel incentive program fisheries or into the other fishery category. The data for each of the incentive program fisheries were sorted by fishery, quarter, halibut (or red king crab) bycatch rate, and vessel month to calculate the distribution of catch and bycatch by quarter for each fishery. The sorted data were then used to select tentative bycatch rate standards and to estimate the effects of those standards on average bycatch rates.

For each fishery and quarter, for which there are sufficient data: (1) the average bycatch rate is stated; (2) the average bycatch rate for the vessel month observations with the lowest bycatch rates but that account for about 80% of the catch is given; (3) the tentative standard is set equal to the latter average bycatch rate; and (4) an estimate of the effect of that standard is presented. In some cases, the small number of observations prevented the identification and use of the bycatch rate associated with the 80% of the catch with the lowest bycatch rates. For the Gulf, halibut bycatch rates are presented as a percentage of groundfish catch excluding arrowtooth flounder.

The estimate of the effect of a standard on the average bycatch rate of a fishery is naturally quite speculative. The estimates presented below were generated by eliminating all vessel month observations with a bycatch rate greater than twice the standard. The implicit assumptions are that no operation will exceed the standard by more than 100% and that those that did in 1990 would have taken actions such that their bycatch performance would have duplicated that of operations that did not exceed the standard by more than 100%.

The 1990 bycatch rate, the tentative standard, and an estimate of the resulting bycatch rate by fishery and quarter are summarized in Table 1.

If it is determined that cod fishery halibut bycatch rates differ substantially between the Western Gulf and Central Gulf, it may be desirable to establish the Gulf cod fishery standard based on the bycatch rate data from the area with the higher rates. Due in part to the flexibility there is in establishing the halibut PSC limit for the GOA trawl fishery and to the distribution of bycatch rates among vessels, a more lenient standard for the GOA cod fishery may not result in a substantially earlier closure of the GOA bottom trawl fishery.

4.2.3.1.1 Halibut bycatch rates

<u>First quarter BSAI cod fishery</u> The data used for the cod fishery consists of all vessel week observations for which cod accounted for at least 45% of a vessel's weekly groundfish catch and for which Greenland turbot accounted for less than 35% of the catch. During the first quarter, the average halibut bycatch rate for the fishery as a whole was 1.35% (i.e., 1.35 mt of halibut per 100 mt of groundfish). However, about 80% of the catch was taken

in the set of vessel month observations that had an average bycatch rate of 0.89%. The other (higher bycatch rate) observations accounted for 20% of the groundfish catch but for almost 48% of the halibut bycatch. If the bycatch rate standard had been 0.89%, it is estimated that the average bycatch rate also would have been 0.89% and about 52% more groundfish catch could have been taken with the same amount of halibut bycatch.

Second quarter BSAI cod fishery During the second quarter, the average halibut bycatch rate for the fishery as a whole was 1.85%. However, about 80% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.05%. The other (higher bycatch rate) observations accounted for 20% of the groundfish catch but for 54% of the halibut bycatch. If the bycatch rate standard had been 1.05%, it is estimated that the average bycatch rate would have been 0.96% and about 93% more groundfish catch could have been taken with the same amount of halibut bycatch.

Third and fourth quarters BSAI cod fishery Due to the PSC limit induced closures, there is not sufficient data from the 1990 DAP fishery to establish standard rates or estimate the effects of such standards. Both will be done, to the extent possible, using data from the 1986-89 joint venture fisheries.

First quarter BSAI flatfish fishery The data used for the flatfish fishery consists of all vessel week observations for which flatfish accounted for at least 40% of a vessel's weekly groundfish catch and for which Greenland turbot accounted for less than 35% of the catch and cod accounted for less than 45% of the catch. During the first quarter, the average halibut bycatch rate for the fishery as a whole was 1.31% (i.e., 1.31 mt of halibut per 100 mt of groundfish). However, about 80% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.94%. The other (higher bycatch rate) observations accounted for 20% of the groundfish catch but for almost 42% of the halibut bycatch. If the bycatch rate standard had been 0.94%, it is estimated that the average bycatch rate would have been 0.92% and about 42% more groundfish catch could have been taken with the same amount of halibut bycatch.

Second quarter BSAI flatfish fishery Due to the PSC limit induced closures, there is not sufficient data from the 1990 DAP fishery to establish standard rates or estimate the effects of such standards. Both will be done, to the extent possible, using data from the 1986-89 joint venture fisheries.

Third quarter BSAI flatfish fishery During the third quarter, the average halibut bycatch rate for the fishery as a whole was 0.17%. However, about 85% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.08%. The other (higher bycatch rate) observations accounted for 15% of the groundfish catch but for 59% of the halibut bycatch. If the bycatch rate standard had been 0.08%, it is estimated that the average bycatch rate also would have been 0.08% and about 125% more groundfish catch could have been taken with the same amount of halibut bycatch.

The average rate that was achieved during the third quarter was primarily the effect of a voluntary industry program to reduce halibut bycatch rates. Further reductions or even the maintenance of this low rate may be difficult. Therefore, the tentative standard is set at 0.17%.

Fourth quarter BSAI flatfish fishery During the first part of the fourth quarter, the average halibut bycatch rate for the fishery as a whole was 0.19%. However, about 77% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.11%. The other (higher bycatch rate) observations accounted for 23% of the groundfish catch but for 54% of the halibut bycatch. If the bycatch rate standard had been 0.11%, it is estimated that the average bycatch rate also would have been 0.11% and about 73% more groundfish catch could have been taken with the same amount of halibut bycatch.

The average rate that was achieved during the first part of the fourth quarter was primarily the effect of a voluntary industry program to reduce halibut bycatch rates. Further reductions or even the maintenance of this low rate may be difficult. Therefore, the tentative standard is set at 0.19%.

First quarter GOA rockfish fishery The data used for the rockfish fishery consists of all vessel week observations for which rockfish accounted for at least 30% of a vessel's weekly groundfish catch excluding arrowtooth flounder and for which Pacific cod accounted for less than 45% of the catch. During the first quarter, the average halibut bycatch rate for the fishery as a whole was 2.91% (i.e., 2.91 mt of halibut per 100 mt of groundfish). However, about 64% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.17%. The other (higher bycatch rate) observations accounted for 36% of the groundfish catch but for 74% of the halibut bycatch. If the bycatch rate standard had been 1.17%, it is estimated that the average bycatch rate would have been 1.12% and about 160% more groundfish catch could have been taken with the same amount of halibut bycatch.

Second quarter GOA rockfish fishery During the second quarter, the average halibut bycatch rate for the fishery as a whole was 3.31%. However, about 81% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.89%. The other (higher bycatch rate) observations accounted for 19% of the groundfish catch but for 54% of the halibut bycatch. If the bycatch rate standard had been 1.89%, it is estimated that the average bycatch rate would have been 1.65% and about 100% more groundfish catch could have been taken with the same amount of halibut bycatch.

<u>Third quarter GOA rockfish fishery</u> During the third quarter, the average halibut bycatch rate for the fishery as a whole was 1.96%. However, about 81% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.94%. The other (higher bycatch rate) observations accounted for 19% of the groundfish catch but for 64% of the halibut bycatch. If the bycatch rate standard had been 0.94%, it is estimated that the average bycatch rate would have been 0.83% and about 136% more groundfish catch could have been taken with the same amount of halibut bycatch.

<u>Fourth quarter GOA rockfish fishery</u> During the first part of the fourth quarter, the average halibut bycatch rate for the fishery as a whole was 8.49%. About 89% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.25%. The other (higher bycatch rate) observations accounted for 11% of the groundfish catch but for 97% of the halibut bycatch. If the bycatch rate standard had been 0.25%, it is estimated that the average bycatch rate would have been 0.01 and a huge amount of groundfish could have been taken with the same amount of halibut bycatch.

<u>First quarter GOA cod fishery</u> The data used for the cod fishery consists of all vessel week observations for which cod accounted for at least 45% of a vessel's weekly groundfish catch excluding arrowtooth flounder. During the first quarter, the average halibut bycatch rate for the fishery as a whole was 3.31% (i.e., 3.31 mt of halibut per 100 mt of groundfish). However, about 80% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 0.52%. The other (higher bycatch rate) observations accounted for 20% of the groundfish catch but for 87% of the halibut bycatch. If the bycatch rate standard had been 0.52%, it is estimated that the average bycatch rate would have been 0.33% and about 900% more groundfish catch could have been taken with the same amount of halibut bycatch.

If the proposed first quarter rockfish standard of 1.17% had been used for the cod fishery in 1990, it is estimated that the average bycatch rate in the cod fishery would have been 0.62% and about 434% more groundfish could have been taken with the same amount of halibut bycatch.

<u>Second quarter GOA cod fishery</u> During the second quarter the average halibut bycatch rate for the fishery as a whole was 3.06%. However, about 81% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.18%. The other (higher bycatch rate) observations accounted for 19% of the groundfish catch but for 69% of the halibut

bycatch. If the bycatch rate standard had been 1.18%, it is estimated that the average bycatch rate would have been 0.46% and about 565% more groundfish catch could have been taken with the same amount of halibut bycatch.

If the proposed second quarter rockfish standard of 1.89% had been used for the cod fishery in 1990, it is estimated that the average bycatch rate in the cod fishery would have been 0.99% and about 209% more groundfish could have been taken with the same amount of halibut bycatch.

Third quarter GOA cod fishery During the third quarter the average halibut bycatch rate for the fishery as a whole was 3.29%. However, about 81% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.04%. The other (higher bycatch rate) observations accounted for 19% of the groundfish catch but for 74% of the halibut bycatch. If the bycatch rate standard had been 1.04%, it is estimated that the average bycatch rate also would have been 0.42% and about 683% more groundfish catch could have been taken with the same amount of halibut bycatch.

If the proposed third quarter rockfish standard of 0.94% had been used for the cod fishery in 1990, it is estimated that the average bycatch rate in the cod fishery would have been 0.29%, and groundfish catch could have increased by a factor of 10 without increasing the amount of halibut that was taken.

Fourth quarter GOA cod fishery During the first part of the fourth quarter, the average halibut bycatch rate for the fishery as a whole was 5.15%. However, about 87% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.24%. The other (higher bycatch rate) observations accounted for 13% of the groundfish catch but for 79% of the halibut bycatch. If the bycatch rate standard had been 1.24%, it is estimated that the average bycatch rate would have been 0.48% and groundfish catch could have increased by a factor of almost 10 without increasing the amount of halibut that was taken.

If the proposed fourth quarter rockfish standard of 0.25% had been used for the cod fishery in 1990, it is estimated that the average bycatch rate in the cod fishery would have been 0.17%, and groundfish catch could have increased by much more than a factor of 10 without increasing the amount of halibut that was taken.

4.2.3.1.2 Zone 1 red king crab bycatch rates

First quarter BSAI flatfish fishery The data used for the flatfish fishery consists of all vessel week observations for which flatfish accounted for at least 40% of a vessel's weekly groundfish catch and for which Greenland turbot accounted for less than 35% of the catch and cod accounted for less than 45% of the catch. During the first quarter, the average red king crab bycatch rate for the fishery as a whole was 2.88 (i.e., 2.88 red king crab per mt of groundfish). However, 78% of the catch was taken in the set of vessel month observations that had an average bycatch rate of 1.70. The other (higher bycatch rate) observations accounted for 22% of the groundfish catch but for 54% of the red king crab bycatch. If the bycatch rate standard had been 1.70, it is estimated that the average bycatch rate would have been 0.56 and over 400% more groundfish catch could have been taken with the same amount of red king crab bycatch.

Second through fourth quarters BSAI flatfish fishery Due to the PSC limit induced closures, there is not sufficient data from the 1990 DAP fishery to establish standard rates or estimate the effects of such standards. Both will be done, to the extent possible, using data from the 1986-89 joint venture fisheries.

4.2.4 Fishery Check Points and Penalties

Monthly check points will be used to provide a balance between the benefits and costs of periods of various lengths. Within a month, a fishing operation would have an opportunity either to bank catch with low bycatch rates against the possibility of having high bycatch rates for a short period or to make adjustments if it initially had high bycatch rates. Weekly check points would not provide such opportunities and in fact may provide little opportunity for corrective actions by a fishing operations due in part to the time delay that can occur in providing the fishing operation with observer program estimates of bycatch rates. The objective of the program is to reduce overall bycatch rates by having each fishing operation take corrective actions when its bycatch rates are too high. The objective is not to assure that high bycatch rates never occur for short periods of time.

A longer period between check points would provide a greater opportunity for fishing operations to make the necessary adjustments. However, it would both decrease the perceived urgency of making the appropriate corrections and decrease the potential timeliness of enforcement action against a vessel which has excessive bycatch. The effectiveness of the program is dependent on the potential of a quick and certain response when a fishing operation is imposing large costs on the fishery as a whole.

The range of penalties is sufficiently broad that the penalty for taking excessive bycatch can be comparable to the costs that the excessive bycatch imposes on a specific trawl fishery. If this is done, the penalties will eliminate the externalities that provide fishing operations an incentive to have bycatch rates that are too high from the perspective of a fishery as a whole. To the extent that this is done, the cost that a specific PSC limit apportionment imposes on a trawl fishery will tend to be minimized.

To do this, the normal vessel penalties could be based on three factors: (1) the extent to which a vessel exceeds a standard bycatch rate during a month; (2) the vessel's total catch of allocated groundfish species for the month; and (3) an estimate of the value of the foregone groundfish catch per unit of excessive bycatch. The estimate of the vessel's total groundfish catch would be based on product weights and discards reported weekly by a catcher/processor or on fish ticket data including discards for catcher vessels. The value of the foregone groundfish catch would be based on the groundfish catch per unit of bycatch at the bycatch rate standard. For example, if the halibut bycatch standard is 1%, if the vessel has a bycatch rate of 1.5%, if the vessel's groundfish catch is 1,000 mt, and if the net value of groundfish catch is $400/mt, the normal penalty would be calculated as follows:

estimated bycatch = 15 mt of halibut (0.015 x 1,000 mt)

acceptable bycatch = 10 mt of halibut (0.01 x 1,000 mt)

excessive bycatch = 5 mt of halibut (15 mt - 10 mt)

foregone value/mt of excess bycatch = $40,000 ($400/mt of groundfish x 100 mt of groundfish/mt of halibut bycatch)

penalty = $200,000 (5 mt of halibut x $40,000/mt of halibut).

In this example, the penalty of $200,000 would be within the range of permissible penalties if the vessel had exceeded the halibut bycatch rate standard in at least two weeks during the month. If the civil penalties were not adequate to cover the costs imposed on the fishery, additional sanctions could be used. These would include permit restrictions or vessel seizure. The range of sanctions is expected to be sufficiently broad that they could be used to eliminate the externalities.

By holding a fishing operation accountable for the cost its excess bycatch imposes on a fishery, a fishing operation with a high bycatch rate before the end of a month and with little expectation of being able to meet the standard for the month, would have an incentive to voluntarily cease fishing. If instead a flat rate fine for exceeding a standard is used, the same fishing operation would have an incentive to continue to fish that month and perhaps with an even higher bycatch rate.

Penalties based on the amount of excess bycatch, as opposed to those based only on whether or not a bycatch rate standard was exceeded, will not only tend to produce a more efficient solution, they will also tend to produce a more equitable one. It will be more equitable in three ways. First, The disparity in treatment of operations just under and just over the standard is substantially reduced. Second, penalties are reduced in direct proportion to the success of an operation in reducing its bycatch. Finally, the operations that impose the greatest costs on a trawl fishery will have the largest penalties.

In implementing an effective vessel incentive program, the industry has two important advantages compared to the Council and NMFS. The regulatory and budgetary constraints are less severe for industry. However, these advantages are offset by the lack of enforcement authority by industry. In recognition of the fact that a successful industry program can assist in both decreasing the cost that PSC limits impose on the trawl fisheries and decreasing the agency costs associated with bycatch management, the Council, NMFS, and GCAK will encourage and support industry programs to reduce bycatch rates. This will be done by providing bycatch rate information for such programs, to the extent possible given the resources that are available. GCAK could also consider, among other factors, any relevant participation in such programs when recommending penalties in response to a violation of seasonal bycatch rate standards. This level of support for voluntary industry programs could make them more attractive to fishing operations. There is not expected to be sufficient time or resources to develop and implement a vessel incentive program that can support more fully the voluntary programs in 1991.

The effectiveness of the program will also be increased by instituting an enforcement policy to expedite citation and penalty procedures for vessels with the most flagrant apparent violations (those that have imposed the greatest cost on a trawl fishery) which are identified inseason. Once such a vessel was preliminarily identified through weekly observer reports, the vessel could be placed on a priority list for observer debriefing, citation, and GCAK legal proceedings. This will increase the expectation by fishing operations that they will indeed be held accountable for the costs they impose on a trawl fishery.

The ability of individual observers to accurately report catch and bycatch is critical to the success of any vessel incentive program. Any such program will place additional burdens on the observer and provide an increased incentive for a fishing operations to have the observers' estimates understate the actual bycatch rates. These problems and the need to protect the ability of the observers to collect accurate data for a variety of purposes other than bycatch management are recognized and are being considered by the Observer Program.

Although these problems cannot be eliminated, they can be reduced. One method of doing this is to distance an observer from the action that will be taken against a vessel which exceeds a bycatch rate standard. This will be accomplished to some degree by both the use of monthly check points, as opposed to more frequent check points, and the use of delayed civil penalties, as opposed to the immediate sanctions envisioned in the initial vessel incentive program that was disapproved.

5.0 BIOLOGICAL AND PHYSICAL IMPACTS

The expected differential effects of the two alternatives on bycatch, groundfish catch, marine mammals and birds, and the physical environment are discussed below.

5.1 Bycatch

Compared to Alternative 1 (i.e., the status quo), Alternative 2 will tend to decrease bycatch. However, its primary effect is expected to be reduced bycatch rates that will permit more groundfish to be taken by the trawl fisheries before the PSC limits are reached. The reduction in bycatch could occur for one of two reasons. First, the bycatch in the trawl fisheries is constrained by the PSC limits under either alternative; however, with Alternative 1, groundfish catch and bycatch will be greater in the fixed gear fisheries than with Alternative 2. Second, Alternative 2 may reduce bycatch rates sufficiently that groundfish TACs are reached and fisheries are closed before the PSC limits are fully utilized.

The vessel incentive program is expected to increase the differences in bycatch rates between observed and unobserved fishing operations. This will make it more difficult to estimate the bycatch of unobserved operations and, therefore, total bycatch. This will be more of a problem in the GOA than in the BSAI because a much larger percentage of total groundfish catch will be accounted for by vessels in the length categories that have either no observer coverage or only 30% coverage. To date, approximately 54.7 percent of the bottom trawl catch in the BSAI has been observed compared to about 39.6 percent in the GOA. The differences in bycatch rates could certainly be great enough that it would be inappropriate to use unadjusted observed bycatch rates to estimate total bycatch.

The difference in bycatch rates will increase the difficulty and cost of estimating total bycatch. It will not necessarily increase the probability that actual bycatch will be underestimated, that the PSC limits will be exceeded, or that bycatch will increase.

5.2 Groundfish Catch

Compared to Alternative 1, Alternative 2 is expected to result in increased groundfish catch in the trawl fishery. The flatfish TACs are expected to be more fully utilized with Alternative 2. The Pacific cod TAC will also be more fully utilized with Alternative 2 unless the fixed gear fisheries would increase their cod catch under Alternative 1 enough to fully offset the lower trawl cod catch that would occur with Alternative 1. With either alternative, groundfish catch would be limited by existing TACs; therefore, neither alternative is expected to adversely affect the biological productivity of the groundfish resources in the BSAI or GAO.

5.3 Marine Mammals and Birds

The difference between the alternatives in terms of their effects on marine mammals and sea birds is not expected to be measurable.

5.4 Physical Environment

The increased bottom trawl effort that is expected to occur with Alternative 2 is within the levels of effort that have occurred in recent years and is not expected to affect the physical environment in a way that will have a measurable effect on the biological productivity of the BSAI or GOA ecosystem.

6.0 SOCIOECONOMIC IMPACTS

6.1 Reporting Costs

Existing reporting practices by industry would not need to be augmented to implement Alternative 2.

6.2 Administrative, Enforcement, and Information Costs

Alternative 2 will result in increased agency costs of up to $400,000. Violation of a bycatch rate standard implemented under Alternative 2 would be prosecuted under the Magnuson Act and other applicable law. The Magnuson Act describes prohibited acts, civil penalties, criminal offenses, and civil forfeitures in sections 307-310 (16 USC 1857-1860). A specific schedule of penalties for violation of bycatch rates standards would be developed by NOAA, General Counsel in consultation with NMFS. The penalty schedule would be designed in such a manner that a economic incentive would exist to comply with the bycatch rate standards established under Alternative 2.

6.2.1 NMFS, Office of Enforcement.

Enforcement of bycatch rate standards would occur after observers have been debriefed and their data checked and corrected. Once a vessel's bycatch rate has been preliminarily determined to be in violation of a bycatch rate standard, additional work would be necessary to develop a case history to support prosecution of the vessel's operator/owner. The work load necessary to prosecute 10 to 15 cases per year would require an additional full time enforcement agent at the GS-11 level ($43,000). Due to the remote nature of Alaska fishing communities, travel of enforcement agents to obtain initial interviews of observers, crew, vessel operators/owners, and others necessary for case documentation is estimated at about $1,000 per case. Expenses for observer travel necessary for additional case documentation is estimated at another $1,000 per case. Given a case load of 10 to 15 violations per year, therefore, travel costs necessary to develop supporting evidence could reach $30,000 per year. This value would increase to the extent that NMFS would incur the salary costs of observers during the period they are being interviewed and away from their contracted duties as an observer.

6.2.2 General Counsel, Alaska Region (GCAK).

Under Alternative 2, additional legal work involving prosecution of violations of bycatch rate standards would require one additional staff attorney for GCAK. Assuming the staff attorney would be hired at the GS-13 level, salary and benefits for additional staff are estimated at about $61,000.

6.2.3 Administrative Costs

Under Alternative 2, up to 120 vessels could receive additional monitoring for halibut and/or red king crab bycatch rates. This estimate is based on the number of vessels that participated in the 1990 Pacific cod and flatfish fisheries in the BSAI and the Pacific cod and bottom rockfish fisheries in the GOA. This level of monitoring would require an additional part-time computer systems analyst/programmer (.5 FTE at the GS-13 level) and up to two additional staff for processing of observer reports, verifying information, key punching data, and responding to industry requests for updated information on vessel and fleet bycatch rates. Given that different fisheries are prosecuted at different times of the year, staff needs may be irregularly spaced throughout the year. A portion of the additional positions, therefore, could be filled by short-term reassignments of personnel from other programs or agencies. Full funding of 2.5 additional personnel would cost about $94,000 annually.

6.2.4 Enhancement of the NMFS observer program

The bycatch reduction program proposed under Alternative 2 is dependent on verified observer data. As such, additional personnel would need to be hired to conduct observer debriefings and other verification of observer data. The augmented program would require 2 to 3 persons to debrief observers in Dutch Harbor, 1 to 2 persons in Kodiak, and 1 person that would cover Southeast Alaska. ADF&G personnel may help out with some of the debriefing process, but NMFS will need to hire 2 to 3 additional persons for timely debriefing of observers and provide funds for appropriate office space at remote sites. The estimated costs of the enhancements of the observer program is $150,000.

6.3 Distribution of Costs and Benefits

Table 1 provides estimates of the reductions in bycatch rates that would result from the implementation of the vessel incentive program of Alternative 2. The estimated reductions in bycatch rates would allow substantial increases in groundfish catch in the trawl fisheries. The resulting increase in first wholesale value of the associated groundfish products could exceed $100 million and the increase in wholesale value net of variable costs could approach $50 million. These estimates are based on the bycatch model that was used to evaluate Amendment 16a and exclude the potential benefits in the GOA.

The benefits to the trawl fishery from increased cod catch will be offset to some extent by decreased cod catch in the fixed gear fisheries and increased competition in cod markets. The benefits to the trawl fishery from increased flatfish catch are not expected to have similar offsets for the fixed gear fishery.

Alternative 2 will impose costs on the trawl fishery. They include the cost of the adjustments necessary to keep bycatch rates below the standards, paying the penalties when such adjustments are not made, or voluntarily not fishing. Having these choices usually will be preferable to not being able to fish because a PSC limit has been reached.

With the exception of the increased agency costs, the differences in the distribution of benefits and cost will be focussed on those directly involved in the groundfish fisheries. The alternatives are not expected to have measurably different effects on consumers.

The net benefits to those who are directly involved in the groundfish fisheries are expected to substantially exceed the agency costs associated with Alternative 2. Alternative 2 will decrease the costs that the PSC limits will impose on the trawl fishery and it will decrease some of the inequities associated with the distribution of those costs among fishing operations. It does this through the use of civil penalties that will reduce the externalities associate with decreasing bycatch rates. This is an administratively cumbersome method of reducing the externalities. However, a more effective method is not available in a timely manner. Therefore, Alternative 2 is expected to provide a cost effective solution for 1991 and to provide information that can be used in the development of a more comprehensive, effective, equitable, and efficient long-term bycatch management regime.

IMPACT OF THE AMENDMENTS RELATIVE TO THE REGULATORY FLEXIBILITY ACT

The Regulatory Flexibility Act (RFA) requires that impacts of regulatory measures imposed on small entities (i.e., small business, small organizations, and small governmental jurisdictions with limited resources) be examined to determine whether a substantial number of such small entities will be significantly impacted by the measures. Fishing vessels are considered to be small business. A total of 1,500 vessels may fish for groundfish off Alaska in 1991, based on the anticipated number of Federal groundfish permits that will be issued for the 1991 fishing year. While these numbers of vessels are considered substantial, regulatory measures considered under Alternative 2 (the vessel incentive program) would only affect a small proportion of the fleet (150 - 200 trawl vessels).

FINDINGS OF NO SIGNIFICANT IMPACT

For the reasons discussed above, implementation of neither Alternative 1 nor 2 would significantly affect the quality of the human environment, and the preparation of an environmental impact statement on the final action is not required by Section 102(2)(c) of the National Environmental Policy Act or its implementing regulations.

Michael F. Tillman — 4/24/91

Assistant Administrator for Fisheries — Date

Table 1--1990 bycatch rates, the tentative standards, and estimates of the resulting average bycatch rates by fishery and quarter.

Halibut bycatch as a percentage of groundfish catch

Fishery and quarter	1990 bycatch rate	bycatch standard	resulting bycatch rate
BSAI Pacific cod			
Qt 1	1.35	0.89	0.89
Qt 2	1.85	1.05	0.96
Qt 3		no fishery in 1990	
Qt 4		no fishery in 1990	
BSAI flatfish			
Qt 1	1.31	0.94	0.92
Qt 2		no fishery in 1990	
Qt 3	0.17	0.17	0.17
Qt 4	0.19	0.19	0.19
GOA rockfish			
Qt 1	2.91	1.17	1.12
Qt 2	3.31	1.89	1.65
Qt 3	1.96	0.94	0.83
Qt 4	8.49	0.25	0.01
GOA Pacific cod			
(with standard based on cod fishery bycatch rates)			
Qt 1	3.31	0.52	0.33
Qt 2	3.06	1.18	0.46
Qt 3	3.29	1.04	0.42
Qt 4	5.15	1.24	0.48
(with standard based on rockfish fishery bycatch rates)			
Qt 1	3.31	1.17	0.62
Qt 2	3.06	1.89	0.99
Qt 3	3.29	0.94	0.29
Qt 4	5.15	0.25	0.17

Table 1--(continued)

Zone 1 red king crab bycatch rates
(crab/mt of groundfish)

Fishery and quarter	1990 bycatch rate	bycatch standard	resulting bycatch rate
BSAI flatfish			
Qt 1	2.88	1.70	0.56
Qt 2-4	no fishery in Zone 1 in 1990		

Note the following:

1. The estimates of the resulting average bycatch rates were generated by eliminating vessel month observations which exceeded a standard by more than 100%.

2. For the BSAI, bycatch rates are calculated using the sum of the catch of the major groundfish species.

3. For the GOA, bycatch rates are calculated using the sum of the catch of all groundfish species excluding non-allocated species.

4. Observer Program data from the 1986-89 joint venture fisheries will be used, to the extent possible, to estimate bycatch rates, establish standards, and estimate the effects of those standards on average bycatch rates for the fisheries and quarters for which there was no fishing in 1990.

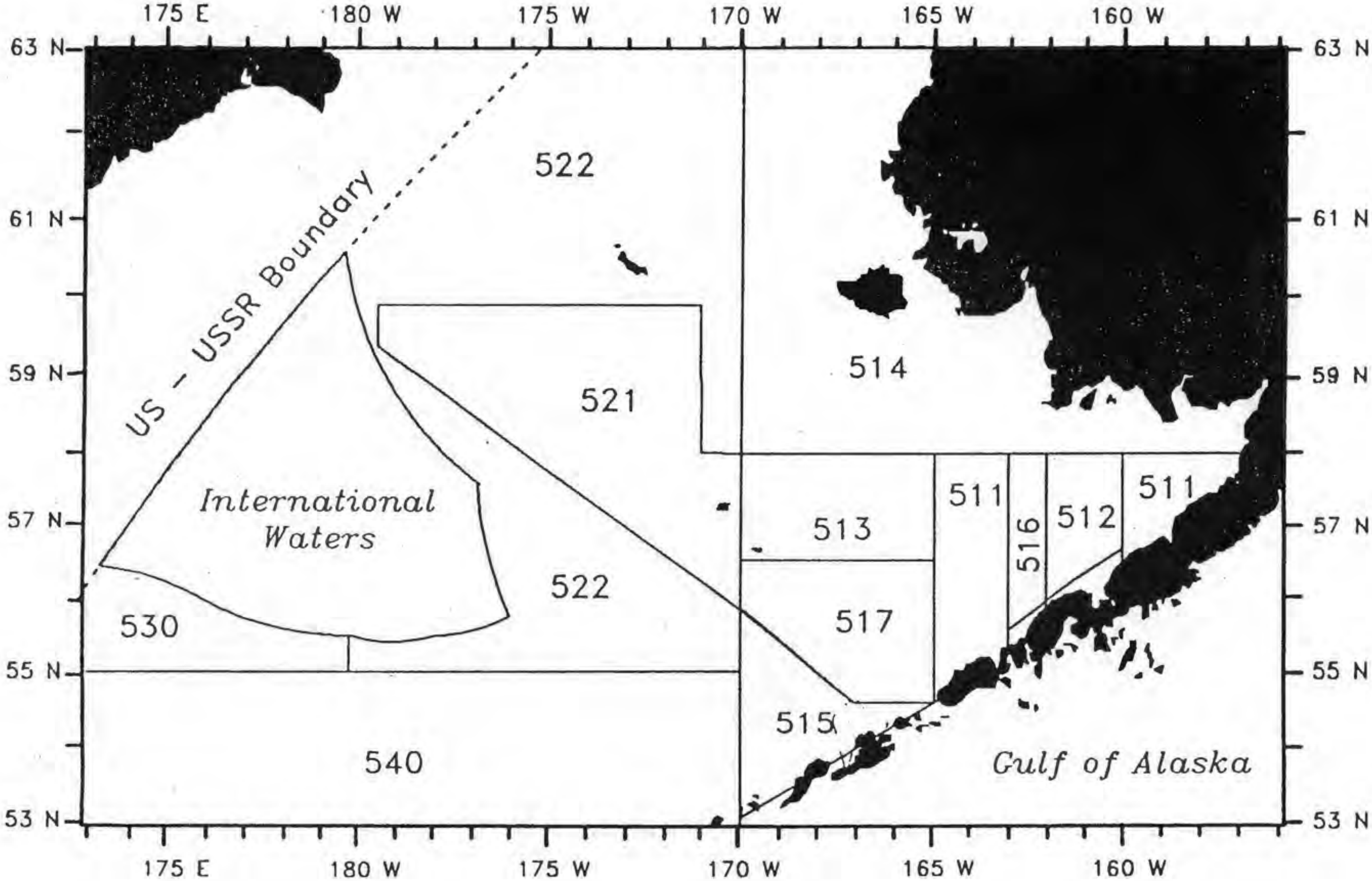

Figure 1.1 Statistical reporting areas in the BS/AI (Amendment 12A)

Bycatch protection zones: Zone 1 = 511 + 512 + 516
Zone 2 = 513 + 517 + 521
Zone 2H = 517

COORD TION WITH OTHERS

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TEXT TO AMEND THE GROUNDFISH FISHERY MANAGEMENT PLANS

BERING SEA/ALEUTIAN ISLANDS GROUNDFISH FMP

Section 14.4.2.4 Incentive program to reduce bycatch rates of prohibited species.

This new section is added as follows:

> The Secretary of Commerce, after consultation with the Council, may implement by regulation measures that provide incentives to individual vessels to reduce bycatch rates oi prohibited species for which PSC limits are established under section 14.4.2.2. The intended effect of such measures are to increase the opportunity to harvest groundfish TACs before established PSC limits are reached.

GULF OF ALASKA GROUNDFISH FMP

Section 4.2.2 Inseason adjustment of time and area, is redesignated as section 4.2.5, And a new section 4.2.4 is added to read as follows:

Section 4.2.4 Incentive programs to reduce bycatch rates of halibut.

> The Secretary of Commerce, after consultation with the Council, may implement by regulation measures that provide incentives to individual vessels to reduce bycatch rates of prohibited species for which PSC limits are established under Section 4.2.3.1. The intended effect of such measures are to increase the opportunity to harvest groundfish TACs before established PSC limits are reached.

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
The Chief Scientist
Washington, D.C. 20230

To All Interested Government Agencies and Public Groups:

Pursuant to the National Environmental Policy Act, an environmental review has been performed on the following action:

TITLE: Environmental Assessment of Amendment 16 to the Fishery Management Plan for the Bering Sea/Aleutian Islands Groundfish (BSAI FMP) and Amendment 21 to the Fishery Management Plan for Groundfish of the Gulf of Alaska (GOA FMP)

LOCATION: Exclusive Economic Zone of the Bering Sea and Aleutian Islands and the Gulf of Alaska

SUMMARY: Management measures for Amendments 16 and 21 address the following issues: (1) prohibited species bycatch management, (2) procedures for specifying total allowable catch, and (3) gear restrictions. Regulations specific to Amendment 21 address management of demersal shelf rockfish. Definitions of overfishing for groundfish are included in both amendments.

RESPONSIBLE OFFICIAL: William W. Fox, Jr.
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The environmental review process led us to conclude that this action will not have a significant effect on the human environment. Therefore, an environmental impact statement will not be prepared. A copy of the environmental assessment, including the finding of no significant impact, is enclosed for your information. Also, please send one copy of your comments to me in Room 6222, CS/EC, U.S. Department of Commerce, Washington, D.C. 20230.

Sincerely,

David Cottingham

David Cottingham
Director
Ecology and Environmental
Conservation Office

Enclosure

ENVIRONMENTAL ASSESSMENT/REGULATORY IMPACT REVIEW/
INITIAL REGULATORY FLEXIBILITY ANALYSIS
FOR AMENDMENT 21
TO THE FISHERY MANAGEMENT PLAN FOR
GROUNDFISH OF THE GULF OF ALASKA
AND AMENDMENT 16
TO THE FISHERY MANAGEMENT PLAN FOR
GROUNDFISH OF THE BERING SEA/ALEUTIAN ISLANDS

Prepared by Members of the Plan Teams for the
Groundfish Fisheries of the Gulf of Alaska
and the Bering Sea/Aleutian Islands,
the staff of the North Pacific Fishery Management Council,
and Members of the National Marine Fisheries Service,
the Alaska Department of Fish and Game,
and the International Pacific Halibut Commission

Anchorage, Alaska

July 31, 1990

SUMMARY OF AMENDMENTS 16 AND 21
TO THE
GROUNDFISH FISHERY MANAGEMENT PLANS
FOR THE BERING SEA/ALEUTIAN ISLANDS
AND THE GULF OF ALASKA

As part of the annual plan amendment cycle for the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish fishery management plans (FMPs), the North Pacific Fishery Management Council reviews proposed changes submitted by the public and management agencies. Upon recommendations of the Plan Amendment Advisory Group, the Advisory Panel, and the Scientific and Statistical Committee, the Council forwards those proposals of merit to the Plan Teams for analyses in January, and reviews the initial analyses in April. Soon after the April Council meeting, a draft amendment package, including a draft environmental assessment/regulatory impact review/initial regulatory flexibility analysis (EA/RIR/IRFA) is released for public comment. In June, the Council reviews the public comments and decides which amendment issues should go forward for approval and implementation by the Secretary of Commerce.

At its meeting on June 25-30, 1990, the Council considered four amendment proposals for the Bering Sea/Aleutian Islands groundfish FMP and five amendment proposals for the Gulf of Alaska groundfish FMP. These amendment proposals, with synopses for the rationale for their selection, are:

(1) Revise crab and halibut bycatch management measures for the Bering Sea/Aleutian Islands (BSAI FMP)

Substantial amounts of crab and halibut are taken in the groundfish bottom trawl fisheries in the BSAI. Crab and halibut bycatch management measures, implemented under Amendment 12a to the BSAI FMP, expire at the end of 1990. This proposal would extend the basic structure of Amendment 12a regulations for an indefinite period of time. Fixed caps for Pacific halibut, C. bairdi Tanner crab, and red king crab would be apportioned among competing fisheries. Attainment of a PSC apportionment by a defined fishery would close that fishery in the affected zone for the balance of the year. This proposal modifies the Amendment 12a bycatch management structure by (1) apportioning PSC caps to two additional fisheries: DAP rock sole and DAP deepwater sablefish and turbot; (2) allows for seasonal apportionment of PSC caps; and (3) provides for the imposition of sanctions on vessels with excessively high bycatch rates.

The Council preferred this alternative over (1) no action (the expiration of bycatch management measures on December 31, 1990) and (2) a simple continuation of Amendment 12a provisions. The Council felt it important that bycatch management measures remain in place to limit the impact of bottom trawl fisheries on directed fisheries for crab and halibut. At the same time, it felt that modifications to the Amendment 12a structure were necessary for fairer and fuller utilization of the groundfish optimum yield. These measures are intended to be interim in nature: the Council expects to use data from the newly instituted domestic observer program to design and implement more comprehensive bycatch management measures in future amendments.

(2) Define Overfishing (BSAI and GOA FMPs)

Guidelines for Fishery Management Plans prepared by the National Oceanic and Atmospheric Administration require each FMP to include an objective and measurable definition of overfishing for each stock or stock complex under management. The Council considered several alternatives which defined overfishing on the basis of minimum biomass levels, maximum fishing mortality levels, or both. It chose an alternative which defines overfishing as a variable fishing mortality rate (F) dependent on stock biomass (B). For all stock biomass levels above that corresponding to maximum sustained yield (B_{msy}), the maximum fishing mortality rate would be F_{msy}. For stock sizes less than B_{msy}, the maximum allowable fishing mortality rate would decrease linearly with biomass. In general, application of the F_{msy} fishing mortality rate will allow stocks to increase in size and its application is not expected to result in decreases in stock biomass due to fishing mortality. The Council felt that this alternative provided the best safeguard to the groundfish stocks under management combined with flexibility of management and stability of harvest.

(3) Interim Groundfish Specifications (BSAI and GOA FMPs)

Annual specifications of groundfish total allowable catches (TACs) and apportionments among user groups are based on the January 1 - December 31 calendar year. Insufficient time is available during the period between the end of the December Council meeting and January 1 of the new fishing year for the NMFS, Alaska Region, to prepare, and the Secretary of Commerce to review and implement final TACs by publishing them in the Federal Register. Without annual specifications having been filed with the Office of the Federal Register, authority does not exist to allow enforcement of regulations, e.g. fishing area closures or directed fishing prohibitions.

To close this gap in management authority, the Council chose an alternative which would extend one-fourth (25%) of the proposed TAC specifications, made at its September meeting, into the new fishing year until superseded by publication of the final specifications. It preferred this alternative to both the status quo and another alternative which would extend 100% of the proposed September TAC specification into the new fishing year until superseded. It found the preferred alternative to be superior to the extent that it reduces the risk of overharvesting a species' TAC and thereby promotes stability in both the resource and the industry.

(4) Modify the Authorization Language for Demersal Shelf Rockfish Management in the Gulf of Alaska (GOA FMP)

Amendment 14 to the GOA groundfish FMP provided limited authority to the State of Alaska to manage demersal shelf rockfish in Federal waters. Since that time, the State has adopted measures to provide for conservation of the resource and to maximize the value of this fishery. These measures extend beyond the specific provisions of the FMP.

The Council chose to modify the authorization language of the GOA FMP to allow the State of Alaska to manage demersal shelf rockfish more effectively in the Eastern Gulf. State regulations will apply only to vessels registered in the State of Alaska. The Council will provide oversight and will continue to set the annual TAC for demersal shelf rockfish.

(5) Fishing Gear Restrictions (BSAI and GOA FMPs)

The Council approved a general measure to allow legal fishing gear to be defined by regulatory amendment. In addition the Council approved four specific measures to be included in the regulations: (1) a requirement for groundfish pots to have biodegradable panels; (2) a requirement for groundfish pots to have halibut excluder devices; (3) a new definition of pelagic trawl gear; and (4) a requirement that owner identification be on groundfish pots, as well as buoys. These four measures are intended to decrease lost gear, deadloss due to ghost fishing by lost gear, crab and halibut bycatch, and gear conflicts. In general, the ability to define legal fishing gear by regulatory amendment will help management to keep pace with rapidly evolving fisheries.

(6) Expand Halibut Bycatch Management Measures for the Gulf of Alaska (GOA FMP)

Incidental catch of halibut in the groundfish fisheries of the GOA is a major bycatch management issue. The existing framework for managing halibut bycatch in the Gulf provides substantial flexibility, but is unclear with respect to whether PSC limits may be established for distinct DAP fisheries, whether PSC limits may be divided into seasonal allowances, or whether vessel incentives to fish with reduced bycatch rates may be implemented. The Council voted to expand and clarify the halibut bycatch management framework. Specifically, it approved measures to apportion the halibut PSC limits by season and to set levels of fixed gear halibut PSC limits by (a) longline, and (b) pot gear groups. In addition, the Council voted to adopt an incentive program to impose sanctions on vessels which fish with excessively high bycatch rates.

The attached EA/RIR/IRFA presents a detailed assessment of the likely impacts resulting from the implementation of the various proposed alternatives to amend the Bering Sea/Aleutian Islands groundfish FMP (Amendment 16) and the Gulf of Alaska groundfish FMP (amendment 21).

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1.0 INTRODUCTION

The domestic and joint venture groundfish fisheries in the exclusive economic zone (3-200 miles offshore) of the Gulf of Alaska and Bering Sea/Aleutian Islands are managed under the Fishery Management Plan (FMP) for Groundfish of the Gulf of Alaska (GOA) and the FMP for the Groundfish Fishery of the Bering Sea/Aleutian Islands (BSAI). Both FMPs were developed by the North Pacific Fishery Management Council (Council) under the Magnuson Fishery Conservation and Management Act (Magnuson Act).

The GOA FMP was approved by the Assistant Administrator for Fisheries, NOAA (Assistant Administrator), and became effective December 11, 1978 (43 FR 52709, November 14, 1978). It is implemented by Federal regulations appearing at 50 CFR Parts 611, 620, and 672. Seventeen amendments to the GOA FMP have been approved by the Assistant Administrator. An additional amendment (Amendment 12) was adopted initially by the Council at its July and December 1982 meetings but was later rescinded by the Council at its September 1984 meeting without having been submitted formally for Secretarial review. Amendments 19 (a ban on pollock roe stripping), 20 (sablefish effort limitation measures), and 22 (inshore-offshore allocations) are currently being prepared by the Council.

The BSAI Groundfish FMP was approved by the Assistant Administrator and became effective on January 1, 1982 (46 FR 63295, December 31, 1981). This FMP is implemented by Federal regulations appearing at 50 CFR Parts 611, 620, and 675. Fourteen amendments to the BSAI FMP have been approved by the Assistant Administrator. An additional amendment (Amendment 6) was adopted by the Council but was disapproved by the Assistant Administrator. Amendments 14 (a ban on pollock roe stripping), 15 (sablefish effort limitation measures), 16a (herring, crab and halibut bycatch management measures), and 17 (inshore-offshore allocations) are currently being prepared by the Council.

The Council solicits public recommendations for amending the GOA or the BSAI groundfish FMPs on an annual basis. Amendment proposals are then reviewed by the Council's GOA and BSAI groundfish FMP Plan Teams (PTs), Plan Amendment Advisory Group (PAAG), Advisory Panel (AP), and Scientific and Statistical Committee (SSC). These advisory bodies make recommendations to the Council on which proposals merit consideration for plan amendment.

Amendment proposals and appropriate alternatives accepted by the Council are then analyzed by the PTs for their efficacy and for their potential biological and socioeconomic impacts. After reviewing this analysis the AP and SSC make recommendations as to whether the amendment alternatives should be rejected or changed in any way, whether and how the analysis should be refined, and whether to release the analysis for general public review and comment. If an amendment proposal and accompanying analysis is released for public review, then the AP, SSC, and the Council will consider subsequent public comments before deciding whether to submit the proposals to the Secretary of Commerce for approval and implementation.

1.1 List of Amendment Proposals

Chapter

2. Revise Crab and Halibut Bycatch Management Measures in the BSAI
3. Define Overfishing in the GOA and BSAI
4. Establish Procedures For Interim TAC Specifications in the BSAI & GOA
5. Modify Demersal Shelf Rockfish Management in the GOA
6. Change Fishing Gear Restrictions in the BSAI & GOA
7. Expand Halibut Bycatch Management Measures in the GOA

1.2 Purpose of the Document

This document provides background information and assessments necessary for the Secretary of Commerce to determine that the FMP amendments are consistent with the Magnuson Act and other applicable law.

1.2.1 Environmental Assessment

One part of the package is the environmental assessment (EA) that is required by NOAA in compliance with the National Environmental Policy Act of 1969 (NEPA). The purpose of the EA is to analyze the impacts of major federal actions on the quality of the human environment. The EA serves as a means of determining if significant environmental impacts could result from a proposed action. If the action is determined not to be significant, the EA and resulting finding of no significant impact (FONSI) would be the final environmental documents required by NEPA. An EIS must be prepared if the proposed action may be reasonably expected: (1) to jeopardize the productive capability of the target resource species or any related stocks that may be affected by the action; (2) to allow substantial damage to the ocean and coastal habitats; (3) to have a substantial adverse impact on public health or safety; (4) to affect adversely an endangered or threatened species or a marine mammal population; or (5) to result in cumulative effects that could have a substantial adverse effect on the target resource species or any related stocks that may be affected by the action. Following the end of the public review period the Council could determine that Amendment 21 to the GOA FMP or Amendment 16 to the BSAI FMP will have significant impacts on the human environment, and proceed directly with preparation of an EIS required by NEPA. This EA is prepared to analyze the possible impacts of management measures and their alternatives that are contained in these amendments.

Certain management measures are expected to have some impact on the environment. Such measures are those directed at harvests of stocks and may occur either directly from the actual harvests (e.g. removals of fish from the ecosystem) or indirectly as a result of harvest operations (e.g. effects of bottom trawling on the benthos--animals and plants living on, or in, the bottom substrate). Environmental impacts of management measures may be beneficial when they accomplish their intended effects (e.g. prevention of overharvesting stocks as a result of quota management). Conversely, of course, such impacts may be harmful when management measures do not accomplish their intended effects (e.g. overharvesting may occur if quotas are incorrectly specified). The extent of the harm is dependent on the risk of overfishing that has occurred. For purposes of this EA, the term "overfishing" is that which is described in the "Guidelines to Fishery Management Plans" (48 FR

7402, February 18, 1983). It is a level of fishing mortality that jeopardizes the capacity of a stock(s) to recover to a level at which it can produce maximum biological yield or economic value on a long-term basis under prevailing biological and environmental conditions. Environmental impacts that may occur as a result of fishery management practices are categorized as changes in predator-prey relations among invertebrates and vertebrates, including marine mammals and birds, physical changes as a direct result of fishing practices, and nutrient changes due to processing and dumping of fish wastes. If more or less groundfish biomass is removed from the ecosystem, then oscillations occur in the ecosystem until equilibrium is again achieved.

1.2.2 Regulatory Impact Review

Another part of the package is the Regulatory Impact Review (RIR) that is required by National Marine Fisheries Service (NMFS) for all regulatory actions or for significant Department of Commerce or NOAA policy changes that are of significant public interest. The RIR: (1) provides a comprehensive review of the level and incidence of impacts associated with a proposed or final regulatory action; (2) provides a review of the problems and policy objectives prompting the regulatory proposals and an evaluation of the major alternatives that could be used to solve the problems; and (3) ensures that the regulatory agency systematically and comprehensively considers all available alternatives so that the public welfare can be enhanced in the most efficient and cost effective way.

The RIR also serves as the basis for determining whether any proposed regulations are major under criteria provided in Executive Order 12291 and whether or not proposed regulations will have a significant economic impact on a substantial number of small entities in compliance with the Regulatory Flexibility Act (P.L. 96-354, RFA). The primary purpose of the RFA is to relieve small businesses, small organizations, and small governmental jurisdictions (collectively, "small entities") of burdensome regulatory and recordkeeping requirements. This Act requires that if regulatory and recordkeeping requirements are not burdensome, then the head of an agency must certify that the requirement, if promulgated, will not have a significant effect on a substantial number of small entities.

This RIR analyzes the impacts that Amendment 21 and 16 alternatives would have on the groundfish fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands, respectively. It also provides a description of and an estimate of the number of vessels (small entities) to which regulations implementing these amendments would apply.

1.3 Catch and Value of Groundfish in the Gulf of Alaska and in the Bering Sea/Aleutian Islands Area

In the Bering Sea, domestic harvests increased from about 75,000 mt in 1988 to slightly over 1.2 million mt in 1989, which is an increase of 84 percent. Domestic (domestic annual processing=DAP) catches of pollock increased by 90 percent, from 533,000 mt to about 1,016,000 mt. DAP catches of Atka mackerel also increased markedly, from 2,066 mt to over 18,000 mt, which is an increase of 793 percent.

In the Gulf of Alaska, domestic harvests increased from about 147,000 mt in 1988 to over 179,000 mt in 1989, which is an increase of 22 percent. Pacific cod showed a strong 36 percent increase, from about 30,500 mt in 1988 to over 41,500 mt in 1989. Although absolute tonnages are small, the catch of pelagic rockfish showed a strong increase, from 883 mt in 1988 to over 1,700 mt in 1989.

1.4 Description of the 1990 Domestic Fishing Fleet Operating in the Gulf of Alaska and in the Bering Sea/Aleutians Islands Area

The NMFS vessel permit database has been examined to determine the current composition of the domestic groundfish fishing fleet. A total of 1,348 vessels may fish for groundfish in the Bering Sea and Gulf of Alaska in 1990 (Table 1.2). This number is based on 1990 Federal groundfish permits that have been issued to domestic vessels as of March 29, 1990.

Fishing operations in which these vessels participate include: harvesting only, harvesting and processing, processing only, and support. The latter type of operation includes transporting fishermen, fuel, groceries, and other supplies to other vessels.

Of the total 1,740 vessels, 95%, or 1,655, are five net tons or larger. Five percent, or 85 vessels, are less than five net tons.

Vessels Five Net Tons or Larger

The larger vessels, i.e., those that are 5 net tons or larger, are based in Seattle, Sitka, Kodiak, and Dutch Harbor, and other ports. Most of these larger vessels come from Alaska, based on telephone area codes given with permit applications. The numbers of vessels that come from Alaska is 1,026, the number from the Seattle area is 453, and the number from other areas is 169. These numbers are summarized in Table 1.3 by processing mode.

The total number of catcher vessels (harvesting only) and catcher/processor vessels (harvesting/ processing) is 1,446 and 140, respectively (Tables 1.4 and 1.5). Net tonnages of catcher vessels and catcher/processor vessels vary widely. The total net tonnage of the catcher vessels is 56,333 tons, and the total net tonnage of the catcher/processor vessels is 61,236 tons.

Vessels involved in harvesting only (catcher vessels) employ mostly three types of gear: hook-and-line, trawls, or pots. Most of the catcher vessels are hook-and-line vessels and number 1,158 (Table 1.4). They are the smallest vessels fishing groundfish, having average net tonnage capacities equal to 30 tons and average lengths of 49 feet. Pot vessels number 39 and trawl vessels number 243. Their respective average net tonnage capacities are 139 and 112 tons. Their respective average lengths are 99 and 88 feet.

Vessels involved in harvesting and processing (catcher/processor vessels) also employ mostly hook-and-line, trawls, or pots. The number of catcher/processor vessels using hook-and-line gear is 63 (Table 1.5). These vessels are the smallest of the catcher/processor vessels, having average net tonnage capacities equal to 161 tons and average lengths of 93 feet, but are larger than the catcher vessels using hook-and-line gear. Pot vessels number 7 and trawl vessels number 70. Their respective average net tonnage capacities are 343 and 860 tons. Their respective average lengths are 144 and

194 feet. Twenty-three vessels are involved in processing only (motherships). These vessels average 2,330 net tons and lengths of 251 feet.

The number of vessels by length, by gear type, and by operating mode varies. Table 1.6 summarizes these parameters.

Table 1.1 Comparison of 1988 and 1989 DAP Groundfish catches (metric tons) in the Bering Sea/Aleutians and the Gulf of Alaska.

BERING SEA/ALEUTIANS

	1988	1989	% change
ARROWTOOTH FLOUNDER	2735	4964	94
ATKA MACKEREL	2066	18457	793
GREENLAND TURBOT	6713	8948	33
OTHER FLATFISHES	25932	9922	-62
OTHER ROCKFISH	544	791	45
OTHER SPECIES	1019	4140	306
PACIFIC COD	86733	126505	46
PACIFIC OCEAN PERCH	2195	6891	214
POLLOCK	533053	1015968	90
ROCK SOLE	N/A	33582	N/A
SABLEFISH	6588	4401	-33
SQUID	279	329	18
YELLOWFIN SOLE	7771	5320	-31
Total	675628	1240218	84

GULF OF ALASKA

	1988	1989	% change
DEMERSAL SHELF ROCKFISH	883	412	-53
FLOUNDERS	11910	11652	2
OTHER ROCKFISH	14507	19002	31
OTHER SPECIES	765	1675	118
PACIFIC COD	30542	41544	36
PELAGIC ROCKFISH	883	1736	96
POLLOCK	56634	72393	28
SABLEFISH	28725	28052	-2
THORNYHEADS	2482	3056	23
Total	147331	179522	22

Table 1.2 Numbers of groundfish vessels that are less than 5 net tons or 5 net tons and larger that are Federally permitted in 1990 to fish off Alaska.

	Number of Vessels		
Mode	< 5 net tons	>= 5 net tons	
HARVESTING ONLY	84	1446	
HARVESTING/PROCESSING	0	140	
PROCESSING ONLY	0	23	
SUPPORT ONLY	0	39	
OTHER	1	7	
TOTAL VESSELS =	85	1655=	1740

Table 1.3 Numbers of groundfish vessels that are Federally permitted to fish off Alaska in 1990 from the Seattle area, Alaska, and from other areas. All vessels 5 net tons or larger.

Mode	Number: Seattle Area	Alaska	Other Areas
HARVESTING ONLY	314	974	158
HARVESTING/PROCESSING	92	40	8
PROCESSING ONLY	20	3	0
SUPPORT ONLY	27	9	3
TOTAL	453	1026	169

Table 1.4 Numbers and statistics of CATCHER VESSELS by gear type that are Federally permitted to fish off Alaska in 1990 All vessels 5 net tons or larger.

Mode	Number	Avg. Net Tons	Avg. length (ft)
HOOK-AND-LINE	1158	30	49
POTS	39	139	99
TRAWL	243	112	88
OTHER GEAR 1/	6	37	48
TOTAL	1446		

1/ Other gear includes combinations of hook-and-line, pots trawls, jigs, troll gear, and gillnets.

Table 1.5 Numbers and statistics of CATCHER/PROCESSOR and MOTHERSHIP (processing only) VESSELS by gear type that are Federally permitted to fish off Alaska in 1990. All vessels 5 net tons or larger.

Mode	Number	Avg. Net Tons	Avg. length (ft)
HOOK-AND-LINE	63	161	93
POTS	7	343	144
TRAWL	70	860	194
OTHER GEAR 1/	0	0	0
TOTAL	140		
MOTHERSHIPS	23	2330	251

1/ Other gear includes combinations of hook-and-line, pots, trawls, jigs, troll gear, and gillnets.

Table 1.6 Numbers of vessels Federally permitted to fish off Alaska in 1990 by 25-foot length increments, by gear type and by operating mode. Support vessels are excluded. M* = multiple gear.

	Catcher				Catcher/Processor				Mothership
Length (ft)	Trawl	Pot	LL	M*	Trawl	Pot	LL	M*	
<= 24	2	0	34	1	0	0	0	0	0
25 - 49	26	8	773	6	3	1	19	0	0
50 - 74	59	3	352	1	0	0	9	0	0
75 - 99	87	5	55	1	5	0	9	0	0
100-124	48	14	14	0	2	0	4	0	0
125-149	11	2	2	0	8	1	9	0	1
150-174	10	8	3	0	8	4	8	0	5
>= 175	5	0	0	0	44	1	5	0	17
SUBTOTALS	248	40	1233	9	70	7	63	0	23

TOTAL CATCHER & PROCESSORS VESSELS 1693

TOTAL SUPPORT VESSELS 39 TOTAL OTHER MODES 8

TOTAL VESSELS 1740

2.0 Revise Crab and Halibut Bycatch Management Measures for the BSAI

2.1 Need for Action

Trawl, hook and longline, and pot groundfish fisheries use partially non-selective harvesting techniques in that incidental (bycatch) species, including crab and halibut, are taken in addition to targeted species. A conflict occurs when bycatch in one fishery measurably impacts the level of resource available to another fishery. Bycatch management is an attempt to balance the effects of various fisheries on each other. It is a particularly contentious allocation issue because compared to crab or halibut fishermen, groundfish fishermen value the use of crab or halibut very differently. The incidental catch of red king crab, C. bairdi Tanner crab, and Pacific halibut in trawl fisheries targeting groundfish has been of particular concern and is addressed in this chapter.

With the exception of the prohibition on the retention of crab and halibut taken as bycatch in the groundfish fisheries, the management measures that control the bycatch of crab and halibut in the domestic and joint venture groundfish fisheries in the Bering Sea/Aleutian Islands Area (BSAI) were implemented as the result of Amendment 12a. These management measures expire at the end of 1990.

The prohibition on retention eliminates the incentive that the groundfish fleets might otherwise have to target on crab and halibut, but it does not provide a substantial incentive for them to avoid or control bycatch. Therefore, the North Pacific Fishery Management Council (Council) has determined that in the absence of additional management measures to control bycatch, the levels of red king crab, C. bairdi Tanner crab, and Pacific halibut bycatch would be too high. At its January 1990 meeting, the Council instructed the Plan Team to develop, by the April 1990 meeting, a bycatch management amendment package evaluating three alternatives.

The amendment package was reviewed by the Council in April. Based on recommendations from the Ad Hoc Bycatch Committee, the Alaska Regional Office, and the Advisory Panel, the Council took three actions with respect to controlling the bycatch of crab and halibut in the groundfish bottom trawl fisheries. First, it instructed the Plan Team to substantially change the third alternative and to prepare a revised amendment package to be released for public comment in May. This would allow the Council to take final action on this amendment in June and allow the preferred alternative to be in place at the beginning of the 1991 fishing year. The three alternatives included in Amendment 16 are:

(1) the status quo which allows the 12a provisions to expire at the end of 1990;

(2) a one year extension of the 12a provisions; and

(3) a one year or indefinite extension of Amendment 12a provisions modified to:

- add PSC cap apportionments for the DAP rock sole and deep-water trawl (Greenland turbot/sablefish) fisheries,
- permit seasonal allowances of PSC limits, and

- provide for sanctions against vessels whose bycatch rates for red king crab, C. bairdi Tanner crab or halibut significantly exceed a fishery average.

These alternatives were analyzed in Chapter 2 of the Amendment 21/16 EA/RIR/IRFA that was made available to the public on May 16, 1990. The bycatch model used to analyze these alternatives was revised in early June. The analysis based on the revised model was presented to the Council at the June meeting and are included in this chapter.

The Council also instructed the Plan Team to prepare a second amendment package that the Council reviewed for the first time in June and will take final action on in September. This action was taken because there was insufficient time to consider additional bycatch management measures for Amendment 16. The preferred alternative from Amendment 16a could be in place by the second quarter of the 1991 fishing year. Amendment 16a includes alternatives that would:

(1) provide the Regional Director the authority to temporarily close limited areas in-season due to high bycatch rates;

(2) permit the Regional Director to set a limit on the amount of the pollock TACs that can be taken in other than the mid-water pollock fisheries; and

(3) set PSC caps for red king crab, C. bairdi Tanner crab and halibut at 50%, 100% and 150% of current levels.

Finally, the Council also instructed its Ad Hoc Bycatch Committee and the Plan Team to develop more effective and comprehensive solutions to the bycatch problem. This work would begin after the June Council meeting. The approaches to be considered include incentives for individual vessels and vessel pools and other fundamental changes to the existing management measures to control bycatch. The preferred alternative among such solutions could possibly be in place for the beginning of the 1992 fishing year.

When Amendment 12a was recommended, approved, and used to apportion the prohibited species catch (PSC) caps for the 1990 fisheries, it was generally assumed that the groundfish fleets would reduce their bycatch rates sufficiently in response to the caps to be able to fully utilize the groundfish TACs. Since the January Council meeting, it has become clear that this assumption was not valid.

To date the 1990 closures have been as follows:

1. JVP flatfish in Zone 1 - January 25 due to red king crab bycatch;

2. JVP flatfish in Zones 1 and 2H - February 27 due to halibut bycatch;

3. JVP flatfish in all of BSAI - March 5 due to halibut bycatch;

4. DAP flatfish in Zones 1 and 2H - March 14 due to halibut bycatch;

5. DAP flatfish in all of BSAI - March 19 due to halibut bycatch;

6. DAP Pacific cod and pollock bottom trawl in Zones 1 and 2H - May 30 due to halibut bycatch;

7. DAP Pacific cod and pollock bottom trawl in all of BSAI -- June 30; and

8. JVP flatfish in all of BSAI - July 1 due to halibut bycatch (this JVP fishery had reopened on June 24 as 22 mt of its halibut PSC apportionment had not been taken).

Through June 30, 1990, the unused DAP groundfish apportionments are about 71,000 mt for Pacific cod and 48,000 mt for all flatfish species. At the time of the final cod and pollock bottom trawl closures, the unused DAP pollock apportionment was about 464,000 mt; however, much of that will probably be taken with off-bottom gear. It is not known how much additional catch will be taken when the DAP flatfish fishery is reopened on August 4 to allow it to take the 44 mt remainder of its halibut PSC apportionment nor is it known how much of the remaining cod TAC will be taken with fixed gear or by other than on-bottom trawl gear. In addition to the DAP apportionments that may be foregone, approximately 122,000 mt of JVP sole and other flatfish apportionments were left after the final closure of the JVP flatfish fishery on July 1.

The first wholesale value of the foregone catch could exceed $100 million. Such a loss could impose severe financial hardships on those involved in harvesting, processing, and marketing groundfish and on others whose income and well being are dependent on the BSAI groundfish industry. The closures in the BSAI will also adversely affect those who are dependent on the Gulf of Alaska or other west coast groundfish fisheries. This is because some of the vessels displaced from the BSAI will enter these other fisheries and decrease the catch that otherwise would have been available to other fishermen and processors.

It is not known to what extent the closures of the bottom-trawl fisheries will benefit the fixed gear fisheries that are developing or to what extent trawl gear will be modified so that it can continue to be used in the cod fishery despite the ban on bottom trawling. It is possible that trawl gear other than bottom trawls could be used in the cod fishery and it is not known whether the halibut bycatch rates for such trawl gear will be higher or lower than that of the bottom trawl gear that is prohibited by the closures.

2.2 Nature and Source of the Problem

The groundfish fishery results in incidental fishing mortality for crab, halibut, and other prohibited species. This use of crab and halibut is one of several competing uses of the crab and halibut resources. Crab and halibut can also be used in the crab and halibut fisheries, respectively, as current or future catch. This future use as catch necessarily requires that the crab and halibut are left in the sea to contribute to the productivity of the crab and halibut stocks. Crab and halibut can also be left in the sea to contribute to other components of the ecosystem, or they can be used as incidental fishing mortality in non-groundfish fisheries.

The analysis of bycatch management in the groundfish fishery focuses on two uses of crab and halibut. They are (1) the use as bycatch in the groundfish fishery and (2) the use as present or future retained catch in the crab and halibut fisheries. The use of crab and halibut as contributors to the rest of the ecosystem is not germane if, out of consideration of the future productivity of the crab and halibut fisheries, the crab and halibut stocks are maintained at levels that do not adversely affect the ecosystem as a whole. The use of crab and halibut as incidental fishing mortality in non-groundfish fisheries is probably more important in determining the appropriate combined total removals by the groundfish, crab, and halibut fisheries than in determining the appropriate distribution of these removals between these two uses.

With respect to these two competing uses of crab and halibut resources, fishery managers are faced with the task of providing for the appropriate allocation between these two uses. This consists of both assuring that an acceptable level of total removals (i.e., fishing mortality) is not exceeded for any stock and assuring that an appropriate use of crab and halibut as bycatch in the groundfish fisheries may occur.

The optimal allocation of the crab and halibut resources among these two competing uses depends on the relative values of these uses, where value is as broadly defined as in the MFCMA, Executive Order 12291, other applicable Federal regulations, and the goals and objectives of the Council. The values of competing uses would include their effects on biological conservation, the maintenance of traditional fisheries and dependent communities, and the maintenance of international treaty obligations, as well as on components of the value of a use that are more readily measured in monetary terms.

From a National perspective, the optimal allocation of crab or halibut between the crab or halibut fishery and the groundfish fishery is the one that provides the greatest value to the Nation. With one exception, this is the allocation for which the values of an additional unit of crab or halibut for both uses are equal. For example, if the value to the Nation of 100,000 more crab for bycatch in the groundfish fishery is $1 million and if the value to the Nation of 100,000 more comparable crab left at sea for the crab fishery is $1.5 million, the benefit to the Nation would be greater if the 100,000 crab were used for the crab fishery. In this case, the total value of the use of crab could be increased by reallocating crab from the groundfish fishery to the crab fishery until the marginal values of both uses are equal.

The exception to the rule of equal marginal values occurs when the marginal value of one use is greater than that of another regardless of how a resource is allocated among the two uses. In this case, the optimal allocation would result in none of the resource going to the lower valued use.

Within a given general type of use, such as bycatch, the value of additional crab or halibut depends on how it is used. For example, the value of an additional 100,000 crab for bycatch depends in part on whether those crab are used in such a way that the amount of additional cod that can be harvested is 100,000 mt or 10,000 mt. To maximize the value of the 100,000 crab for bycatch, it is necessary that the marginal values of the alternative bycatch uses of crab are equal, except in the case noted above. This means that the appropriate levels of halibut and crab to be used in the groundfish fishery depend on how they will be used. Therefore, the appropriate decisions about PSC caps and how the caps will be used are interdependent and should be made simultaneously.

The appropriate levels of bycatch (i.e., use in the groundfish fishery) also can be thought of as the levels that minimize the cost of bycatch, where that cost has three components: (1) the present and future costs imposed on those who benefit from the crab and halibut fisheries or the existence of crab and halibut stocks; (2) the costs imposed on those who benefit from the groundfish fisheries; and (3) management costs associated with regulating bycatch. These three types of costs will be referred to as impact costs, control costs, and agency costs, respectively.

The impact costs are those associated with changes in catch in the crab and halibut fisheries or changes in stock conditions due to incidental fishing mortality of halibut and crab in the groundfish fisheries. This mortality will be generally referred to simply as bycatch. The control costs are those imposed on the groundfish fleet to limit bycatch. The agency costs are those borne by agencies (e.g., the Council, NMFS, etc.) and the general public to select, implement, administer, and enforce the bycatch program.

There is a need for regulatory intervention, because there are competing uses of crab and halibut and because there is no mechanism in place to assure an allocation of these resources that will minimize the cost of bycatch or, equivalently, produce an efficient allocation of crab and halibut among alternative uses. In making decisions concerning bycatch, a groundfish fisherman considers his bycatch control costs because he bears them but he principally ignores the impact costs because they are borne by others. Because he ignores impact costs, he will tend to take too much bycatch from a National perspective. Therefore, the root of the problem is that impact costs are an external cost to the business of fishing for groundfish.

It has been argued that the PSC caps provide fishermen an incentive to reduce bycatch rates because the bycatch rates and the caps jointly determine whether the TACs can be utilized fully. That is, by reducing bycatch rates, fishermen would be able to catch more fish. This argument fails to recognize that, although it is in the best interest of the groundfish fleet as a whole to increase the amount of groundfish that could be harvested by reducing bycatch rates, it is in the best interest of each individual operation to ignore bycatch and harvest groundfish as rapidly as possible. This is a "tragedy of the commons" (Hardin, 1968) and is similar to the situation in an open access fishery in which each operation has an incentive to incur the costs necessary to increase the rate at which it can harvest fish even though for the fleet as a whole this will increase costs without increasing catch.

Instead of having a mechanism that rewards each individual operation for its success in reducing bycatch, there is a mechanism that penalizes those who attempted to reduce bycatch rates and rewards those who did not. This perverse mechanism is in part the result of the race for fish which was intensified by the PSC caps. The intensified race substantially increased the opportunity cost to individual operations of controlling bycatch rates. Therefore, fewer actions were taken to control bycatch and bycatch rates were higher than they would have otherwise been.

If the fisherman did bear this cost, he would tend to make different decisions concerning his own actions to control bycatch. His decisions would tend to be the correct ones from both his perspective and society's. Therefore, the bycatch problem would be eliminated, that is, the cost of bycatch would be minimized.

The alternative to eliminating the root of the problem by internalizing the impact costs is to find some other way to influence each fisherman's decisions concerning bycatch. This has been the traditional management response to the bycatch problem. It has included the use of time/area closures, gear restrictions, PSC caps, reduced groundfish TACs, and the designation of prohibited species. One problem with these approaches is that they require a substantial amount of information that typically is not available. In the absence of that information, it is highly unlikely that the use of these measures will result in the cost of bycatch being minimized. The potential for the cost of bycatch being substantially higher than necessary is great. This problem would exist if there were only one bycatch species. It is greatly increased because there are multiple bycatch species and because the traditional management measures that are imposed to reduce the bycatch of one species often increase that of other species.

One difficulty in determining the appropriate allocation of crab and halibut between the two competing uses is determining the marginal (incremental) value of each use. Although there is some disagreement about the marginal value of crab and halibut left on the grounds for the crab and halibut fisheries, the issue of the marginal value of bycatch to the groundfish fishery is probably much more contentious.

The valuation of the use of crab or halibut is confounded by the fact that crab and halibut fisheries take different segments of the population than are taken as bycatch in groundfish fisheries. For example, crab taken as bycatch in the trawl fisheries consist of juveniles, and adult females, as well as adult male crabs. Although other crab may be taken, only adult males can be retained in the crab fishery. Consequently, the estimation of the impact cost of crab bycatch in the groundfish fishery must attempt to account for the impacts on stock reproductive potential from the bycatch mortality of females, and the natural mortality of juvenile male crab in the intervening time between incidental catch and when they would have been recruited to the crab fishery. A method of estimating the impact cost of crab bycatch in the groundfish fisheries is presented in Appendix 2.1.

Similar adjustments must be performed for halibut. The International Pacific Halibut Commission (IPHC) currently estimates annual halibut bycatch mortality in the combined BSAI and GOA management areas, calculates the adult equivalents of the bycatch mortality, and decreases future halibut fishery quotas based on this calculation.

In addition to the difficulty of estimating the extent to which leaving additional crab or halibut in the sea will contribute to future catch in the crab or halibut fishery, the non-monetary benefits of increases in the future harvest of crab or halibut, such as the maintenance of traditional fisheries and dependent communities, and the maintenance of international treaty obligations are difficult to estimate and may not be estimable in monetary terms.

There are other reasons why it is difficult to estimate the value of bycatch to the groundfish fisheries. If the groundfish fishery is constrained by its bycatch allocation, the marginal value of bycatch equals the cost to the groundfish fleet of reducing bycatch by one unit. Naturally, if it is not constrained by its allocation, the marginal value is zero. Bycatch mortality can be reduced by: (1) reducing the bycatch rate (i.e., the amount of bycatch per unit of groundfish); (2) reducing discard mortality rates (i.e., the percentage of bycatch that does not survive being captured and discarded); or (3) reducing groundfish catch. Bycatch and discard mortality rates can be reduced by changing fishing strategies or techniques. Crab and halibut fishermen argue that bycatch and discard mortality rates can be significantly reduced at little cost to the groundfish fishery. However, groundfish fishermen argue that the cost of reducing bycatch and discard mortality rates can be high and at some point it is less costly to forego target catch than to further reduce bycatch or discard mortality rates.

It should be noted that the cost of some of the techniques available to the groundfish fishery to reduce these rates are affected by the groundfish fishery management plan (FMP). For example, the cost of fishing either later in the year or at a slower pace to reduce bycatch or discard mortality rates may be prohibitively high due to the race for fish resulting with the existing groundfish management regime.

If the PSC caps cause closure of a groundfish fishery before the target TACs are taken, the marginal value of bycatch to the groundfish fishery can be estimated using the bycatch rate, the discard mortality rate, and an estimate of product value per metric ton of groundfish catch net of variable costs. For example, if (1) only the halibut PSC cap is constraining groundfish catch, (2) the bycatch rate is 1% (i.e., 1 mt of halibut per 100 mt of groundfish, (3) the discard mortality rate is 50%, and (4) the value of groundfish catch net of variable costs is $100 per mt, then the fishing operation would be able to harvest an additional 200 mt of groundfish with 1 mt of additional halibut bycatch mortality. As a result, the fishing operation should be willing to pay up to $20,000 (200 mt x $100/mt) to do so. Therefore, in this hypothetical example, the short-run marginal value of the additional mt of halibut bycatch mortality is $20,000.

In general, if the price of the groundfish product of the fishing operation is not very responsive to the amount supplied by the BSAI groundfish fisheries or if the products are principally supplied to foreign markets, the foregone product value net of variable costs will tend to provide a reasonable estimate of the marginal bycatch control cost when groundfish catch is constrained by PSC caps. It also tends to indicate what the groundfish fishery would be willing to pay in the short-run to be able to take an additional unit of bycatch. If the groundfish fishery changes its fishing practices to keep from exceeding PSC caps and does not decrease its target catch as a result, the marginal bycatch control cost or the marginal value of bycatch to the groundfish fishery would tend to be less than if catch is reduced by the caps.

In the absence of either accurate information on the effectiveness and costs of alternative techniques for reducing bycatch and discard mortality rates or a market mechanism that will provide good estimates of the cost to the groundfish fishery, the marginal value of bycatch will remain a contentious issue. As a result, the bycatch management decision process potentially will be less objective, more political, less equitable, and more likely to make the wrong decisions.

In recognition of the economic origin of the bycatch problem, the Council is expected to consider market-oriented solutions. However, due to the desire to have bycatch control measures in place on January 1, 1991 when the management measures implemented under Amendment 12a expire, the Council is currently considering only limited use of such solutions. Specifically it is considering extending the provisions of Amendment 12a in combination with economic incentives to decrease bycatch rates. The more extensive use of market oriented solutions will be considered in a separate amendment that will address more effective and comprehensive intermediate to long-term solutions to the bycatch problem.

2.3 The Alternatives

There are three alternatives for Amendment 16.

2.3.1 Alternative 1: Do Nothing.

Adoption of this alternative would allow bycatch control measures to expire. Existing domestic and joint venture bycatch cap provisions and closed areas under Amendment 12a expire on December 31, 1990. Bycatch control regulations for the domestic and joint venture groundfish fisheries would be limited to the prohibited species classification that prevents retention. This would remain a deterrent to targeting on crab, Pacific halibut, Pacific herring (addressed in a separate amendment package), and salmonids, but it would provide only a minimal incentive to control bycatch rates.

2.3.2 Alternative 2: Extend the Amendment 12a provisions for one year.

Adoption of this alternative would extend the bycatch provisions of Amendment 12a for one year. These provisions are limited to controlling the bottom trawl bycatch of C. bairdi Tanner crab, red king crab, and Pacific halibut in the DAP and JVP groundfish fisheries. The bycatch of these prohibited species with longline or pot gear does not count against the PSC caps and only the use of bottom trawl gear is prohibited once a PSC cap is taken.

Aggregate prohibited species catch (PSC) limits for C. bairdi Tanner crab, red king crab, and Pacific halibut, to be apportioned among DAP and JVP flatfish and other bottom trawl groundfish fisheries, would remain:

C. bairdi Tanner crab:	1,000,000 crabs in Zone 1 for Zone 1 closure 3,000,000 crabs in Zone 2 for Zone 2 closure
Red king crab:	200,000 crabs in Zone 1 for Zone 1 closure
Halibut:	4,400 mt catch in BSAI for Zones 1 and 2H closure 5,333 mt catch in BSAI for BSAI closure

Figure 2.1 presents bycatch protection zones in relation to statistical areas. Zone 1 includes statistical areas 511, 512, and 516. The Crab and Halibut Protection Zone (statistical area 512, and statistical area 516 from March 15 to June 15) would be retained. A discretionary provision to allow trawling for Pacific cod shoreward of the line approximating the 25 fathom depth contour would also continue. Existing requirements for approved data gathering programs and a 12,000 crab PSC limit for red king crab in this cod fishery will also continue. Zone 2 includes areas 513, 517 and 521. Zone 2H includes area 517 only. Statistical areas 514, 515, 522, 530 and 540 make up Zone 3.

Bycatch limits will be apportioned to the following four bottom trawl fisheries in proportion to their anticipated bycatch "need": (1) U.S. processed (DAP) flatfish fisheries (including yellowfin sole, rock sole, and other flatfish); (2) other DAP groundfish fisheries; (3) joint venture (JVP) flatfish fisheries; and (4) other JVP groundfish fisheries. If a flatfish fishery attains one of its bycatch apportionments, then bottom trawling for flatfish (yellowfin sole, rock sole, and other flatfish) will be closed in the associated areas (zone). If other fisheries attain one of their bycatch apportionments, then bottom trawling for only pollock and Pacific cod will be closed in the associated zone. As under Amendment 12a, the Regional Director of NMFS is expected to reapportion the respective bycatch caps among fisheries as necessary to minimize foregone groundfish catch if the closure of one fishery results in unused caps for other species.

2.3.3 Alternative 3: (Preferred) Modify and add to the Amendment 12a provisions and extend them for one year or an indefinite period.

The Council preferred this alternative, and adopted it for an indefinite time period. The overall PSC caps shall be reviewed annually, and possibly adjusted based on changes in population number or biomass of PSC and target species. This alternative modifies and adds to the bycatch provisions of Amendment 12a. These provisions are similar to those of Amendment 12a or Alternative 2 in that they are limited to controlling the bottom trawl bycatch of C. bairdi Tanner crab, red king crab, and Pacific halibut in the DAP and JVP groundfish fisheries. Similarly, the bycatch of these prohibited species with longline or pot gear does not count against the PSC caps and only the use of bottom trawl gear is prohibited once a PSC cap is taken.

Aggregate prohibited species catch (PSC) limits for C. bairdi Tanner crab, red king crab, and Pacific halibut would be the same as those of Amendment 12a or Alternative 2. The same is true for the definitions of Zones 1, 2, 2H, 3, and the Crab and Halibut Protection Zone. The restrictions on the trawl fishery for Pacific cod that could occur in the last zone would also be the same as under Amendment 12a.

The Regional Director in consultation with the Council will apportion the caps based on an assessment of bycatch needs with an evaluation of the best available information, to achieve optimal distribution for the purpose of maximizing groundfish harvest in order to achieve OY. Those apportionments may be divided into seasonal allowances. Target fisheries receiving apportionments of PSC caps will be implemented by regulations and may be changed by regulatory amendment. Until changed by regulatory amendment, the apportionment of the halibut, king crab, and C. bairdi Tanner crab caps will be among the following five trawl fisheries:

(1) JV flatfish

(2) DAP rock sole

(3) DAP flatfish (yellowfin sole/other flatfish)

(4) DAP turbot (deep water turbot/sablefish)

(5) DAP other (bottom trawl pollock, cod, rockfish, Atka mackerel)

In comparison to 12a or Alternative 2 cap apportionments, the differences are (1) the addition of the DAP rock sole fishery and the DAP turbot fishery, (2) the deletion of the JVP "other" fishery, and (3) the addition of the ability to make seasonal allowances of PSC limits.

If one of the four flatfish fisheries attains one of its bycatch apportionments, then bottom trawling in that fishery will be closed in the associated zone until an additional apportionment is available. If the other fishery attains one of its bycatch apportionments, then bottom trawling for only pollock and Pacific cod will be closed in the associated zone until an additional apportionment is available. As under Amendment 12a and Alternative 2, the Regional Director of NMFS is expected to reapportion the respective bycatch caps among fisheries as necessary to minimize foregone groundfish catch when the closure of one fishery results in unused caps for other species.

A major addition with Alternative 3 is that it provides for a program to identify and penalize bottom trawl vessels with excessive bycatch rates of halibut, red king crab, or C. bairdi Tanner crab. Each vessel participating in the bottom trawl fishery will be placed in one fishery each week based on its total BSAI catch (not retained catch) during that fishing week. The rules for identifying the fishery for each vessel and fishing week are as follows (N.B. the percentage figure following the fishery refers to the minimum proportion of the specified species in the overall groundfish catch):

(1) rock sole: 35%

(2) deep water turbot/sablefish: 35% (only Greenland turbot and arrowtooth flounder catch would be used to identify this fishery)

(3) Pacific cod: 45%

(4) Atka mackerel: 20%

(5) rockfish: 20%

(6) bottom trawl pollock: 50%

(7) sablefish: 20%

(8) yellowfin sole/other flatfish: 20%

(9) all other bottom trawl fisheries.

A vessel will be assigned to the first fishery for which it meets the minimum catch requirement; therefore, both the minimum catch composition rule and the order of the rules are important in identifying the fishery for a vessel each week. A distinction will be made between DAP and JVP fisheries.

This program would be based on bycatch rates observed on vessels such that:

(a) Weekly monitoring of each vessel's observed bycatch rates would be conducted to determine the vessel's average bycatch rates for each evaluation period. The evaluation period would be one week building up to the preceding four week period.

(b) All vessels with at least 2 days observer coverage during a fishing week will be included in the program for that week.

(c) Observed bycatch rates would be based on total catch rather than retained catch.

(d) If a vessel's average rate for any of the three bycatch species exceeds 2 times the fishery average for the evaluation period, that vessel will be suspended from further groundfish fishing in the exclusive economic zone off Alaska. The Council considered, but did not adopt, an option that no vessel would be penalized if it meets the historic industry average based on an update (1986-1989) of the rates in the NOAA Technical Memorandum NMFS F/NWC-155.

(e) Suspension periods would be five days for the first offense, two weeks for the second offense, and six weeks for the third offense. Multiple offenses would be counted "within PSC species" only. The period for accruing multiple offenses would be the most recent twelve month period.

(f) Unless otherwise required to do so by the domestic observer program, vessels returning to the fishery after suspension for a second offense would be required to carry an observer for the following two weeks. Vessels returning after a third offense would be required to carry an observer for the following four weeks.

(g) This program assumes that various fisheries can be adequately defined based on the definitions listed above. Revisions to these definitions will be based on the best information available.

(h) The number of target fishery cells to which the program will be applied will be determined by the Regional Director, in consultation with Council, based on optimal utilization of resources available to him.

This program assumes that the opening of flatfish fisheries, other than rock sole, will be delayed until May 1. It is also assumed that the directed fishing definition will be changed by regulatory amendment to allow greater retention of yellowfin sole/other flatfish in the rock sole fishery. The Council has requested the NMFS to prepare regulatory amendments to implement these changes.

2.4 Biological Background

2.4.1 Terms of Reference

To understand the proposed alternatives for bycatch management it is necessary to define and describe several terms.

Target fishing is defined as planned, deliberate operations designed to harvest certain animals within a species or a group of species. Fishing pots for hard shell male crab over a certain size, longlines for halibut over the minimum size limit, and trawls for a mixture of marketable flounder species are all examples of targeting. All major regulatory restrictions which are applied to a fishery will limit the options available to fishermen to some degree. However, controls specific to a target species (such as protection of female crab) are intended to increase sustained yields from the resource (in this case male crab). Similarly, minimum size limits are used in the halibut fishery since it is believed that the estimated hooking mortality on small fish (plus additional natural mortality) will be more than offset by weight gains in the survivors.

Bycatch is any incidental catch of nontarget species. Examples include crab and halibut taken in groundfish trawl fisheries. An important variable determining amount of bycatch is the density of that part of the population susceptible to the gear. Because portions of a population taken as bycatch in the groundfish fishery may not be the same as those targeted on in the crab and halibut fisheries, a large trawl bycatch of small crab might be taken in the same year that the crab pot fishery was completely shut down due to a low abundance of legal-sized males. However, size of the susceptible bycatch biomass is not the only important variable. The magnitude of the target fishery (both amount and rate of fishing) is important along with harvesting areas and times and fishing strategy and technique.

Substantial modifications in bycatch can also occur due to specific bycatch regulatory controls. In this case, regulations are intended to benefit sustained yields in fisheries directed at the bycatch species and not the target fishery being regulated for bycatch. Whenever this latter group's ability to harvest from the greatest concentrations of fish is impaired, then greater total effort will be required to take the same level of target harvest. Under such controls, costs of target fishing invariably go up. In addition, catches of other bycatch species, which perhaps were not covered under the original regulations, may increase markedly due to forced changes in fishing operations.

Bycatch rates in groundfish fisheries are generally expressed as numbers of crabs or metric tons of halibut (or other fish species) per metric ton of groundfish.

Fishing and bycatch exploitation rates are expressed in a number of different ways that sometimes add confusion to the bycatch issue. For example, a 40% annual exploitation rate on crab normally means that, on the average, 40% of the available male crab over a certain minimum size are taken each year by the directed pot fishery. The situation is similar for the halibut longline fishery since quotas and rates of harvest are generally computed for the exploitable or legal-sized biomass. However, the population effects of bycatch are normally evaluated as the impact on the entire population that is vulnerable to the groundfish gear.

Incidental mortality is comprised of all animals of non-target species that die as a result of encounters with fishing operations. It is the sum of (1) bycatch retained, (2) non-retained bycatch that dies as a result of capture and handling, and (3) individuals that are killed by the gear but are not observed as bycatch taken on board. Generally, only the first two elements are estimated in efforts to quantify incidental mortality. These two elements, representing mortality of incidental catch, are termed bycatch mortality. There can be a great deal of variability in mortality depending upon gear and mode of operation as well as size and condition of the individuals present. An example at the "low end" of the possible mortality range is the 1.2% mortality rate observed by ADF&G personnel during 1978-1981 for trawl-caught hard shell king crab in the Kodiak area (this estimate did not include mortality caused by deck time or delayed mortality caused by injuries once the crab were returned to the sea). At the high end of the range is the common assumption of 100% crab and halibut mortality in trawl fisheries with codend transfers or long towing and sorting times. Examples of intermediate values would be rates of halibut mortality of 65% for short trawl tows with rapid sorting and 13% from longline gear. The latter rates are currently used by the IPHC and the Gulf of Alaska Plan Team in assessing halibut bycatch. However, there are no similar estimates available for crab bycatch mortality rates.

Adult equivalents is a term that expresses catch of different age groups in standardized units and requires use of growth estimates as well as fishing and natural mortality rates. This allows for a direct comparison of the incidental take of bycatch species, generally juveniles in the case of halibut and crab, to the harvest of adults taken by directed fisheries. For example, the IPHC staff has developed a method of accounting for halibut bycatch mortality that determines the short-term yield loss to the directed halibut fishery. In this case, bycatch mortality is multiplied by 1.6 to estimate the amount of lost yield (mortality and yield are expressed in metric tons). This factor incorporates lost growth of juvenile halibut and natural mortality from the average age of bycatch to harvest in the halibut longline fishery. The information provided in Appendix 2.1 can be used to generate estimates of adult equivalents for C. bairdi Tanner crab and red king crab.

2.4.2 Biological Background

Basic data on historical population status and the bycatch of C. bairdi, red king crab, and halibut in foreign and joint venture groundfish fisheries are presented in Tables 2.1 - 2.4. Crab data are for the Bering Sea only but the data for Pacific halibut are, by necessity, presented in a broader context due to significant stock interchanges between management areas. These tables report only foreign and joint venture bycatch derived from the foreign fisheries observer program. The levels of crab and halibut bycatch in the DAP groundfish fisheries have not been monitored with an observer program; therefore, only rough estimates of this bycatch are available. The same is true for crab and halibut bycatch in other fisheries, including the crab fisheries.

It is apparent from these data (Table 2.1) that numbers of C. bairdi legal males were depressed in the mid-1980s relative to their status in the late 1970s, but have recovered partially in recent years. The Bering Sea harvest of C. bairdi fell from 42.5 million pounds in 1979 to 1.2 million pounds in 1984 and 3.3 million pounds in 1985. The fishery was closed in 1986 and 1987, but reopened in 1988. In 1989, 6.9 million pounds were harvested. Foreign and joint venture trawl fishery bycatch of C. bairdi has fluctuated, not necessarily in direct proportion to crab population size, from a high of 7.5 million animals in 1979 to values less than one million since 1982. Under various control programs since 1980, including no limits on joint ventures in early years, bycatch of C. bairdi other than DAP has been well below 1% of the concurrent population estimate. Current estimates of total population (summer 1989) indicated 949.9 million C. bairdi in the Bering Sea east of 173° E.

The abundance of legal male red king crab also declined sharply since the late 1970s, and is still depressed with only a limited recovery by 1989 (Table 2.2). From a high of 130 million pounds in 1980, the red king crab fishery in Bristol Bay took an average of only 2.8 million pounds during 1982-85, including no fishing in 1983. Harvests increased to 11.4 million pounds in 1986, and 12.3 million pounds in 1987, but declined to 10.2 million pounds in 1989. Foreign and joint venture trawl bycatch has remained below 1% of the concurrent population estimate of Bering Sea red king crab, except during 1985 after which emergency bycatch controls preceding Amendment 10 were implemented.

The estimated coast-wide exploitable biomass of Pacific halibut peaked in 1986 at approximately 259 million pounds and has declined to approximately 232 million pounds in 1988. The overall biomass, however, has remained near historically high levels and the decline in the exploitable biomass of Pacific halibut is consistent with the long-term cycles in abundance that have been observed for this population. Stock assessments for the Bering Sea/Aleutian Islands area indicate that biomass more than doubled from 1974 to 1986 and estimated abundance for that area is near the biomass that produces MSY (IPHC 1988, 1989).

Foreign and joint venture trawl and longline bycatch has resulted in an estimated 2,000-5,000 mt of annual halibut bycatch mortality since 1982. Coast-wide, halibut bycatch mortality decreased from 1980 to 1985, but increased sharply in 1988 (Table 2.3 and Figure 2.2). Adult equivalents of this bycatch mortality accounted for approximately 22.5% of total estimated halibut removals in 1989 (Table 2.4 and Figure 2.3). The IPHC uses a factor of 1.6 to expand from bycatch weight to adult equivalent weight. This accounts for growth and natural mortality between the age halibut are typically taken as bycatch and the age at which they are taken in the halibut fishery.

The groundfish fishery takes incidentally crabs of smaller sizes and younger ages than the crab fisheries. It also takes females crab that are not retained in the crab fisheries. The average age of male C. bairdi taken as bycatch is four years less than the average age of males in the pot fishery (Figure 2.4). The percentage decline in the exploitable population resulting from bycatch that annually removes a given percentage of the estimated total male population can be approximated by assuming that the size distributions of crabs taken as trawl fishery bycatch and of crabs sampled in population trawl surveys are the same. Note that the effect of the bycatch of female crab on future exploitable populations is not being addressed; however, it is elsewhere in this document.

The following example shows what would happen to 1,000 small male C. bairdi subject to four years of bycatch at 1% before the expected crab fishery harvest, under an assumption of 0.45 annual average natural mortality (J. Reeves, pers. comm.) and under the assumption that the size distributions are the same.

Assume 45% Annual Loss (no bycatch) 55% Survival	Assume 46% Annual Loss (1% bycatch) 54% Survival
1,000 Crabs	1,000 Crabs
Year 1 X 0.55 = 550 crabs	Year 1 X 0.54 = 540 crabs
Year 2 X 0.55 = 303 crabs	Year 2 X 0.54 = 292 crabs
Year 3 X 0.55 = 166 crabs	Year 3 X 0.54 = 157 crabs
Year 4 X 0.55 = 92 crabs	Year 4 X 0.54 = 85 crabs

One percent bycatch would have reduced the exploitable population by 7 crabs (92-85), a 7.6% reduction (7/92) from that which would have been available had no bycatch occurred. Note that this is only an approximation of the effect because the size distributions are not identical (Figure 2.5).

Depending on how these size distributions actually differ, this approximation could overstate or understate the actual effect.

There are approximately two years between average age of bycatch and catch of male red king crab in the crab fishery (Figures 2.6 and 2.7). An exercise similar to that developed above for C. bairdi would predict a 3.2% impact on exploitable populations of red king crab resulting from a 1% annual bycatch rate.

Assume 36% Annual Loss (no bycatch) 64% Survival	Assume 37% Annual Loss (1% bycatch) 63% Survival
1,000 Crabs	1,000 Crabs
Year 1 X 0.64 = 640 crabs	Year 1 X 0.63 = 630 crabs
Year 2 X 0.64 = 410 crabs	Year 2 X 0.63 = 397 crabs

Again, this 3.2% impact [(410-397)/410] is only an approximation of the effect of bycatch that annually removes 1% of the estimated total population of male crab.

Less than 10% of the bycatch of halibut, by number, in joint venture trawl fisheries is of animals of size (80 cm) and age that occur in the halibut longline fishery. On average, there is a difference of five years between age of trawl bycatch and catch in the halibut longline fishery (Figure 2.8).

The situation for Pacific halibut needs to be examined in a broader context than that used for crab since there is a major migration of fish between management areas. There is a general eastward migration from the Bering Sea to the Gulf of Alaska and a southward shift from Alaskan waters to areas off British Columbia, Washington and Oregon (Figure 2.9). The impact of Bering Sea bycatch on yield loss in other areas depends on migration rates from the Bering Sea; these rates are currently unknown.

General Caveats for Biological Impacts

Bycatch is primarily an issue of allocating surplus production among different resource users. When abundant crab and halibut resources are involved there is essentially no biological risk associated with anticipated levels of bycatch as long as catch in the crab and halibut fisheries are adjusted accordingly. However, when any population is reduced to a low level, potential for risk appears and accelerates rapidly as the population declines further, particularly if bycatch is restricted with numerical limits that do not reflect current stock conditions of the bycatch species. In some recent years, there have been no fisheries for C. bairdi and red king crab in the Bering Sea; thus only bycatch and natural mortality took place. With any population, a realistic assessment of risk requires an understanding of types of mortality and relationships between spawners and recruits. Unfortunately, these types of relationships are poorly defined for Bering Sea bycatch species. The absence of this information requires that management of bycatch be particularly conservative when stocks are at such low levels that the fisheries that target on them are not allowed to occur. This was the case twice for C. bairdi and once for red king crab during the mid 1980s.

Another reason for caution is the relative imprecision of population estimates for C. bairdi, red king crab, and possibly halibut. Crab surveys conducted since 1976 have a stated average confidence of plus or minus 31% for C. bairdi and plus or minus 39% for red king crab (Stevens and MacIntosh, 1989). Such wide confidence limits discount the relative importance of low percentage rates of bycatch because bycatch mortality is essentially masked by this variability. Assumptions of average annual mortality, such as 45% for C. bairdi and 36% for red king crab, and the 1.6 adult equivalent conversion for halibut, are also imprecise. Moreover, ADF&G reports errors of 6.6% to 19.9% in managing actual harvests of red king crab (1985-1988) to match inseason target levels (D. Schmidt, pers. comm.). Although the impact of bycatch is real, it is difficult to estimate its impact on eventual crab or halibut fishery harvests with a high degree of confidence.

Another important data gap is the rate and amount of bycatch encountered in DAP groundfish fisheries. Beginning in 1990, the domestic vessel observer program authorized under Amendments 18 and 13 to the GOA and BSAI groundfish FMPs will provide observer coverage for much of the BSAI groundfish catch. Previously, observer coverage was required only on foreign fishing vessels and processors. The latter provided bycatch information in joint venture catches. There was no comprehensive program to obtain similar information from wholly domestic fisheries. This lack of information on DAP fisheries impacts the evaluation of bycatch control alternatives and is increasingly important as DAP operators now capture the majority of the total groundfish harvest. In lieu of a domestic observer program, accounting of past DAP bycatch had to rely upon discarded-catch reports filed by DAP fishermen or on assumptions equating DAP bycatch rates to some proportion of those identified for JVP fisheries. In the past, the reporting of discards has not been uniformly complied with, and it is difficult to validate such reports. However, the IPHC has estimated halibut bycatch by fishery, including those for which few direct measures of bycatch exist.

2.5 Analysis of the Alternatives

To project the possible consequences of the alternatives being considered, it is necessary to predict the bycatch that might occur under each. This is difficult to do because bycatch will be determined by three factors, each of which can be highly variable. The three factors are: (1) future bycatch rates by fishery, area, and season; (2) future TACs; and (3) the future distribution of those TACs among fisheries, areas, and seasons. The annual variability in bycatch rates is demonstrated by the estimates of current (1987 - 1989) bycatch rates and total bycatch by fishery and zone presented in Tables 2.5 and 2.6.

The first analytical issue is the choice of appropriate bycatch rates. Future bycatch rates are unknown; only historically observed rates are available. This means that the rates used will be up to two years out of date (1989 and 1990 vs. 1991). However, bycatch rates are extremely variable, particularly for crab, and it is already evident that bycatch rates experienced in the 1990 fishery exceed those of recent experience. Further, with the exception of first quarter 1990 bycatch estimates for the DAP fisheries, the estimates of bycatch rates in the DAP fishery are assumed to equal the rates observed in the joint venture fisheries in 1989. This can be a source of error because DAP fishing patterns are not identical to JVP fishing patterns.

Another potential source of error is the assumption that the bycatch rates for an area, quarter, and fishery will be the same regardless of the levels of groundfish effort and catch. If catch per unit of effort decreases in an area and quarter as catch increases, bycatch rates would tend to increase as effort and catch increase. To the extent that this happens, the model projections of bycatch will be too low.

As the fishery has undergone a rapid evolution over the past several years with DAP operations displacing JVP operations, confidence in the implied DAP bycatch rates diminishes. The approach taken here uses the most recent bycatch data; second through fourth quarter 1989 and first quarter 1990 bycatch rates used in evaluating impacts under the 3 alternatives. It is less appropriate to use those rates for examination of the impacts of Alternative 1 because the observed rates occurred in a fishery operating under bycatch controls. However, the alternative of using fishery performance data from 1985, the last year of the uncontrolled fishery, would not necessarily be better because other factors have also caused bycatch rates to change since 1985.

The sum of total allowable catches in the BSAI management area is limited by the 2.0 million metric ton optimum yield cap. While the distribution of species' TACs within this overall cap is subject to fluctuations due to stock assessments and market conditions, the set of TACs adopted by the Council for the 1990 fishing year provides an appropriate set of TACs on which to base analyses for 1991.

The distributions of TACs among fisheries, areas, and seasons are difficult to estimate because the domestic fishery has been growing and changing rapidly in the last few years and because random factors, such as water temperatures, ice coverage, and market conditions, affect the distributions. In the absence of adequate historical data on which to base projections of the distributions of TACs, estimates provided by the groundfish industry are used. These estimates were provided to the NMFS during a meeting with industry representatives in March.

The bycatch rates by fishery, area, and quarter used in the model are in Tables 2.7a and 2.7b. The TACs and their apportionments between DAP and JVP fisheries as used in the model are in Table 2.8. Finally, the estimates of the area and seasonal distributions of TACs used in the model are in Tables 2.9 and 2.10.

The bycatch model developed for Amendment 12a was modified to provide estimates of how each alternative would affect groundfish catch, bycatch, the gross and net values of the groundfish catch, and the impact cost of the bycatch. The main modifications include the use of the input variable values presented in Tables 2.7 through 2.10, the addition of an economic component, the use of a different aggregation of fisheries for Alternative 3, the elimination of the matrix inversion that was used to allocate the DAP apportionments of the TACs among four aggregate fisheries, and the use of three identical periods each quarter to approximate monthly time steps.

The model is run twice for each alternative. The first run is used to estimate what bycatch would be in each of the aggregate fisheries if there were not PSC limits. Those estimates of unconstrained bycatch by area and fishery are used to apportion each PSC limit among the aggregate fisheries. For example, if it is estimated that the total unconstrained bycatch of red king crab in Zone 1 would be 300,000 crab and the unconstrained bycatch in the DAP rock sole fishery would be 150,000 crab, the DAP rock sole fishery would be apportioned 50% of the 200,000 crab PSC limit for Zone 1. The PSC caps would have been "used" more effectively had additional model runs been made with the surplus caps reapportioned to the fisheries that were constrained by their apportionments. There was not sufficient time to do this.

The second run provides estimates of catch, bycatch, and economic performance of the fisheries when they are constrained by the total PSC limits and the apportionments of those limits determined from the unconstrained run. In the second run, a fishery is closed in an area once it takes its apportionment of a PSC limit. When a fishery is closed, the catch that would have been taken from the closed area in each future period is proportionately redistributed among the areas that remain open. For example, if it was assumed that the third quarter catch for a fishery will be 50,000 mt, 60,000 mt, and 90,000 mt, respectively, in Zones 1, 2, and 3, and if Zone 1 is estimated to be closed at the end of the second quarter, the third quarter catches would be 0 mt, 80,000 mt, and 120,000 mt for the three zones.

The estimates of the gross and net values of the groundfish catch for each alternative are based on: (1) estimates of catch by fishery, area, and quarter; (2) estimates of catch per unit of effort (CPUE) by fishery, area, and quarter, in terms of groundfish catch per hour of trawling time (Table 2.11); (3) estimates of fixed costs, variable costs that are dependent on CPUE, and variable costs that are only dependent on catch (Table 2.12); and (4) estimates of the gross value per metric ton of groundfish catch (Table 2.13). For the joint venture fisheries, the exvessel price received by domestic fishermen was used to estimate the value of catch. For the domestic fisheries, the first wholesale value of the resulting processed products was used.

The estimates of the bycatch impact costs are the products of estimated bycatch and estimates of the impact cost per crab or per metric ton of halibut taken as bycatch. It is assumed that bycatch mortality is 100%. The impact costs can be adjusted to reflect alternative mortality assumptions by multiplying the impact costs presented in this report by alternative mortality rates. The estimated impact costs are in terms of the present discounted value of foregone gross exvessel value. A real discount rate of 5% is used. The estimates for crab are based on the expected growth and natural mortality that would occur between the typical ages of capture as bycatch in the groundfish fishery and retention in the crab fishery. The estimation procedure and this measure of impact cost are more fully discussed in Appendix 2.1.

A different method is used to estimate the impact cost of halibut bycatch because the quotas in the halibut fisheries are adjusted based on estimated bycatch mortality. In the past, the IPHC reduced the total quota for the halibut fishery by about 1.6 mt for each 1 mt of estimated bycatch mortality in the groundfish fishery. The policy of the IPHC is now to maintain reproductive output (egg production) at the same level it would be in the absence of bycatch. This results in bycatch in one year affecting halibut quotas over a 9-year period. Based on IPHC estimates of the effect by year for each of the nine years (Will Clark, IPHC, personal communication), the discounted present value of the resulting change in quotas is approximately 1.32 mt of halibut for each 1 mt of halibut bycatch mortality. This means that if the dressed weight exvessel price of halibut is $1.51 per pound, as it was on average in 1989, if the dressed weight recovery factor is 0.75, and if the exvessel price is not affected by the decrease in halibut catch, each 1 mt of halibut bycatch mortality will decrease the discounted present value of halibut fishery gross exvessel value by about $3,300 (2,205 lbs x 1.32 x 0.75 x $1.51).

2.5.1 Summary of Bycatch Model Results

Four sets of model runs were made to estimate the effects of the alternatives being considered in Amendment 16. The cases considered for each alternative are as follows:

Alternative 1: 12a provisions expire

JVP flatfish fisheries begin the first quarter and 75% of the pollock TAC is taken in the mid-water fishery

Alternative 2: 12a provisions extended

Case A: JVP flatfish fisheries begin the first quarter and 75% of the pollock TAC is taken in the mid-water fishery

Case B: JVP flatfish fisheries begin May 15 and 75% of the pollock TAC is taken in the mid-water fishery

Alternative 3: 12a provisions extended and modified, and the use of vessel incentives changes bycatch rates

JVP flatfish fisheries begin May 15 and 75% of the pollock TAC is taken in the mid-water fishery.

The results are summarized in Tables 2.14 through 2.18. Table 2.14 contains the projected apportionments of the individual PSC caps.

2.5.1.1 Alternative 1

The results suggest that, in the absence of the 12a regulations, bycatch for all of the BSAI would include about 760,000 red king crab, 3.7 million C. bairdi Tanner crab, and 5,900 mt of halibut and the total bycatch impact cost would be about $31.5 million (Table 2.15). With Alternative 1, it is projected that four of the expired PSC caps would be exceeded. They are the red king crab and C. bairdi Tanner crab PSC caps in Zone 1 and the primary and secondary BSAI area-wide halibut caps. The expired crab caps would be exceeded by about 546,000 red king crab (273%), 1.5 million Tanner crab (150%) (Table 2.16). The expired primary and secondary halibut caps would be exceeded by 1,500 mt of halibut (34%) and 576 mt of halibut (11%), respectively.

2.5.1.2 Alternative 2

Case A

The results suggest that, if the 12a regulations are extended, if the JVP flatfish fishery begins early in the year, and if 75% of the pollock TAC is taken with mid-water trawls, bycatch would be substantially less than if the regulations were not extended. For all of the BSAI, bycatch would include about 270,000 red king crab, 2.1 million C. bairdi Tanner crab, and 4,900 mt of halibut and the total bycatch impact cost would be about $20.7 million (Table 2.15). It is projected that both the Zone 1 red king crab PSC cap and the primary halibut PSC cap would be exceeded. The 200,000 king crab cap would be exceeded by 55,300 crab (28%) and the 4,400 mt halibut cap would be exceeded by 465 mt of halibut (10.6%).

The attainment of the king crab cap in January would close the Zone 1 DAP rock sole fishery, the DAP other fishery (Pacific cod and bottom trawl pollock), and the JVP flatfish fishery (Table 2.17). The other projected closures are the DAP other fishery in Zones 1 and 2H and then in the BSAI as a whole and the DAP turbot fishery in the BSAI.

Case B

If the JVP flatfish fishery is delayed until May 15 and 75% of the pollock TAC is taken in the mid-water fishery, the projections are quite different than if the JVP fishery is not delayed: (1) there are no closures due to the crab caps; (2) the primary and BSAI area-wide halibut cap apportionments would be taken and close the DAP turbot and other fisheries and the JVP flatfish fishery, but the 5,333 mt cap would not be exceeded; (3) halibut bycatch would increase with the primary halibut cap being exceeded by 800 mt (24%); (4) no other cap is attained; (5) projected bycatches for all of the BSAI are about 155,000 red king crab, 2.0 million C. bairdi Tanner crab, and 5,200 mt of halibut; and (6) the total bycatch impact cost would be about $20.3 million.

The delay of the JVP flatfish fishery is projected to reduce red king crab bycatch substantially, have little effect on C. bairdi Tanner crab bycatch, increase halibut bycatch, and have little effect on total bycatch impact costs, but allow increases in groundfish catch and revenue. Therefore, the delay of the JVP flatfish fishery is projected to provide net benefits.

2.5.1.3 Alternative 3: (Preferred)

There are three major differences between Alternative 3 and Case B of Alternative 2. First, with Alternative 3, there are two additional DAP fisheries which receive PSC cap apportionments. They are the deep water turbot fishery and the rock sole fishery. Second, the PSC caps can be divided into seasonal allowances in addition to being apportioned by fishery. Third, there is a provision for sanctions against vessels with excessive bycatch rates. The merits of each of these three differences are discussed below.

The turbot fishery took a disproportionately large share of the other DAP fishery halibut PSC apportionment in 1990 because there was not a separate PSC apportionments for turbot. The bycatch rate in the turbot fishery was about 8.2 mt of halibut per 100 mt of groundfish. The comparable rates for the pollock and cod bottom trawl fisheries are 0.3 and 1.2, respectively. The high bycatch rates in the turbot fishery mean that less groundfish can be taken before the halibut PSC closures for Zones 1 and 2H and the BSAI as a whole. This adversely affects the bottom trawl pollock and cod fisheries because they are the only fisheries that are closed once the other DAP fishery PSC apportionment is taken. Therefore, the absence of separate PSC apportionments for the turbot fishery resulted in both equity and efficiency problems. The ability to establish separate PSC apportionments for the turbot fishery provides managers with greater flexibility in controlling bycatch in an equitable and efficient manner. This is a benefit if it is used to enable a greater proportion of groundfish TACs to be harvested within a PSC apportionment.

The lack of separate PSC apportionments for the rock sole fishery in 1990 precluded the possibility of a DAP flatfish fishery after March 19 because the DAP rock sole fishery took the BSAI wide DAP flatfish apportionment by that date. The roe rock sole fishery is currently the most profitable DAP flatfish fishery and most flatfish fishermen would probably prefer to be able to use the caps to take roe rock sole than less valuable flatfish. The establishment of separate rock sole apportionments could be used to limit the bycatch of crab and halibut in that fishery. Therefore. it could be used to allow for larger PSC apportionments to the DAP flatfish and other bottom trawl fisheries. This could have postponed the expected closures of the bottom trawl pollock and cod fisheries in the BSAI. As noted above, this additional flexibility in managing bycatch equitably and efficiently is a benefit if it results in increased proportions of groundfish TACs harvested for a given PSC apportionment.

The ability to divide PSC apportionments into seasonal allowances can mitigate equity and efficiency problems. With respect to equity, seasonal allowances can be used to assure that a fishery is not precluded from occurring just because it occurs late in the year after other fisheries, including some with much higher bycatch rates, have exhausted the PSC caps. Similarly with respect to efficiency, seasonal allowances can be used to provide an opportunity for a very profitable fishery that occurs late in the year and perhaps with relatively low bycatch rates. The ability to establish an allowance for a fishery when its bycatch rates are lower, could be used to limit a fishery to such a season and allow more groundfish to be harvested for a given set of PSC caps. This is an example of an action that those participating in a fishery, such as the domestic turbot or joint venture flatfish fishery, may choose to take but would be unable to take and enforce by themselves.

Seasonal allowances, once set for a year, will reduce one source of uncertainty for those planning fishing operations. This is because, the potential for an earlier fishery to take all of a PSC apportionment to preclude a later fishery can be reduced or eliminated.

The seasonal allowances would be determined using the same process that has been used under Amendment 12a to apportion the overall PSC caps among fisheries. However, because these allowances can determine the magnitude of the fisheries during the first part of the year, it may be desirable to have the final allowances set well before the beginning of the fishing year. For example, waiting until the December Council meeting could impose heavy costs on those scheduling fishing operations for the beginning of the year.

Seasonal allowances provide additional flexibility for managing bycatch equitably and efficiently. The way that this flexibility is used will determine the benefits of this flexibility. The bycatch prediction model was not used to evaluate alternative seasonal allowances. However, it can be used in determining these allowances just as it can be used in determining the apportionments of individual PSC caps among fisheries.

The third major difference with Alternative 3 is that it includes sanctions on vessels with excessive bycatch rates. Specifically, a vessel with a bycatch rate substantially above a fishery average would be prohibited from further fishing for a specified period of time. The specifics of this program are more fully discussed in Section 2.3.3. This program is intended to discourage vessels from having excessive bycatch rates and, at least temporarily, to remove vessels that do have such rates. This is intended to reduce both equity and efficiency problems.

An equity problem currently exists because a small number of vessels with high bycatch rates can close a fishery well before its TACs have been taken. By so doing, these vessels can inflict very high costs on the fleet as a whole. For example, in the 1990 DAP rock sole fishery, the 4 observed vessel with the highest king crab bycatch rates took about 50% of the observed catch but 88% of the observed red king crab bycatch in that fishery. In the 1990 DAP Pacific cod fishery, the 5 vessels with the highest red king crab bycatch rates took about 15% of the catch but 93% of the red king crab bycatch in that fishery.

An efficiency problem exists for two reasons. Without an incentive for each vessel to consider the costs of an excessive bycatch rate on the rest of the fleet, the benefits that can be derived from a given PSC apportionment will be reduced. Second, the marginal value of bycatch to vessels with uncommonly high bycatch rates may not justify the use of crab and halibut as bycatch. That is, there will be the wrong distribution of the apportionment among groundfish vessels and the wrong apportionment of crab or halibut to bycatch.

By providing sanctions against vessels with exceptionally high bycatch rates, this program holds fishermen individually accountable for their bycatch if it is too high. This will provide fishermen with an incentive not to have excessive bycatch rates. It may have little effect on fishermen who already have bycatch rates that are close to fishery averages.

The periods for which bycatch rates would be measured against the fishery average will be from one week building up to the preceding four week period. With a shorter period, a vessel that has excessive bycatch rates will be penalized more quickly. Therefore, such vessels would have a smaller adverse effect on the rest of the fleet. With a shorter period, there would be less damage caused by a vessel completely ignoring bycatch and having an even higher bycatch rates once it becomes obvious that the vessel cannot reduce its rates to acceptable levels. However, with a short period, a vessel has less of an opportunity to correct its fishing strategy and reduce its bycatch rates to acceptable levels. The management cost would also tend to be higher for shorter and therefore more frequent periods.

Another issue is the duration of penalties. The foregone gross earnings per day can be about $50,000 for a small factory/trawler to significantly more for a large factory/trawler or mothership. It is assumed that a mothership would be held accountable for the bycatch it receives because it can influence the bycatch rates of the catcher boats from which it receives fish. Although the cost to a vessel would be less than the foregone gross earnings because some costs would also be reduced, foregone earnings per day is probably not a bad proxy for the cost to the operation as a whole including lost income to the crew. This means that a penalty of a few days for the first offence would provide a substantial incentive not to have excessive bycatch rates. The provisions for increasing penalties for multiple offenses would provide substantial incentive for a vessel operator to take remedial measures to reduce excessively high bycatch rates.

To provide a rough approximation of the effect of imposing sanctions on each vessel with a bycatch rate greater than twice the fishery mean, the bycatch rates of vessels that had bycatch rates below this level were estimated on a weekly basis using NMFS Observer Program data for the 1989 and 1990 joint venture fisheries and the 1990 domestic fisheries. One surprising result is that, when this rule is applied to each of the three bycatch species, the average bycatch rates for the vessels without excessive bycatch were typically but not always below the average rates for all vessels. The reason why the average bycatch rate can be higher for the vessels without excessive rates than for all vessels is that some vessels that have excessive rates for one bycatch species may have lower than average rates for another species. This points out the importance of remembering that bycatch is a multispecies problem and that an action taken to reduce the bycatch of one species can increase that of another.

The bycatch rates for Alternative 3 are based on estimated average bycatch rates of vessels that on a weekly basis did not exceed twice the weekly average bycatch rate for any of the three bycatch species. This was done for each of the nine fisheries defined in Section 2.3.3. The catch and bycatch of each vessel with an excessive bycatch rate in a week was excluded before the new weekly total catch and bycatch were calculated. The sums of the new weekly catches and bycatches were than used to calculate new average bycatch rates for the five fisheries that receive PSC apportionments. The bycatch rates for these five fisheries for Alternative 3 are presented in Table 2.7b. Note that, for some of the fisheries some bycatch rates are higher with the sanctions than without them.

As with Case B of Alternative 2, the JVP flatfish fishery is delayed until May 15 and 75% of the pollock TAC is taken in the mid-water fishery. The differences are due to the estimated effects of the vessel incentive program. The projections and comparisons to Alternative 2 Case B are as follows: (1) there are no closures (vs. primary or secondary halibut closures); (2) no PSC cap is attained (vs. the primary halibut cap is exceeded); (3) projected bycatches for all of the BSAI are about 206,000 red king crab (vs. 155,000), 1.8 million C. bairdi Tanner crab (vs. 2.0 million), and 4,400 mt of halibut (vs. 5,200 mt); (4) the total bycatch impact cost would be about $18.2 million (vs. $24.9 million); and (5) there are insignificant reductions in groundfish catch and gross or net revenue compared to Alternative 1 (vs. a 13% reduction in catch and a smaller reduction in revenue). This suggests that Alternative 3 is preferable to Alternative 2 in terms of reducing total bycatch impact costs, increasing groundfish catch, and increasing the gross and net revenue associated with that catch.

The benefits of decreased bycatch rates resulting from a vessel incentive program tend to be greater when the PSC caps are expected to be met and constrain groundfish catch. Such incentives provide what may be a critical margin for error in the estimates of bycatch. That is the additional constraints placed on the groundfish fishery by the vessel incentive program of Alternative 3 will increase the probability that the TACs can be utilized fully. However, these constraints will also impose costs on the groundfish fishery. It is difficult to estimate what the costs will be.

The cost of responding to the vessel incentive program is not known. If the penalties for excessive bycatch rates are substantial, the cost of actions taken by groundfish fishermen to reduce bycatch rates could exceed the benefits in terms of reduced bycatch or increased groundfish catch. The disparity between the benefits and costs may be substantial for some fishing operations even if it is not for the groundfish fishery as a whole.

2.5.2 Reporting costs

Current regulations require industry representatives to submit weekly reports to NMFS that summarize each groundfish processor's weekly groundfish production and discard amounts. This information is used by NMFS to extrapolate weekly catch amounts for purposes of groundfish quota monitoring. Observers onboard groundfish vessels and at shoreside processing plants also submit weekly reports on groundfish catch by species and prohibited species bycatch. This information is used to calculate prohibited species bycatch rates for halibut and crab, that are then applied against extrapolated weekly catch amounts to derive weekly bycatch amounts of halibut, C. bairdi, and red king crab for purposes of monitoring fishery apportionments of established PSC caps.

Weekly monitoring of bycatch has proven inadequate for precise monitoring of PSC limits, particularly in short-term fisheries where apportionments of PSC caps are sometimes exceeded. Timely inseason management of PSC limits, particularly under Alternative 3, will require considerable improvement to current communication and information processing systems. A regulatory amendment should be developed to provide the Regional Director with the authority to require groundfish processors to submit daily catch reports as PSC limits or groundfish quotas are approached. More frequent catch reports will provide inseason managers with updated information on which to monitor PSC amounts and enhance their ability to maintain bycatch within specified PSC limits. Prompt processing of daily observer messages and/or processor catch reports will require full implementation of a satellite communication system, e.g., COMSAT Standard C, for direct two-way communication of data and information between vessel operators and/or observers and Regional managers. Costs of this system are estimated at between $5,000 and $10,000 per unit, the burden of which would be borne by participating vessels and processors. The specific costs to the industry to submit daily reports when requested to do so by the Regional Director will be analyzed under the regulatory amendment that is developed to implement this requirement and are not addressed further within the context of the bycatch alternatives considered above. Additional administrative costs may be incurred by NMFS staff if the number of observer reports are increased and additional time and/or personnel are needed to compile, edit, and enter daily observer reports. Computer to computer communication of reports would minimize some of these costs.

2.5.3 Administrative, Enforcement, and Information Costs

Under Alternative 1, administrative, enforcement, and information costs would decrease because monitoring PSC amounts inseason would no longer be necessary.

Under Alternative 2, administrative and enforcement costs would remain at existing levels, or about $100,000 per year. Current administrative costs associated with bycatch management include staff time developing analyses to predict the bycatch needs of four different categories of groundfish fisheries (JVP and DAP flatfish and "other" fisheries); weekly (sometimes daily) analyses of observer reports and reported catch to determine red king crab, C. bairdi, and halibut bycatch amounts occurring in different management areas for each fishery; the development and maintenance of a system that provides for timely inseason monitoring of PSC limits; deriving appropriate control of each fishery as it approaches its specific bycatch allowance; frequent communication with the industry on the status of PSC allowances; and drafting and publishing Federal Register closure notices once a fishery has attained its apportionment of a PSC limit.

Under Alternative 2, a total of 20 separate PSC apportionments would be monitored on at least a weekly basis (daily for fast-paced fisheries or as fisheries approach their apportionment of a PSC limit). NMFS estimates that personnel and administrative costs associated with inseason monitoring of prohibited species bycatch under Alternative 2 will approach $100,000 by 1991. This amount includes personnel costs associated with three statisticians working between 10 and 40 hours a week on PSC monitoring, and one part-time programmer (total personnel costs of about $75,000 per year).

Administrative and enforcement costs under Alternative 3 would be substantially higher than those estimated for Alternative 2 due to additional personnel and computer hardware necessary for individual vessel monitoring and enforcement. Appendix 2.2 to this chapter contains a summary of NMFS' experience with individual vessel/company monitoring, the administrative burden to implement these programs, and risks associated with vessel incentive programs.

The NMFS' experience with vessel incentive programs over recent years indicates that one staff person working a 40-hour week would be required to monitor up to 20 separate vessels or operations if daily monitoring were required. In those situations where weekly monitoring of bycatch were appropriate, a single person working about 20 hours a week could monitor about 40 vessels or operations if the receipt of weekly reports from vessels and observers were spread throughout the week. Assuming the number of observer reports would increase with daily or even weekly monitoring of individual operations, an additional part-time position would be required within the NMFS observer program to receive and verify additional observer reports. The number of vessels requiring individual monitoring would be a function of the usual number of boats participating in a fishery.

Given the number of JVP and DAP vessels fishing in the "flatfish", [rock sole], and/or "other" fisheries, NMFS estimates that a full-time programmer and up to four additional staff would be required for inseason monitoring of individual vessel bycatch rates under Alternative 3 (approximately $150,000 to $170,000 per year). Given that different fisheries are prosecuted at different times of the year, staff needs would likely be irregularly spaced throughout the year, which suggests that some of the additional positions could be filled by short-term assignments of personnel from other regions or agencies.

Additional enforcement costs would also be incurred under Alternative 3. Individual vessels may choose to challenge information used to estimate their bycatch rates and the fishery average rates and may request an adjudicative hearing. How often individual vessels or operations would challenge actions taken against individual vessels as the result of estimated bycatch rates is unknown. However, actions of this sort would be administratively time consuming and costly. Frequent hearings procedures would, at a minimum, require another staff position with the Region's Office of General Counsel (approximately $50,000 per year).

In summary, additional administrative costs for development, implementation, and maintenance of a reliable vessel incentive program under Alternative 3 could be as high as $434,000 during the 1990-1991 development and implementation period and about $355,000 annually thereafter.

Another cost that should be considered is that of the additional burden that may be placed on observers. With any vessel incentive program, there will be substantial pressure to have the observer observe or report less bycatch. The intensity of this pressure may be greater with individual vessel incentive programs than with fleet-wide caps.

2.5.4 Redistribution of Costs and Benefits

The management of incidental catch attempts to minimize losses to those who target on the species and to minimize the cost of avoiding the bycatch species to those who harvest groundfish. Bycatch management is therefore, above all, an allocation of certain amounts of bycatch species to those who target on the species and to those who catch it incidentally while prosecuting other fisheries. The projected effects of each alternative on bycatch, groundfish catch, bycatch impact costs, and both gross and net earnings in the groundfish fishery (Table 2.15) provide estimates of the redistribution of a variety costs and benefits. In using these estimates, it should be realized that the estimates are highly speculative because the variables that determine what the effects will be are subject to large fluctuations that cannot predicted accurately.

2.5.5 Cost/Benefit Conclusions

The bycatch of crabs and halibut in groundfish fisheries results in a reduction in future harvestable populations of crab and halibut. Some of the crab and halibut taken as bycatch would, over time, have grown and become available to their respective target fisheries while others would have died due to natural mortality. By accounting for natural mortality rates, an estimate can be made of the percentage of bycatch that would otherwise have been available to directed crab and halibut fisheries.

The analyses examine the effect on the bycatch species, crab and halibut. It is also apparent that the alternatives would each have a different effect on groundfish harvesters by forcing them to fish in areas of (potentially) lower catch per unit effort. When the harvesters move due to bycatch constraints, their costs would increase for the same amount of catch, resulting in decreased profits of some unknown magnitude. These increased costs have been estimated. However, there are a variety of reasons why the estimates may not be accurate. These costs need to be balanced against the gains to crab and halibut fishermen. Alternatives 2 and 3 may actually restrict groundfish harvests. Although the bycatch model projections indicate that the groundfish TACs will be fully harvested under Alternatives 1 or 3, the current ability to accurately predict bycatch is severely limited due to the potential fluctuations in the determinants of bycatch. Therefore, an alternative that will tend to result in lower bycatch rates can help provide a margin for error that could be critical if the actual bycatches are greater than those projected by the model.

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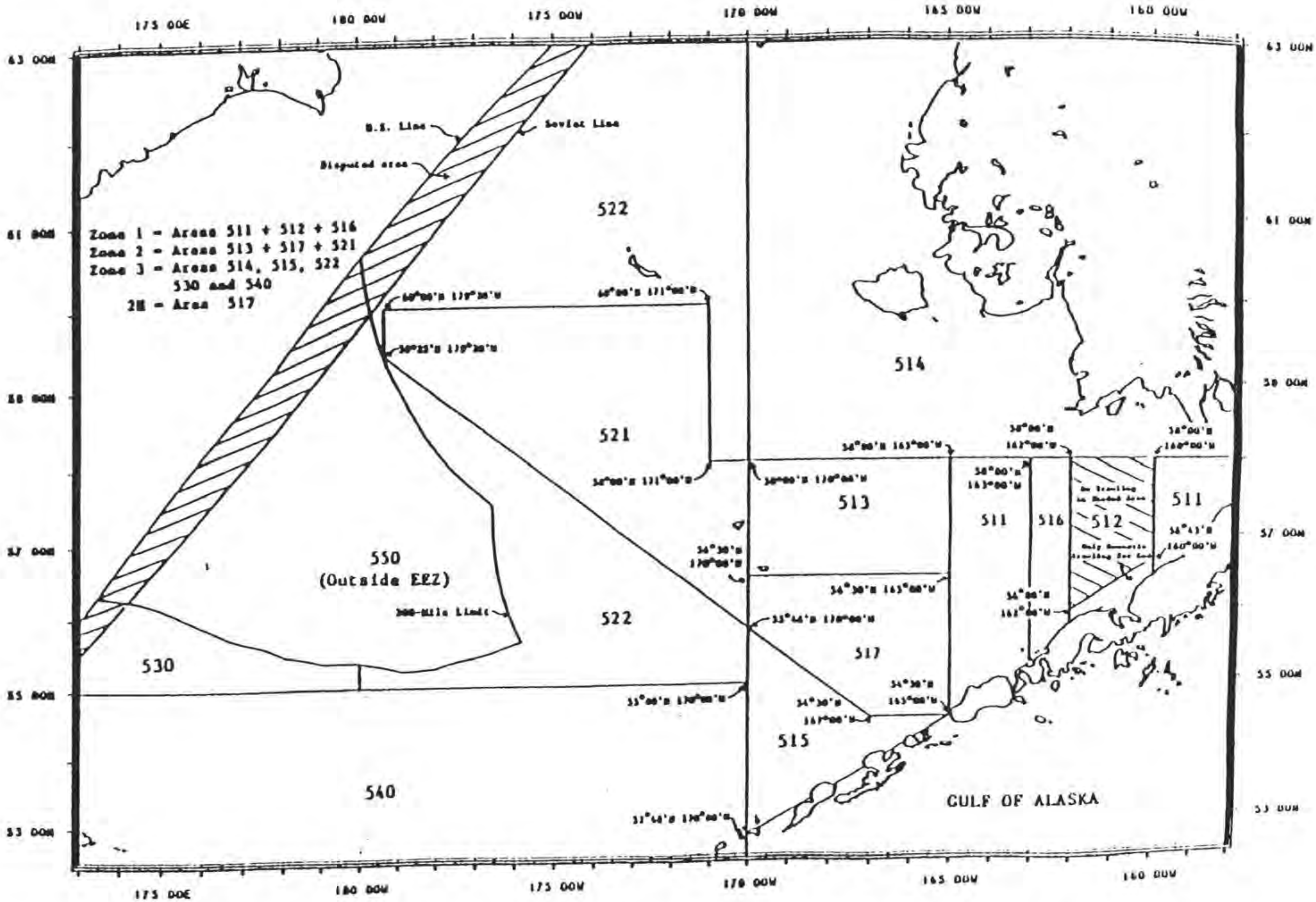

Figure 2-1. Bering Sea zones by which the restrictions on the incidental catch of king and Tanner crab apply.

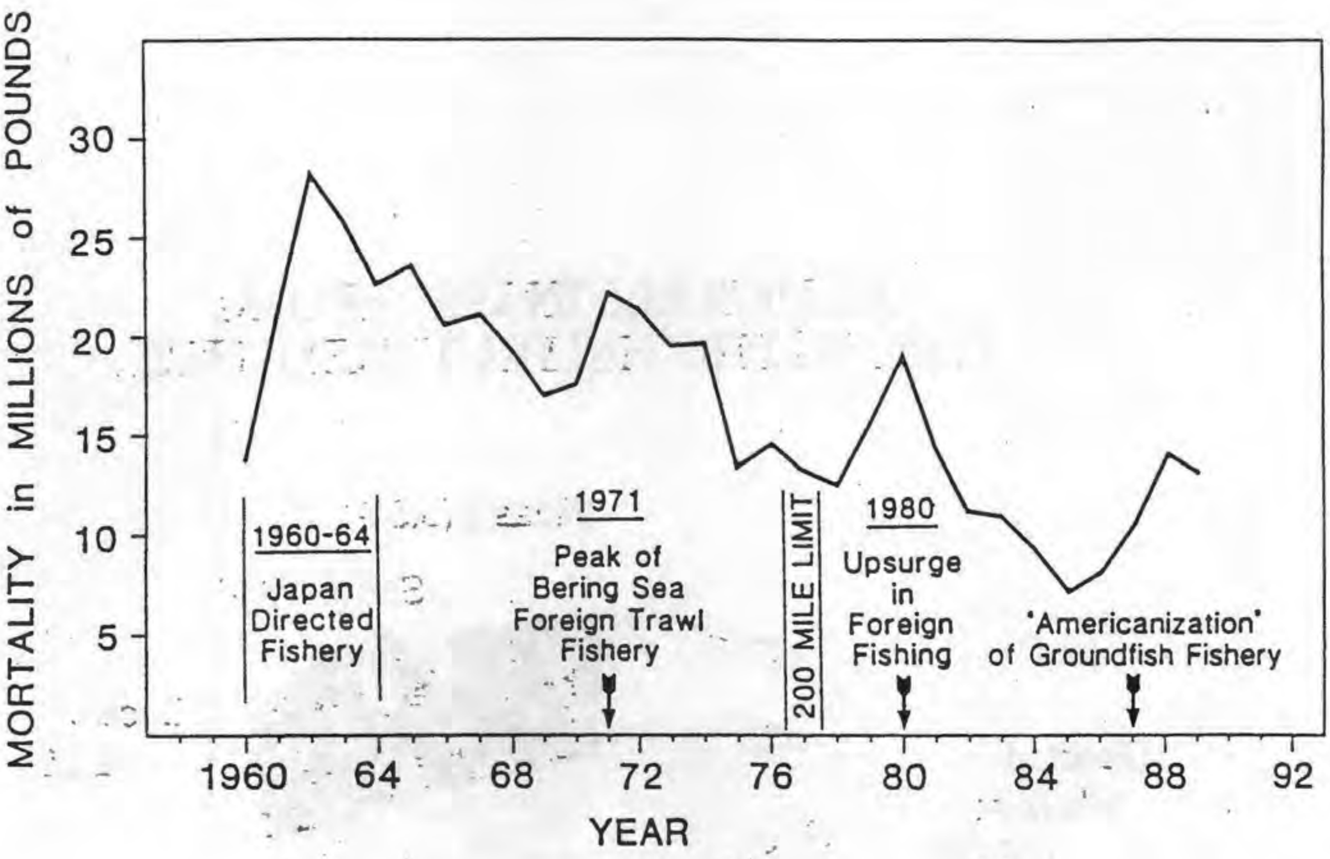

Figure 2.2 Trend in incidental (bycatch) mortality of Pacific halibut coast wide since 1960.
Source: Gregg Williams (IPHC).

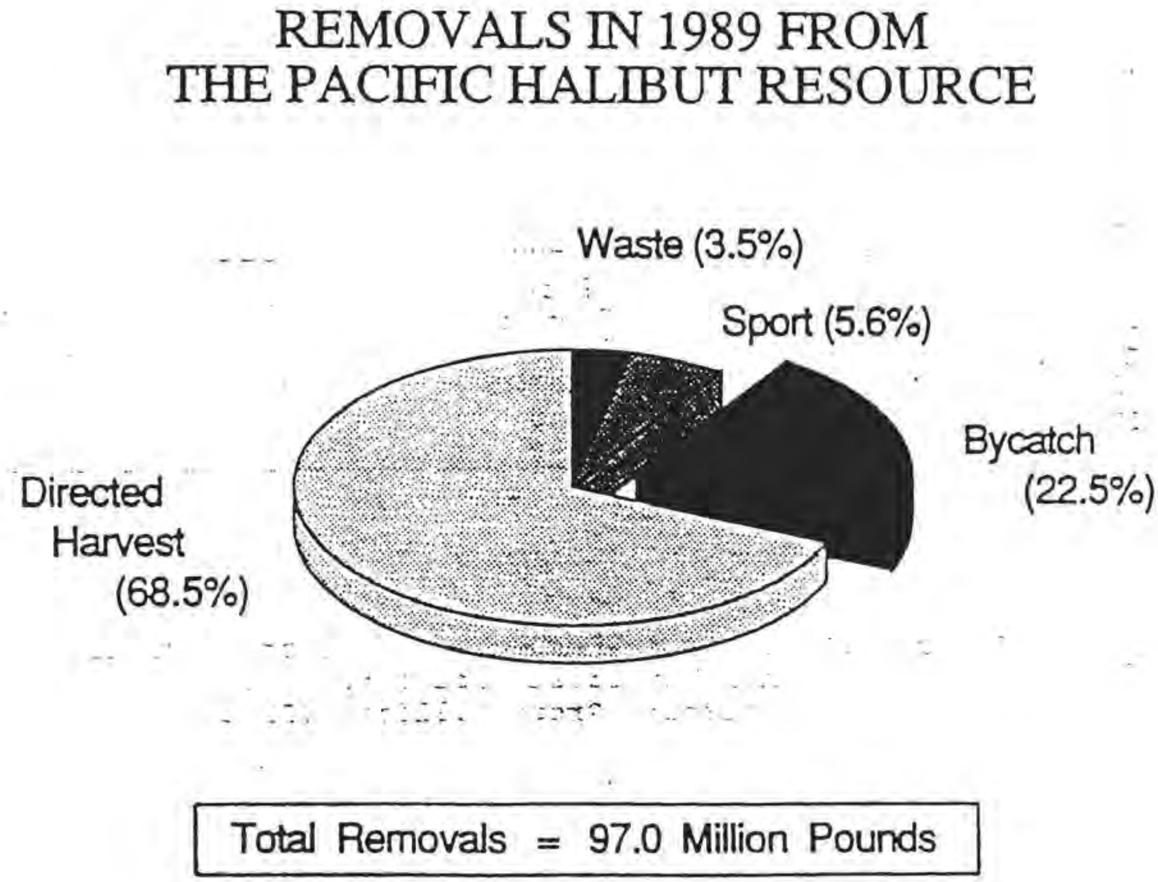

Figure 2.3 Breakdown of Pacific halibut Annual Surplus Production coastwide in 1989. Source: Gregg Williams (IPHC).

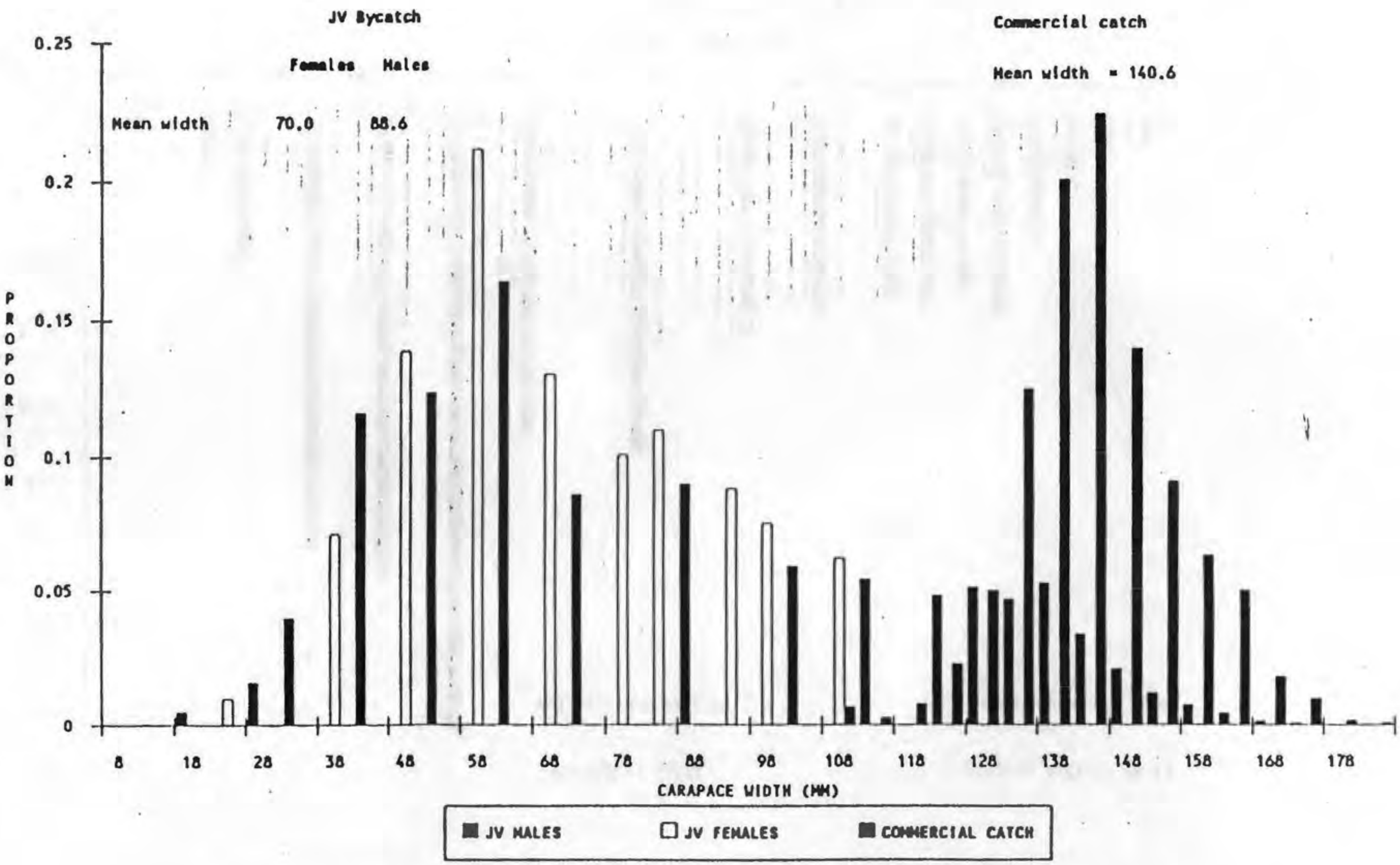

Figure 2.4 Size distribution of C. bairdi in the 1988 JV trawl bycatch and the 1988 commercial pot harvest. Sources: Jerry Berger (AFSC); Ken Griffin (ADF&G).

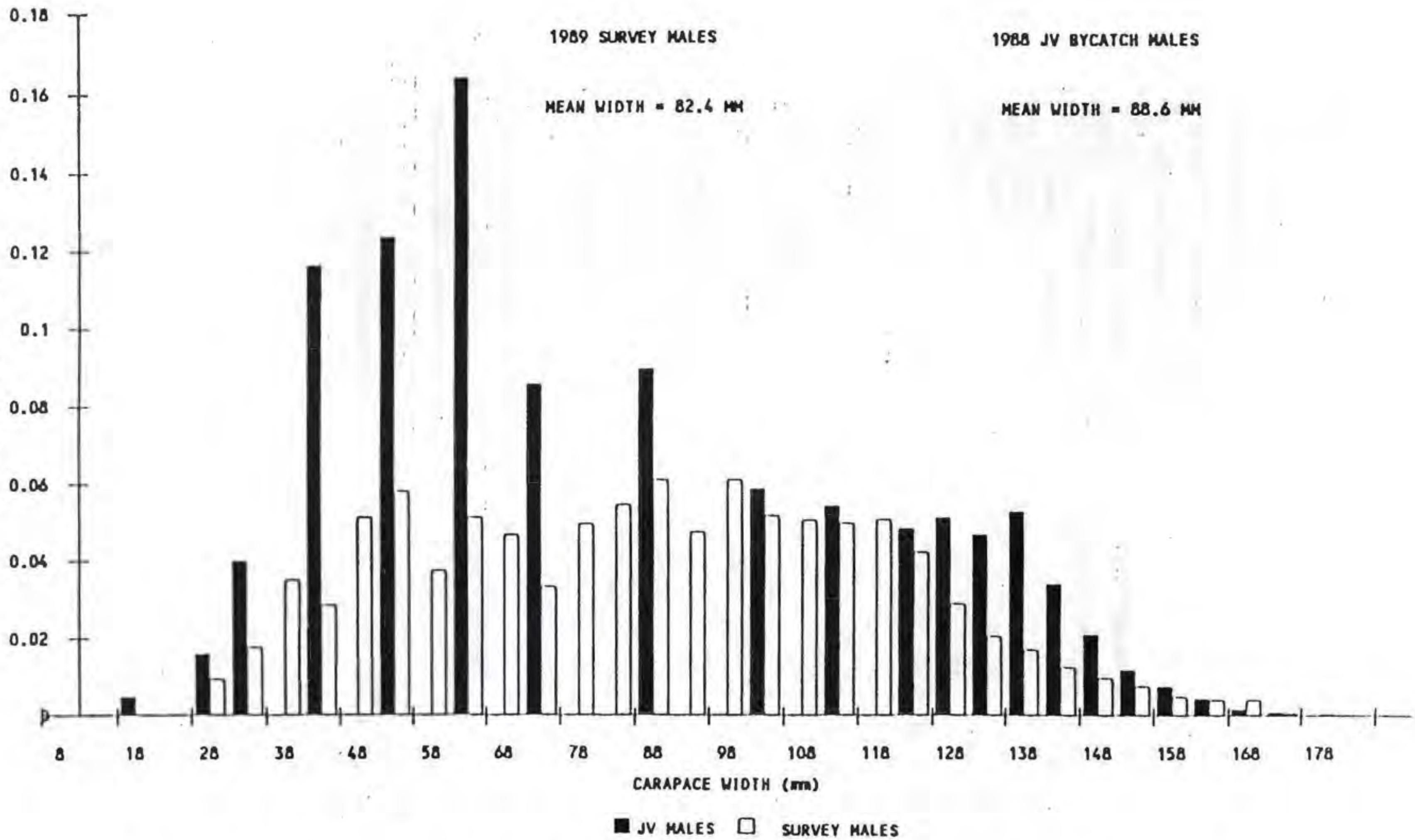

Figure 2.5 Size distribution of C. bairdi from the 1989 Bering Sea trawl survey population estimates and trawl bycatch in the 1988 JV fishery.
Sources: Brad Stevens (AFSC); Jerry Berger (AFSC).

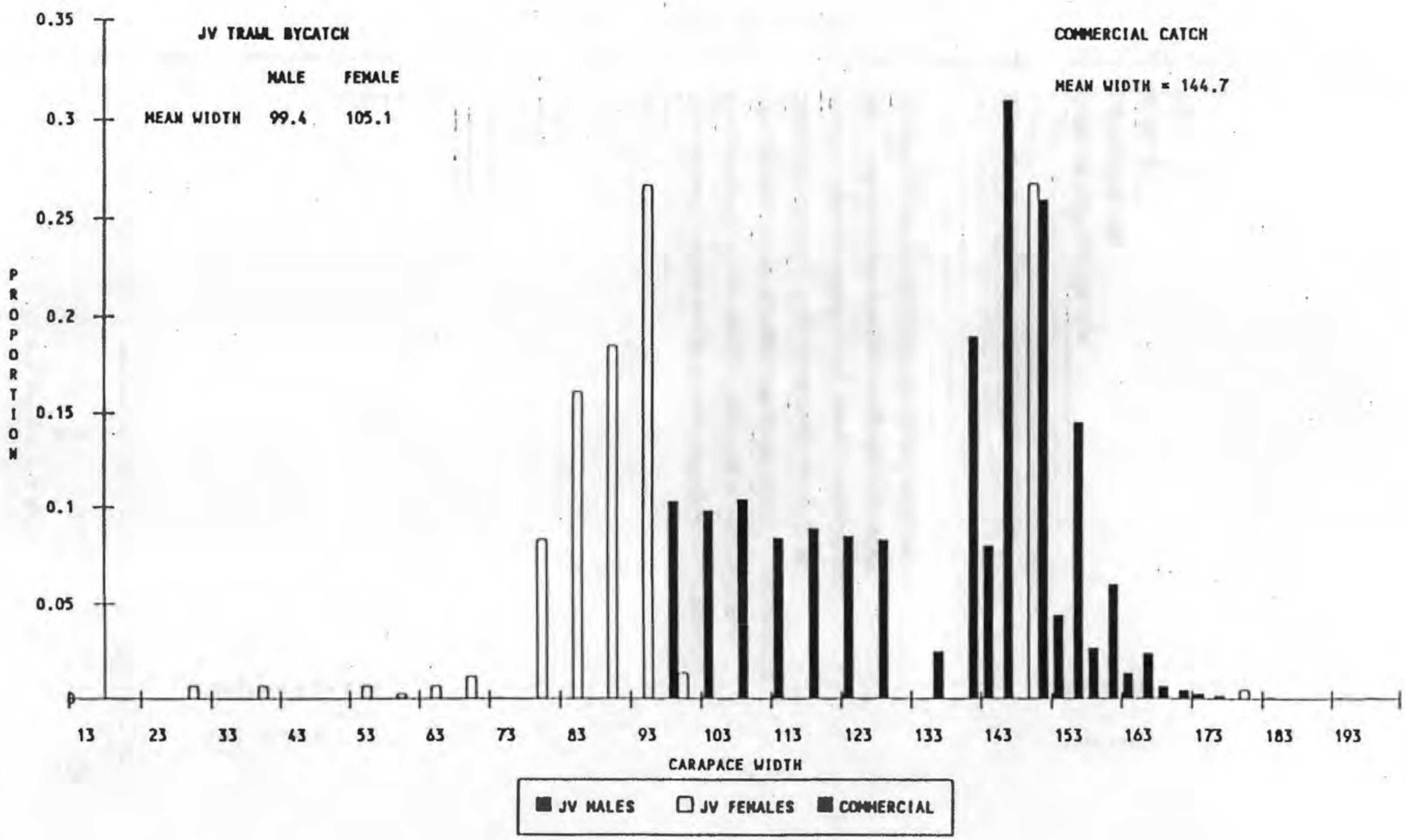

Figure 2.6 Size distribution of red king crab in the 1988 JV trawl bycatch and in the 1988 commercial pot harvest. Sources: Jerry Berger (AFCS); Ken Griffin (ADF&G).

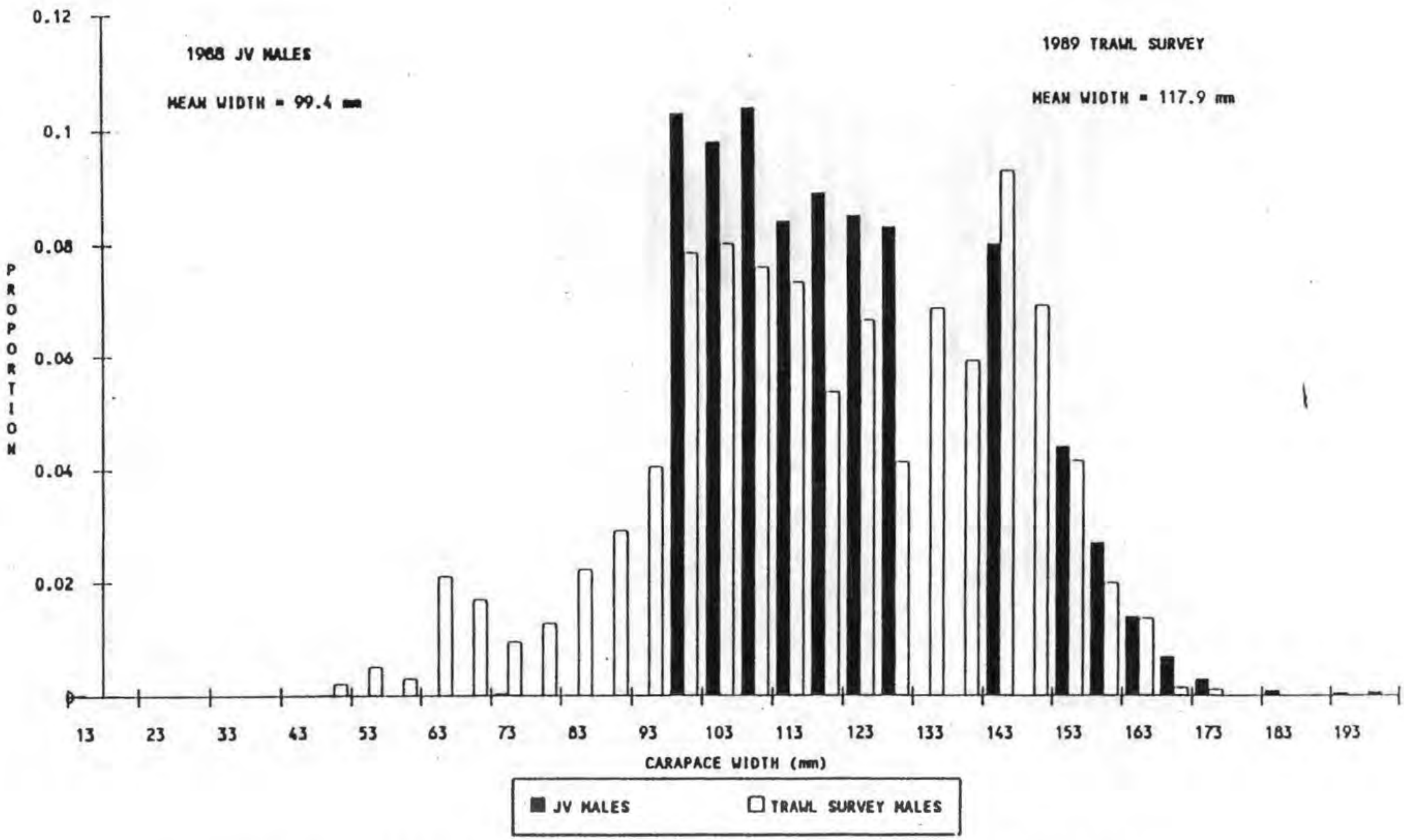

Figure 2.7 Size distribution of red king crab from the 1989 Bering Sea trawl survey population estimates and from the 1988 JV trawl bycatch.
Sources: Brad Stevens (AFSC) and Jerry Berger (AFSC).

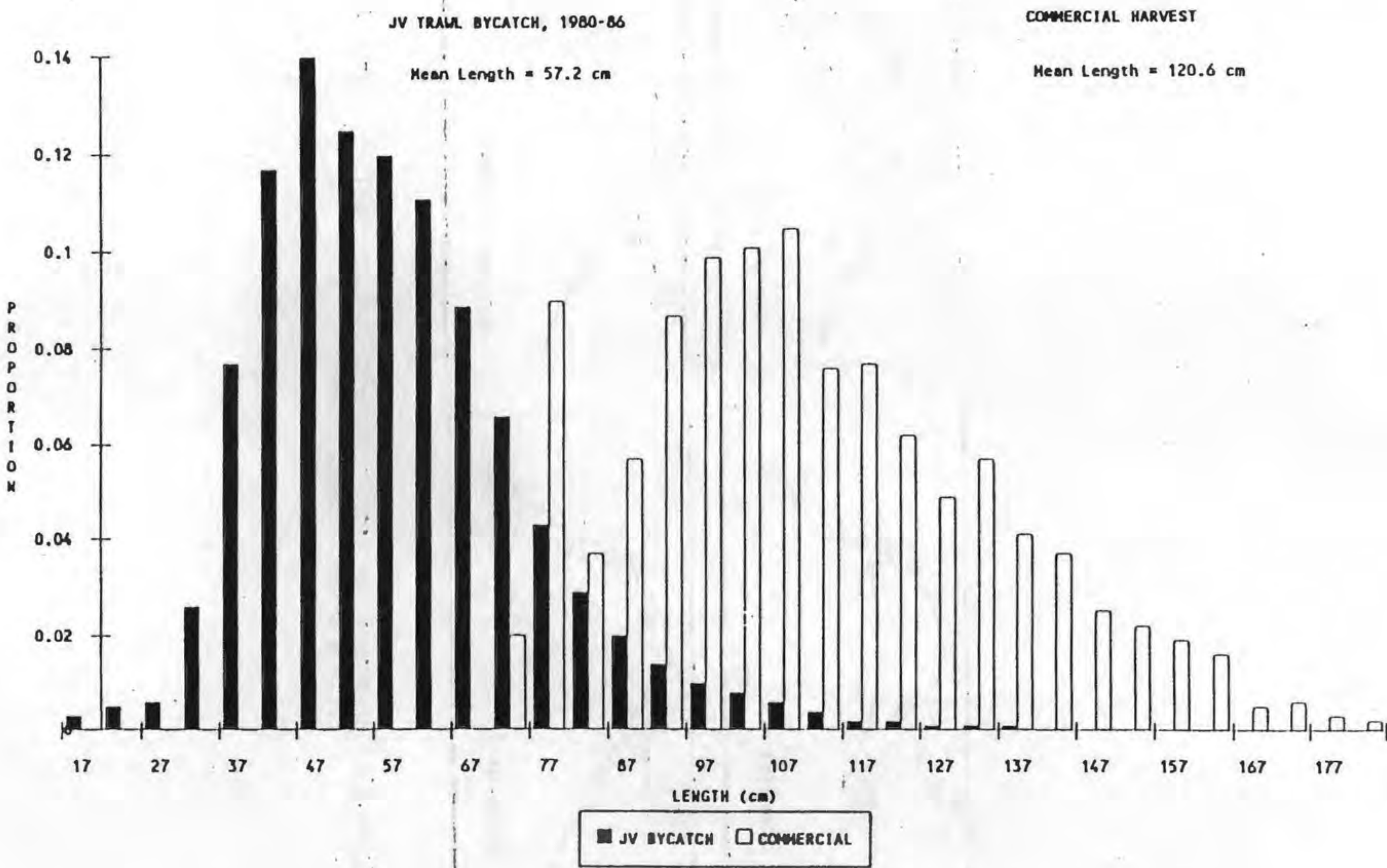

Figure 2.8 Size distribution of halibut in the 1980-86 JV trawl bycatch and in the 1988 commercial longline harvest. Source: Gregg Williams (IPHC).

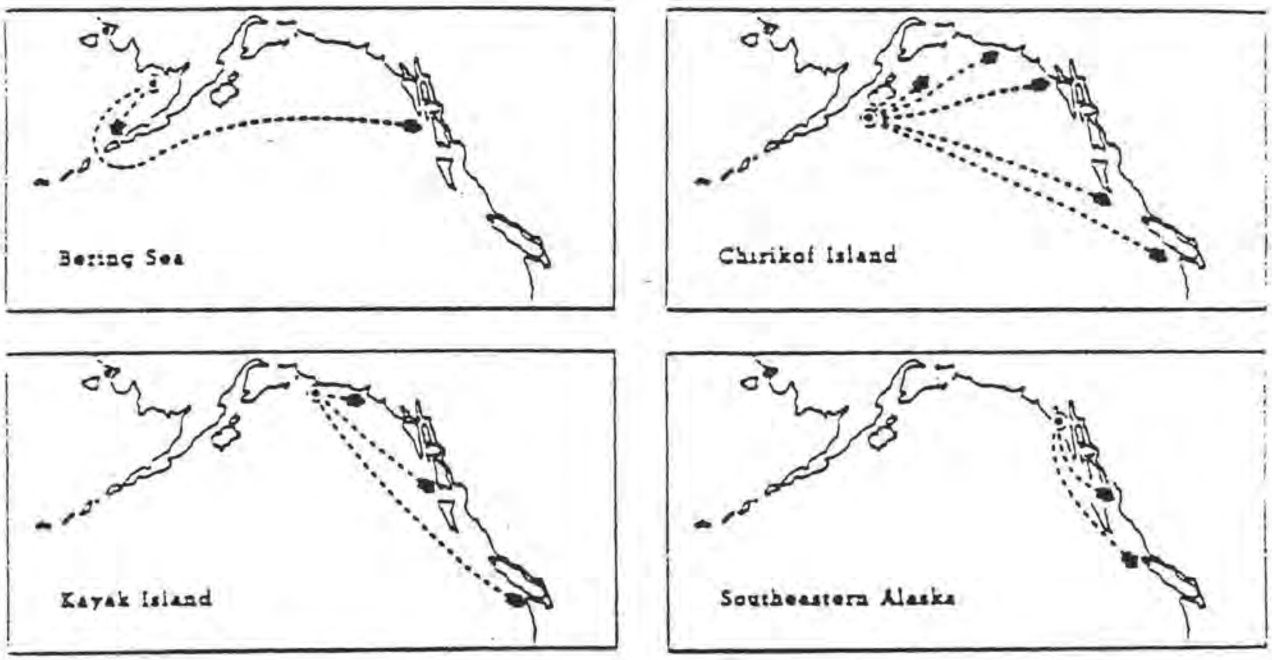

Figure 2.9 Migratory patterns of juvenile Pacific halibut from different tagging sites. Source: IPHC.

Table 2.1 Bering Sea population estimates of *C. Bairdi* Tanner crab, estimated foreign and joint venture bycatch and bycatch expressed as a percentage of the population, 1978-89.

	Population (millions)					Bycatch	
Year	Legal Males	Other Males	Total Males	Females	Total Crabs	Number (millions)	% of Pop.
1978	45.6	205.4	251.0	189.4	440.4	4.1	0.93
1979	31.5	180.8	212.3	164.7	377.0	7.5	1.99
1980	31.0	518.3	549.3	433.7	983.0	3.7	0.38
1981	14.0	327.8	341.8	403.3	745.1	1.6	0.21
1982	10.1	135.7	145.8	210.0	355.8	0.4	0.11
1983	6.7	178.3	185.0	225.5	410.5	0.6	0.15
1984	5.8	106.3	112.1	140.4	252.5	0.7	0.28
1985	4.4	40.5	44.9	39.8	84.7	0.9	1.06
1986	3.1	123.3	126.4	81.9	208.3	0.6	0.29
1987	8.3	249.8	258.1	228.8	486.9	0.5	0.10
1988	17.4	347.0	364.4	265.8	630.2	0.8	0.13
1989	42.3	505.1	547.4	402.4	949.8	0.9	0.01

Table 2.2 Bering Sea population estimates of red king crab, estimated foreign and joint venture bycatch and bycatch expressed as a percentage of the population, 1978-89.

	Population (millions)					Bycatch	
Year	Legal Males	Other Males	Total Males	Females	Total Crabs	Number (millions)	% of Pop.
1978	37.6	144.1	181.7	183.6	365.3	-	-
1979	46.6	110.8	157.4	166.6	324.0	0.32	0.10
1980	43.9	85.3	129.2	156.0	285.2	0.08	0.03
1981	36.1	80.7	116.8	112.5	229.3	0.34	0.15
1982	4.7	124.6	129.3	132.0	261.3	0.27	0.10
1983	1.5	53.7	55.2	34.0	89.2	0.81	0.91
1984	3.1	94.5	97.6	75.1	172.7	0.49	0.28
1985	2.5	23.8	26.3	13.7	40.0	1.17	2.92
1986	5.9	24.1	30.0	9.8	39.8	0.26	0.65
1987	7.9	32.7	40.6	35.1	75.7	0.13	0.17
1988	6.4	14.9	21.3	18.4	39.7	0.08	0.21
1989	11.9	18.0	29.9	21.2	51.1	0.20	0.39

Table 2.3 Bering Sea Pacific halibut bycatch mortality from all fisheries, 1977-89.

Year	Round Wt. (t)
1977	1,758
1978	3,029
1979	3,269
1980	5,570
1981	3,865
1982	2,869
1983	2,137
1984	2,830
1985	2,538
1986	3,363
1987	3,461
1988	5,343
1989[a]	4,332

[a] Preliminary.
Source: IPHC, G. Williams, personal communication.

Table 2.4 Coast-wide removals of Pacific halibut, 1977-89, in thousands of metric tons, round weight.

Year	Directed Catch	Bycatch (Adult Equiv.)	Sport Catch	Waste	Total Removals
1977	13.2	10.9	0.2	0.0	24.3
1978	13.3	11.4	0.2	0.0	24.9
1979	13.6	14.3	0.3	0.0	28.2
1980	13.2	17.6	0.5	0.0	31.3
1981	15.5	13.9	0.7	0.0	30.1
1982	17.5	11.5	0.8	0.0	29.8
1983	23.2	10.0	1.0	0.0	34.2
1984	29.1	9.4	1.1	0.0	39.6
1985	33.8	6.9	1.6	0.9	43.2
1986	42.0	8.0	2.1	1.9	54.0
1987	41.9	10.4	2.5	2.5	57.3
1988	44.8	13.8	3.1	2.1	63.8
1989	40.2	13.1	3.5	2.0	58.8

Source: IPHC, G. Williams, personal communication.

Table 2.5 Joint venture bycatch and bycatch rates by target fishery in the Bering Sea for 1987 through 1989.

Prohibited Species	Target Fishery	Incidental catch[a] 1987	1988	1989	Bycatch rate[bc] 1987	1988	1989
C. Bairdi	JV, flounder	216	512	735	0.88	1.20	3.31
	JV, other	161	239	181	0.15	0.27	0.58
	Foreign	90	NF	NF	1.31	NF	NF
	TOTAL	467	751	916	0.33	0.57	1.72
Other Tanner Crab	JV, flounder	6,146	2,179	1,529	25.04	5.13	6.89
	JV, other	341	191	1,329	0.31	0.22	4.27
	Foreign	265	NF	NF	3.83	NF	NF
	TOTAL	6,752	2,370	2,858	4.78	1.84	5.36
Red King Crab	JV, flounder	76	73	202	0.31	0.17	0.91
	JV, other	48	10	<1	0.04	0.01	<0.01
	Foreign	1	NF	NF	0.02	NF	NF
	TOTAL	125	83	202	0.09	0.06	0.38
Halibut	JV, flounder	586	1,359	337	2.38	3.20	1.52
	JV, other	899	1,221	537	0.81	1.39	1.72
	Foreign	1,077	NF	NF	15.47	NF	NF
	TOTAL	2,562	2,580	874	1.79	1.98	1.64

Source: Berger and Weikart, 1988 and 1989.

a Numbers represent 1000s of animals, except for halibut, which is in tons.
b Bycatch rate represents numbers of animals per ton of groundfish, except for halibut which is kg of halibut per ton of groundfish.
c Totals are overall weighted average of bycatch rates.

Table 2.6 Joint venture bycatch and bycatch rates by zone in the Bering Sea for 1987 through 1989.

		Incidental Catch[a]			Bycatch rate[b]		
Prohibited Species	Zone	1987	1988	1989	1987	1988	1989
C. Bairdi	1	121	232	150	0.61	0.86	0.88
	2	281	458	610	0.43	0.61	1.87
	3	65	61	156	0.11	0.22	4.21
Other Tanner Crab	1	45	29	7	0.23	0.11	0.04
	2	3,139	1,071	3,180	4.84	1.42	6.69
	3	3,567	1,270	671	6.32	4.57	18.09
Red King Crab	1	104	61	179	0.52	0.23	1.05
	2	10	10	22	0.02	0.01	0.07
	3	12	12	1	0.02	0.04	0.02
Halibut	1	297	404	176	1.45	1.50	1.04
	2	595	1779	662	0.59	2.36	2.03
	3	595	397	36	1.07	1.43	0.95

Source: Berger and Weikart, 1988 and 1989.
a Numbers represent 1000s of animals, except halibut, which is in tons.
b Bycatch rate represents numbers of animals per ton of groundfish, except for halibut, which is kg of halibut per ton of groundfish.

Table 2.7a -- Bycatch rates used in the analysis.

(Use estimated functional relationship for DAP halibut, C. bairdi; historical performance for all JVP and all red king crab)

JV 1st Qtr uses 1990, 2nd Qtr uses 1988, 3rd and 4th Qtrs use 1989.

A. Observer Data, 1989

Red king crab

	JVP flatfish					DAP Deep				
Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511/516	2.137	0.136	-	-	1.1705106	0	0	0	0	0
513	0.048	0.02577	0.0032483	0.9887069	0.4161585	0	0	0	0	0
514	-	0.108	0.0088019	0.0158792	0.0110443	0	0	0	0	0
515	0.030329	-	-	-	-	0	0	0	0	0
517	0.030329	-	0	0	0.0275097	0	0	0	0	0
521	0.1578947	0.125	0	0.3633333	0.3510972	0	0	0	0	0
522	-	1.636	-	-	0.7276786	0	0	0	0	0
BSAI-wide	1.075745	0.078	0.0187864	0.6718912	0.9170401	0	0	0	0	0

	DAP flatfish					DAP other				
Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511/516	1.951	0.9450758	-	-	1.210231	0.0353	0.4094488	0.9734484	0	0.2601447
All other	0.012528	0.0149254	0.0721371	0.1602837	0.0419761	0.0002313	0.0491826	0.0116422	0.0039975	0.0227513
BSAI-wide	1.951	0.9073289	0.0721371	0.1602837	1.0411168	0.0175	0.1157613	0.0349806	0.0039975	0.0601529

bairdi Tanner crab

	JVP flatfish					DAP Deep				
Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511	8.296	0.206	-	-	0.8621958	0	0	0	0	0
513	9.422	1.92	5.3215021	11.173621	7.0296997	0	0	0	0	0
514	-	0.147	7.1881624	9.9161503	8.0525218	0	0	0	0	0
515	-	-	-	-	-	0	0	0	0	0
517	3.4655742	-	0	0.0137931	3.1438713	0	0	0	0	0
521	0.2083333	7.497	-	5.5633333	5.2445141	0	0	0	0	0
522	-	16.864	49.59375	-	49.59375	0	0	0	0	0
BSAI-wide	1.0588139	1.045	6.844659	10.515731	2.5413183	0	0	0	0	0

Halibut

Area	JVP flatfish Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	DAP Deep Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511	0.001	0.001	-	-	0.0008417	0	0	0	0	0
513	0.0074	0.0058	0.0010299	0.0031379	0.001925	0	0	0	0	0
514	-	0.0015	0	0	0	0	0	0	0	0
515	-	-	-	-	-	0.0949	0	0	0	0
517	0.0039256	-	0.0076642	0.0017241	0.0040821	0.2366	0	0	0	0
521	0	0.0108	-	0.0066667	0.0059561	0.0398	0	0	0	0
522	-	0.0077	0.0183445	-	0.0183036	0.1417	-	-	0	0
BSAI-wide	0.0010176	0.0034	0.0010262	0.0022416	0.0011206	0.0791	0	0	0	0

B. DAP regression estimators, 1989

C. bairdi	Quarter 1	Quarter 2	Quarter 3	Quarter 4
b1- pollock	0	0	0.5658	0.7548
b2 - cod	2.7521	9.1384	0	0
b3 - y. sole	11.3034	1.045	6.845	1.6668
b4 - o. flat	11.3034	1.5194	2.3976	5.8105

1990 DAP OBSERVED RATES USED IN 1st QTR

halibut	Quarter 1	Quarter 2	Quarter 3	Quarter 4
b1- pollock	1.107	2.3226	3.1192	2.2913
b2 - cod	13.3601	19.3926	8.1258	24.4234
b3 - y. sole	14.2219	0.4108	4.6134	7.2488
b4 - o. flat.	14.2219	6.391	1	2.2

C. Observer Data, 83-88

Herring

Area	DAP Other Bottom Trawl Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	DAP Midwater Trawl Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511	0.00%	0.10%	1.71%	0.00%	0.22%	0.00%	0.01%	0.09%	0.00%	0.01%
513	0.01%	0.25%	0.25%	0.19%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
514	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.03%
515	0.00%	0.03%	5.07%	0.00%	1.36%	0.00%	0.00%	0.08%	0.00%	0.01%
517	0.00%	0.15%	2.00%	0.02%	0.41%	0.00%	0.00%	0.09%	0.00%	0.03%
521	0.00%	0.00%	0.43%	0.02%	0.07%	0.00%	0.00%	0.06%	0.02%	0.05%
522	0.00%	0.06%	0.00%	0.00%	0.06%	0.00%	0.00%	0.02%	0.01%	0.01%

Table 2.7b – Modified bycatch rates used in Alternative 3, Case 2.

Bycatch rates adjusted for estimated effect of penalizing vessels with excessively high bycatch rates.

Red king crab

Area	JVP flatfish Quarter 1	JVP flatfish Quarter 2	JVP flatfish Quarter 3	JVP flatfish Quarter 4	JVP flatfish Annual	DAP Deep Quarter 1	DAP Deep Quarter 2	DAP Deep Quarter 3	DAP Deep Quarter 4	DAP Deep Annual
511/516	1.77371	0.0884	-	-	0.7608319	0	0	0	0	0
513	0.03984	0.0167505	0.0021114	0.6426595	0.270503	0	0	0	0	0
514	-	0.0702	0.0057212	0.0103215	0.0071788	0	0	0	0	0
515	0.025173	-	-	-	-	0	0	0	0	0
517	0.025173	-	0	0	0.0178813	0	0	0	0	0
521	0.1310526	0.08125	0	0.2361667	0.2282132	0	0	0	0	0
522	-	1.0634	-	-	0.4729911	0	0	0	0	0
BSAI-wide	0.8928684	0.0507	0.0122111	0.4367293	0.5960761	0	0	0	0	0

Area	DAP flatfish Quarter 1	DAP flatfish Quarter 2	DAP flatfish Quarter 3	DAP flatfish Quarter 4	DAP flatfish Annual	DAP other Quarter 1	DAP other Quarter 2	DAP other Quarter 3	DAP other Quarter 4	DAP other Annual
511/516	1.951	0.9450758	-	-	1.210231	0.042713	0.9376378	2.2291969	0	0.5957314
All other	0.012528	0.0149254	0.0721371	0.1602837	0.0419761	0.0002313	0.1126282	0.0266606	0.0091542	0.0521004
BSAI-wide	1.951	0.9073289	0.0721371	0.1602837	1.0411168	0.021175	0.2650933	0.0801055	0.0091543	0.1377502

bairdi Tanner crab

Area	JVP flatfish Quarter 1	JVP flatfish Quarter 2	JVP flatfish Quarter 3	JVP flatfish Quarter 4	JVP flatfish Annual	DAP Deep Quarter 1	DAP Deep Quarter 2	DAP Deep Quarter 3	DAP Deep Quarter 4	DAP Deep Annual
511	6.96864	0.13596	-	-	0.5690492	0	0	0	0	0
513	7.91448	1.2672	3.5121914	7.3745897	4.6396018	0	0	0	0	0
514	-	0.09702	4.7441872	6.5446592	5.3146644	0	0	0	0	0
515	-	-	-	-	-	0	0	0	0	0
517	2.9110823	-	0	0.0091034	2.0749551	0	0	0	0	0
521	0.175	4.94802	-	3.6718	3.4613793	0	0	0	0	0
522	-	11.13024	32.731875	-	32.731875	0	0	0	0	0
BSAI-wide	0.8894037	0.6897	4.517475	6.9403826	1.6772701	0	0	0	0	0

Halibut

Area	JVP flatfish					DAP Deep				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511	0.00087	0.00075	-	-	0.0006313	0	0	0	0	0
513	0.006438	0.00435	0.0007725	0.0023534	0.0014438	0	0	0	0	0
514	-	0.001125	0	0	0	0	0	0	0	0
515	-	-	-	-	-	0.0949	0	0	0	0
517	0.0034153	-	0.0057482	0.0012931	0.0030616	0.2366	0	0	0	0
521	0	0.0081	-	0.005	0.0044671	0.0398	0	0	0	0
522	-	0.005775	0.0137584	-	0.0137277	0.1417	-	-	0	0
BSAI-wide	0.0008853	0.00255	0.0007696	0.0016812	0.0008404	0.0791	0	0	0	0

B. DAP regression estimators, 1989

1990 DAP OBSERVED RATES USED IN 1st QTR

	C. bairdi					halibut				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
b1- pollock	0	0	0.33948	0.45288		b1- pollock	0.67527	1.811628	2.432976	1.787214
b2 - cod	1.623739	5.48304	0	0		b2 - cod	8.149661	15.126228	6.338124	19.050252
b3 - y. sole	14.12925	1.045	6.845	1.6668		b3 - y. sole	13.226367	0.4108	4.6134	7.2488
b4 - o. flat.	12.43374	1.5194	2.3976	5.8105		b4 - o. flat.	11.37752	6.391	1	2.2

C. Observer Data, 83-88

Herring

Area	DAP Other Bottom Trawl					DAP Midwater Trawl				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
511	0.00%	0.10%	1.71%	0.00%	0.22%	0.00%	0.01%	0.09%	0.00%	0.01%
513	0.01%	0.25%	0.25%	0.19%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
514	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.03%
515	0.00%	0.03%	5.07%	0.00%	1.36%	0.00%	0.00%	0.08%	0.00%	0.01%
517	0.00%	0.15%	2.00%	0.02%	0.41%	0.00%	0.00%	0.09%	0.00%	0.03%
521	0.00%	0.00%	0.43%	0.02%	0.07%	0.00%	0.00%	0.06%	0.02%	0.05%
522	0.00%	0.06%	0.00%	0.00%	0.06%	0.00%	0.00%	0.02%	0.01%	0.01%

Table 2.8-- ANTICIPATED ANNUAL GROUNDFISH APPORTIONMENTS

Species	Area	ABC	TAC	DAP	JVP
Pollock	BS	1,450,000	1,280,000	1,280,000	0
	AI	153,600	100,000	100,000	0
Pacific cod		417,000	227,000	227,000	0
Yellowfin sole		278,900	207,650	14,663	192,987
Greenland turbot		7,000	7,000	7,000	0
Arrowtooth flounder		106,500	10,000	10,000	0
Rock sole		216,300	60,000	60,000	0
Other flatfish		18,800	60,150	11,730	48,420
Sablefish	BS	3,800	2,700	2,700	0
	AI	9,600	4,500	4,500	0
POP	BS	6,300	6,300	6,300	0
	AI	16,600	6,600	6,600	0
Other rockfish	BS	500	500	425	0
	AI	1,100	1,100	1,100	0
Atka mackerel		24,000	21,000	17,850	0
Squid		10,000	500	425	0
Other species		55,500	5,000	4,250	0
BS/AI TOTAL		2,944,700	2,000,000	1,758,593	241,407

Table 2.9--Quarterly catch (t) by the DAP deep fishery from all alternatives.

Area	Catch (t) 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
515	1,092	420	1,056	738
522	894	342	864	604

Quarterly catch (t) by the JVP flatfish fishery from Alternative 1.

Area	Catch (t) 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
511	274,563	0	0	0

Quarterly catch (t) by the JVP flatfish fishery from Alternative 2 case A.

Area	Catch (t) 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
511	91,521	0	0	0

Quarterly catch (t) of the JVP flatfish fishery from Alternative 2 Case B and Alternative 3 Case A.

Area	Catch (t) 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
511	0	22,880	45,812	0
513	0	22,880	45,812	0
514	0	45,760	45,760	0

Table 2.9 Continued

Quarterly catch (t) by the DAP flatfish fishery from Alternative 1 and Alternative 2 Case A.

Area	Catch (t)			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
511	76,134	2,046	2,046	4,686
513	0	2,046	2,046	4,686
514	0	4,089	4,089	0
517	8,460	0	0	0

Quarterly catch (t) by the DAP flatfish fishery from Alternative 2 Case B and Alternative 3 Case A.

Area	Catch (t)			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
511	61,298	3,444	6,906	0
513	0	3,444	6,906	0
514	0	6,886	13,812	0
517	6,810	0	0	0

Table 2.10--Area Distributions of Groundfish Catch by quarter.

JVP flatfish

Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4
511	100.0%	25.0%	25.0%	50.0%
513	0.0%	25.0%	25.0%	50.0%
514	0.0%	50.0%	50.0%	0.0%
515	0.0%	0.0%	0.0%	0.0%
517	0.0%	0.0%	0.0%	0.0%
521	0.0%	0.0%	0.0%	0.0%
522	0.0%	0.0%	0.0%	0.0%

JVP other

Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4
511	25.0%	33.3%	20.0%	20.0%
513	15.2%	19.5%	11.8%	5.6%
514	0.0%	0.0%	0.0%	0.0%
515	0.0%	33.3%	0.0%	0.0%
517	59.8%	13.9%	28.2%	34.4%
521	0.0%	0.0%	40.0%	40.0%
522	0.0%	0.0%	0.0%	0.0%

DAP flatfish

Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4
511	90.0%	25.0%	25.0%	50.0%
513	0.0%	25.0%	25.0%	50.0%
514	0.0%	50.0%	50.0%	0.0%
515	0.0%	0.0%	0.0%	0.0%
517	10.0%	0.0%	0.0%	0.0%
521	0.0%	0.0%	0.0%	0.0%
522	0.0%	0.0%	0.0%	0.0%

DAP other

Area	Quarter 1	Quarter 2	Quarter 3	Quarter 4
511	10.0%	5.0%	5.0%	5.0%
513	10.0%	15.0%	15.0%	10.0%
514	0.0%	0.0%	0.0%	0.0%
515	50.0%	10.0%	15.0%	20.0%
517	30.0%	35.0%	15.0%	40.0%
521	0.0%	35.0%	50.0%	25.0%
522	0.0%	0.0%	0.0%	0.0%

Table 2.11--Estimated catch per unit effort by area, fishery, and quarter.

Metric tons per hour

Fishery/ Quarter	Areas 511	513	514	515	517	521	522	540
JVP Flatfish[a]								
1	30.3	10.1	6.7	---	9.2	---	---	---
2	6.3	4.0	7.5	8.9	4.0	2.8	2.3	---
3	---	4.1	3.7	---	7.8	3.9	4.6	---
4	---	3.0	3.3	---	4.5	3.8	---	---
DAP Other Bottom Trawl								
1	6.5	9.6	---	6.5	6.2	---	---	---
2	0.4	5.0	9.1	7.8	5.0	12.4	1.0	1.2
3	3.8	8.2	7.5	5.5	6.6	8.6	12.5	2.3
4	3.4	3.4	1.1	3.9	3.2	8.4	11.2	---
DAP Rock Sole								
1	9.6	12.0	6.7	---	9.2	---	---	---
DAP Deep								
1	---	---	---	2.6	5.1	---	1.4	---
DAP Midwater Trawl								
1	23.1	12.0	---	3.1	15.2	3.3	---	3.3
2	0.4	0.4	---	7.8	7.8	7.8	7.8	7.8
3	7.8	6.6	5.4	6.2	6.0	12.1	12.4	19.8
4	3.1	5.4	5.4	6.2	6.0	12.1	12.4	19.8

a DAP flatfish CPUE for the second through fourth quarters are asssumed the same as JVP flatfish.

Notes: Measures of catch per unit of effort were generated using NMFS Observer Program data for the joint venture fisheries. 1989 data was used, supplemented by earlier years' data where observations were missing. Zone 517 was estimated from DAP observation for Qtr 1 and from JVP data from nearby zone 513 for the remainder of the year.
Catch per unit of effort for the first quarter DAP rock sole and DAP deep (Greenland turbot/sablefish) fisheries were calculated from 1990 DAP observer information.

Table 2.12--Representative Vessel Cost Structures (in millions of dollars) used in the unconstrained model.

	DAP	JVP	DAP "deep"
Annual Catch	11,400 mt	10,600 mt	7,000 mt
Fixed Costs	$2.59	$0.55	$1.5
Variable Costs Associated with			
Harvest	$2.98	$0.63	$1.8
Effort	$1.59	$0.40	$1.2
Total Costs	$7.16	$1.58	$4.5

Notes: A 200'-250' factory trawler is used to characterize the DAP fisheries, except for the deep-water sablefish/turbot fishery, where a 150'- 200' factory trawler (H&G) is used. A 100'-150' catcher boat represents the JVP fisheries.

Source: Personal communication with Northern Economics, Pat Burden, 1/90.

Table 2.13--Prices, converted to round weight, used to value crab and halibut bycatch, and groundfish catch.

Bairdi Tanner Crab	$514/1,000 crabs
Red King Crab	$13,300/1,000 crabs
Halibut	$3,3000/mt
Blended Groundfish	
JVP	$ 152/mt
DAP	$ 774/mt
DAP "deep"	$1,639/mt

Notes: JVP groundfish price reflects exvessel level; DAP price assumes a finished product price of $1.17/lb and an average yield rate of 30%, except for DAP deep (turbot/sablefish) which assumes an average finished price of $1.18/lb and a yield of 63% for the head-and-gutted product.

Table 2.14--Distribution of overall PSC limits of crab (animals) and halibut (metric tons) by fishery and area from Alternative 2 Case A.

PSC Species/ fishery	Zone 1[a]	Zone 2	BSAI-wide
C. bairdi			
DAP--flatfish	172,624	274,882	--
DAP--other	26,085	2,725,118	--
JVP--flatfish	801,291	0	--
DAP--Deep	0	0	--
Total	1,000,000	3,000,000	--
Red king crab			
DAP--flatfish	42,536	---	--
DAP--other	111	---	--
JVP--flatfish	157,353	---	--
DAP--Deep	0	---	--
Total	200,000	---	--
Halibut			
DAP--flatfish	1,476	---	1,517
DAP--other	2,505	---	3,326
JVP--flatfish	419	---	419
DAP--deep	0	---	71
Total	4,400 mt		5,333 mt

a. Halibut entry under Zone 1 includes Zone 2H also.

Table 2.14 Continued

Distribution of overall PSC limits of crab (animals) and halibut (metric tons) by fishery and area from Alternative 2 Case B.

PSC Species/ fishery	Zone 1[a]	Zone 2	BSAI-wide
C. bairdi			
DAP--flatfish	768,081	169,016	--
DAP--other	140,081	1,967,812	--
JVP--flatfish	91,838	863,172	--
DAP--Deep	0	0	--
Total	1,000,000	3,000,000	--
Red king crab			
DAP--flatfish	139,316	---	--
DAP--other	439	---	--
JVP--flatfish	60,245	---	--
DAP--Deep	0	---	--
Total	200,000	---	--
Halibut			
DAP--flatfish	1,301	---	1,340
DAP--other	2,988	---	3,746
JVP--flatfish	110	---	181
DAP--deep	0	---	65
Total	4,400 mt	---	5,333 mt

Table 2.15.--A comparison of bycatch model simulation results

	Alternative 1[a]	Alternative 2[b] Case A	Alternative 2 Case B	Alternative 3[c]
Bycatch Amounts				
Red king crab (no.)	759,748	269,718	155,112	205,581
C. bairdi (no.)	3,690,518	2,121,425	1,957,881	1,838,108
Halibut (t)	5,909	4,865	5,220	4,415
Groundfish Catch (t)				
DAP Deep[d]	6,008	6,008	6,008	6,008
DAP rocksole	84,588	84,588	68,106	68,106
DAP flatfish	25,740	25,740	41,400	41,400
DAP other	553,732	498,802	526,267	553,732
DAP subtotal[e]	670,068	615,138	641,781	669,246
JVP flatfish	274,563	91,521	183,146	274,771
DAH total	944,631	706,659	824,927	944,017
Bycatch Impact Costs ($1,000s)				
Red king crab	10,105	3,587	2,063	2,734
C. bairdi	1,897	1,090	1,006	945
Halibut	19,499	16,054	17,225	14,571
Total	31,501	20,731	20,294	18,250
Gross Revenue ($1,000s)				
DAP	523,704	481,197	501,815	523,068
JVP	41,734	13,911	27,838	41,765
DAH	565,438	495,108	529,653	564,833
Gross Revenue-Variable Cost ($1,000s)				
DAP	292,156	270,058	281,831	291,517
JVP	16,646	8,028	10,718	15,852
DAH	308,802	278,086	292,549	307,369
Gross Revenue-Total Cost ($1,000s)				
DAP	139,998	130,317	136,100	139,546
JVP	2,399	3,279	1,215	1,595
DAH	142,397	133,596	137,315	141,141

a Truly unconstrained case with projections provided by industry.
b All Alt. 2 cases use observed bycatch rates; Case A has JV flatfish fishery starting 1st quarter; remaining cases all start JVP and DAP (except rocksole) flatfish fisheries on May 15th; Case A and B are 75% midwater for pollock.
c Use reduced incentive rates for bycatch predication; still 75% midwater assumption.
d New fishery designation which include Greenland turbot, sablefish, and slope rockfish.
e These totals do not include groundfish catch taken in the midwater pollock fishery.

Table 2.16.--A comparison of bycatch from simulation results with Amendment 12A PSC caps by zone.

		Alternative 1[a]	Alternative 2[b]		Alternative 3[c]
	12A Caps		Case A	Case B	
			Red King Crab		
Area					
Zone 1	200,000	745,764	255,308	134,726	168,579
			C. Bairdi		
Zone 1	1,000,000	2,504,358	840,172	388,942	410,351
Zone 2	3,000,000	1,031,780	883,907	803,653	685,760
			Halibut[d]		
BS wide	5,333 t	5,909 t	4,865 t	5,220 t	4,415 t

a Truly unconstrained case with projections provided by industry.

b All these cases use observed bycatch rates; Alt 2. Case A has JVP flatfish starting 1st quarter; Case B starts JVP and DAP (except rocksole) flatfish fisheries on May 15th; Alt. 2 Cases A and B assume 75% of pollock catch by midwater trawl.

c This case used reduced bycatch rates due to incentives for bycatch prediction; it assumes 75% of pollock catch is by midwater trawl. JVP and DAP flatfish (except rock sole) commence on May 15th.

d When BS-wide halibut catch exceeds 4,400 mt then Zone 1, 2H (Areas 511 and 517) are closed to further fishing; the remaining areas remain open until the 5,333 mt cap is exceeded.

Table 2.17--Projected fishery closures as a result of exceeding bycatch apportionments.

Case	Closure	Cause	Apportionment of PSC Cap	Amount Exceeded By
Alt. 2, Case A[b]	JVP flatfish Zone 1	RKC.[a], January	157,353 crabs	38,227 crabs
Alt. 2, Case A	DAP rock sole Zone 1	RKC, January	42,536 crabs	6,973 crabs
Alt. 2, Case A	DAP other Zone 1	RKC, January	111 crabs	27 crabs
Alt. 2, Case A	DAP other Zones 1, 2H	Halibut, August	2,702 mt	116 mt
	BSAI-wide	Halibut, October	3,274 mt	169 mt
Alt. 2, Case A[c]	DAP deep BSAI-wide	Halibut, March	75 mt	155 mt
Alt. 2, Case B	JVP flatfish Zones 1, 2H	Halibut, June	207 mt	17 mt
	BSAI-wide	Halibut, July	250 mt	6 mt
Alt. 2, Case B	DAP deep	Halibut, March BSAI-wide	186 mt	230 mt
Alt. 2, Case B	DAP other Zones 1, 2H	Halibut, October	3,503 mt	368 mt

a Red king crab.

b Under this alternative, the DAP fisheries are able to shift their fishing effort out of Zone 1 and continue to catch groundfish without any loss of total harvest. The JVP fishery is presumed to be a 1st quarter fishery that operates only in Zone 1 and thus foregoes catch due to exceeding its red king crab apportionment.

c Although the DAP deep fishery is closed for halibut in March, it is able to fish April-December because of the assumption of no bycatch of halibut.

Table 2.18--A comparison of differences between unconstrained and various constrained bycatch model simulation results. Simulation results are found in Table 2.15

	Difference between Alt.1 & Alt.2 Case A[a]	Difference between Alt. 1 & Alt. 2 Case B[b]	Difference between Alt. 1 & Alt. 3[c]
Bycatch Amounts			
Red king crab (no.)	490,030	604,636	554,167
C. bairdi (no.)	1,569,093	1,732,637	1,852,410
Halibut (t)	1,044	689	1,494
Groundfish Catch (t)			
DAP Deep[d]	0	0	0
DAP rocksole	0	16,482	16,482
DAP flatfish	0	(15,660)	(15,660)
DAP other	54,930	27,465	0
DAP subtotal[e]	54,930	28,287	822
JVP flatfish	183,042	91,417	(208)
DAH total	237,972	119,704	614
Bycatch Impact Costs ($1,000s)			
Red king crab	6,518	8,042	7,371
C. bairdi	807	891	952
Halibut	3,445	2,274	4,928
Total	10,770	11,207	13,251
Gross Revenue ($1,000s)			
DAP	42,507	21,889	636
JVP	27,823	13,896	(31)
DAH	70,330	35,785	605
Gross Revenue-Variable Cost ($1,000s)			
DAP	22,098	10,325	639
JVP	8,618	5,928	794
DAH	30,716	16,253	1,433
Gross Revenue-Total Cost ($1,000s)			
DAP	9,681	3,898	452
JVP	(880)	1,184	804
DAH	8,801	5,082	1,256

a Truly unconstrained case with projections provided by industry.
b All Alt. 2 cases use observed bycatch rates; Case A has JV flatfish fishery starting 1st quarter; remaining cases all start JVP and DAP (except rocksole) flatfish fisheries on May 15th; Case A and B are 75% midwater for pollock.
c Use reduced incentive rates for bycatch predication; still 75% midwater assumption.
d New fishery designation which include Greenland turbot, sablefish, and slope rockfish.
e These totals do not include groundfish catch taken in the midwater pollock fishery.
f Differences noted are negative unless in parentheses.

APPENDIX 2.1

A METHOD OF ESTIMATING THE POTENTIAL IMPACT COSTS OF BYCATCH IN THE GROUNDFISH FISHERY

This appendix presents a method of estimating the effect of crab and halibut bycatch mortality in the groundfish fisheries on the gross exvessel values of catch in the crab and halibut fisheries. It also addresses the use of such estimates as a measure of the bycatch impact costs imposed on those who benefit from catch in the crab and halibut fisheries.[1]

The method described below was used in generating the crab bycatch impact cost estimates used in Section 2.5.1. A different method was used to estimate the impact costs of halibut bycatch because of the IPHC adjusts halibut quotas based on estimated bycatch. That method was described in Section 2.4.

Estimating the Effect on Future Gross Exvessel Value

The following variables are used to estimate the potential impact cost of bycatch in the groundfish fishery:

1. the number of halibut and crab taken as bycatch,
2. halibut and crab handling/discard mortality rates,
3. the average weight of halibut and crab taken as bycatch,
4. weight at age for halibut and crab,
5. natural mortality rates for halibut and crab,
6. halibut and crab target catch ages,
7. exvessel prices for halibut and crab,
8. round weight to product weight recovery rates, and
9. the discount rate.

The method used is as follows. The initial removals of red king crab, for example, by the groundfish fishery equal the product of the estimated number of crab taken as bycatch and the estimated discard mortality rate. The number of crab taken as bycatch includes the number of crab the groundfish gear came in contact with, not just the number of crab that are brought aboard the vessel. However, it

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1. Any method used to estimate the effects on the crab and halibut fisheries of crab and halibut bycatch mortality in the groundfish fishery will have some deficiencies because there is uncertainty concerning the values of biological and economic parameters of the crab and halibut fisheries. The uncertainty is in part due to the variability of many of these values. The method described below is a relatively simple one; the uncertainty concerning parameter values may negate the benefits of a more complex method. The nature of the potential biases of this method are discussed.

is difficult to estimate the number of crab and discard mortality rates for crab that come in contact with, but are not captured by, the gear.

The subsequent estimated reduction in the number of crab made available to the crab fishery is equal to the initial removals reduced by natural mortality. The number of years of natural mortality is set equal to the target catch age minus the bycatch age. The bycatch age is assumed to equal the age of a crab that has a weight equal to that of the average bycatch weight. Two target catch ages are considered; one is the youngest age at which large numbers of crab are retained in the crab fishery, the other is the age corresponding to the average weight of crab retained in the crab fishery. In many cases, the former age is determined by a minimum legal size regulations. For red king crab in Bristol Bay, these ages were 8 and 10 in 1988. The estimated potential reduction in the crab catch, in pounds, is the product of the reduction in the number of crab made available to the crab fishery and the weight of a target catch age crab.

The estimated potential reductions in the exvessel value of the crab fishery is the product of the exvessel price and the estimated reduction in catch. The estimated potential reduction in the exvessel value of the crab fishery is discounted over the number of years between the estimated bycatch and target catch ages to provide an estimate of the present discounted value of the potential decrease in gross exvessel value of catch in the crab fishery.

If, for example, the average weight of red king crab taken as bycatch is 3.4 pounds (lbs), the bycatch age is estimated to be 7 (Table A2.1.1) and the crab would have been subject to 1 and 3 years of natural mortality for target catch ages of 8 and 10, respectively. Assuming annual natural mortality of 40%, a bycatch mortality of 1,000 crab reduces potential catch by 600 crab with 1 year of natural mortality or by 216 crab with 3 years of natural mortality. In the former case, the weight per crab is 4.27 lbs and the reduction in potential catch is about 2,562 lbs. In the latter case, the weight per crab is 6.24 lbs and about 1,348 lbs of potential crab catch are foregone. Using the 1988 exvessel price of $5.10 per pound round weight (Table A2.1.2), the estimated reductions in gross exvessel value are $13,066 and $6,874, respectively (Table A2.1.3), for the two cases. With a discount rate greater than zero, the discounted value of the foregone reduction in value is necessarily less. Estimates of the reduction in value for discount rates of 5% and 10% are presented in Tables A2.1.3 and A2.1.4, respectively, for two species of crab and halibut.

One problem in estimating the effect of bycatch is determining how bycatch mortality will affect future crab and halibut catch. The method described above is based on one of several feasible sets of assumptions concerning the effect on catch. Two critical assumptions of this method are that: 1) the effect of bycatch mortality on the crab and halibut stocks will be detected and result in modified quotas and catches; and 2) the per unit value of crab and halibut that are taken in crab and halibut fisheries are equal to those of crab and halibut that are left on the grounds to contribute to future catch.

The first assumption may be more tenuous for crab than for halibut. The effect of bycatch on stock size relative to the confidence intervals for the estimates of stock size is quite low for crab. Typically the crab bycatch has been less than 1% of the estimated crab population; however, as noted in Section 2.4.2, crab surveys conducted since 1976 have a stated average confidence interval of plus or minus 31% for C. bairdi Tanner crab and plus or minus 39% for red king crab. If the effect of bycatch on crab stocks is not fully accounted for in the future estimates of crab populations, the reductions in future crab catch due to bycatch may be less than estimated or further in the future than estimated and the decrease in the discounted present value of future gross exvessel value of crab catch would then tend to be overestimated.

The direction of the bias introduced by the latter assumption is not known. However, the validity of this assumption, at least at the margin, is implicit in the management decision that establishes the exploitation rate and that limit retention to males above a specific size. In the case of red king crab with an exploitation rate of less than 40% and a prohibition on retaining female crab or small male crab, much of the estimated effect of bycatch is associated with the value of leaving additional crab on the grounds. The validity of that part of the estimate is quite speculative.

If the stocks are expected to be so depressed that no crab fishery would be permitted when the crab taken as bycatch would have been available to the crab fishery, the implication is that the marginal value of crab left on the grounds is greater than the marginal value of crab for commercial harvest. In this case, the effect of bycatch on future catch in the crab fishery should be estimated in terms of foregone reproductive potential (Reeves and Terry, 1986). If this is not done, the bycatch induced potential decrease in the gross exvessel value of the crab fishery will tend to be under estimated.

The importance of the growth and natural mortality assumptions increases as the difference between the average weights of crab and halibut taken as bycatch and as target catch differ. There is considerable uncertainty concerning the appropriate natural mortality rate for crab, this is in part due to the variability of these rates during the 1980s.

Fluctuations in exvessel prices are an additional potential source of error in the estimates of the effects of bycatch on the exvessel value of the crab and halibut fisheries because bycatch tends to reduce crab or halibut fishery catch one or more years after the bycatch occurs.

Decreases in Gross Exvessel Value and Bycatch Impact Costs

The last issue to be addressed is whether the decrease in gross exvessel value of catch in the crab and halibut fisheries provides a useful measure of the impact cost of bycatch. The decreases in gross exvessel value due to bycatch tend to overstate the effects on the crab and halibut fishermen for two reasons. First, the decrease in fishing costs that would typically accompany a decrease in catch is ignored. Second, the positive price effect of a decrease in catch is also ignored. However, this upward bias is at least partially offset because the decrease in gross exvessel value does not capture impact cost beyond the harvesting sector.

Although the net effect of these opposing biases cannot be precisely determined without more detailed knowledge of the actual demand and supply relationships than is available, some conclusions can be drawn concerning the usefulness of this measure of impact costs. The decrease in benefits associated with a decrease in catch in the crab or halibut fishery tends to be captured by the change in producer and consumer surplus. Therefore, the evaluation of the decrease in gross exvessel value as a measure of bycatch impact costs is made by comparing the change in gross value to the change in producer and consumer surplus.

Producer and consumer surplus for a given level of catch equals the area between the demand and supply curves up to that level of catch. If the quota is set at Q1 and if the quota is a binding constraint, catch equals Q1, the exvessel price equals P1, and producer and consumer surplus equals the area of abcd in Figure A2.1.1. If the quota and catch are reduced to Q2, the price would increase to P2, and the producer and consumer surplus would be equal to the area of aefd. The decrease in the surplus equals the area of ebcf and the decrease in exvessel value, ignoring the increase in price, equals P1 x (Q1 - Q2) or the area of ghci. The difference between the decrease in producer and consumer surplus and the decrease in exvessel value unadjusted for the price increase, is equal to the difference between the areas of icf and ghbe. If the absolute values of the slopes of the demand and supply curves were equal, the areas of icf and ejb would be equal and the decrease in unadjusted exvessel value would be greater than the decrease in the surplus by an amount equal to the area of ghje. But there is no reason to assume that the slopes meet that condition.

If the slope of the supply curve approaches 0 (MC2), the area of ejb also approaches 0, and the comparison can be made between the areas of icf and ghje. The former area equals 0.5 x (P2 - P1) x (Q1 - Q2) and the latter area equals MC2 x (Q1 - Q2). Therefore, if 0.5 x (P2 - P1) is less than MC2, the decrease in producer and consumer surplus is less than the decrease in exvessel value unadjusted for the price increase. There is not sufficient information available to estimate what the marginal cost is or what the change in price would be; however, upper bounds on the expected price increase and lower bounds on the level of the marginal cost can be used to determine whether the unadjusted decrease in exvessel value would probably be greater or less than the decrease in producer and consumer surplus.

It is unlikely that the decrease in catch caused by bycatch has increased the price of crab or halibut by as much as 50% and it is also unlikely that the marginal cost of landing crab or halibut, including the opportunity cost of labor and other variable costs, is less than 25% of the exvessel price. With these outer bounds, the decreases in producer and consumer surplus would equal the decrease in exvessel value unadjusted for the price increase. With what are probably more reasonable estimates of the increase in price and the level of the marginal cost in relation to the price, the decrease in the surplus would be less than the decrease in unadjusted exvessel value. Therefore, when the decrease in the exvessel value of crab and halibut catch is used to estimate the impact cost of crab and halibut bycatch in the groundfish fisheries, the actual decrease in net benefits as measured by the decrease in producer and consumer surplus will tend to be overestimated.

Although uncertainty concerning the values of both biological and economic variables limits our ability to successfully estimate the impact costs of crab and halibut bycatch in the groundfish fisheries, such estimates are implicit in each management decision made concerning bycatch. Efforts to produce generally defensible estimates are essential for an objective and otherwise successful solution to the bycatch problem.

Figure A2.1.1--Comparison of the decrease in producer and consumer surplus with the decrease in gross exvessel value unadjusted for the increase in price.

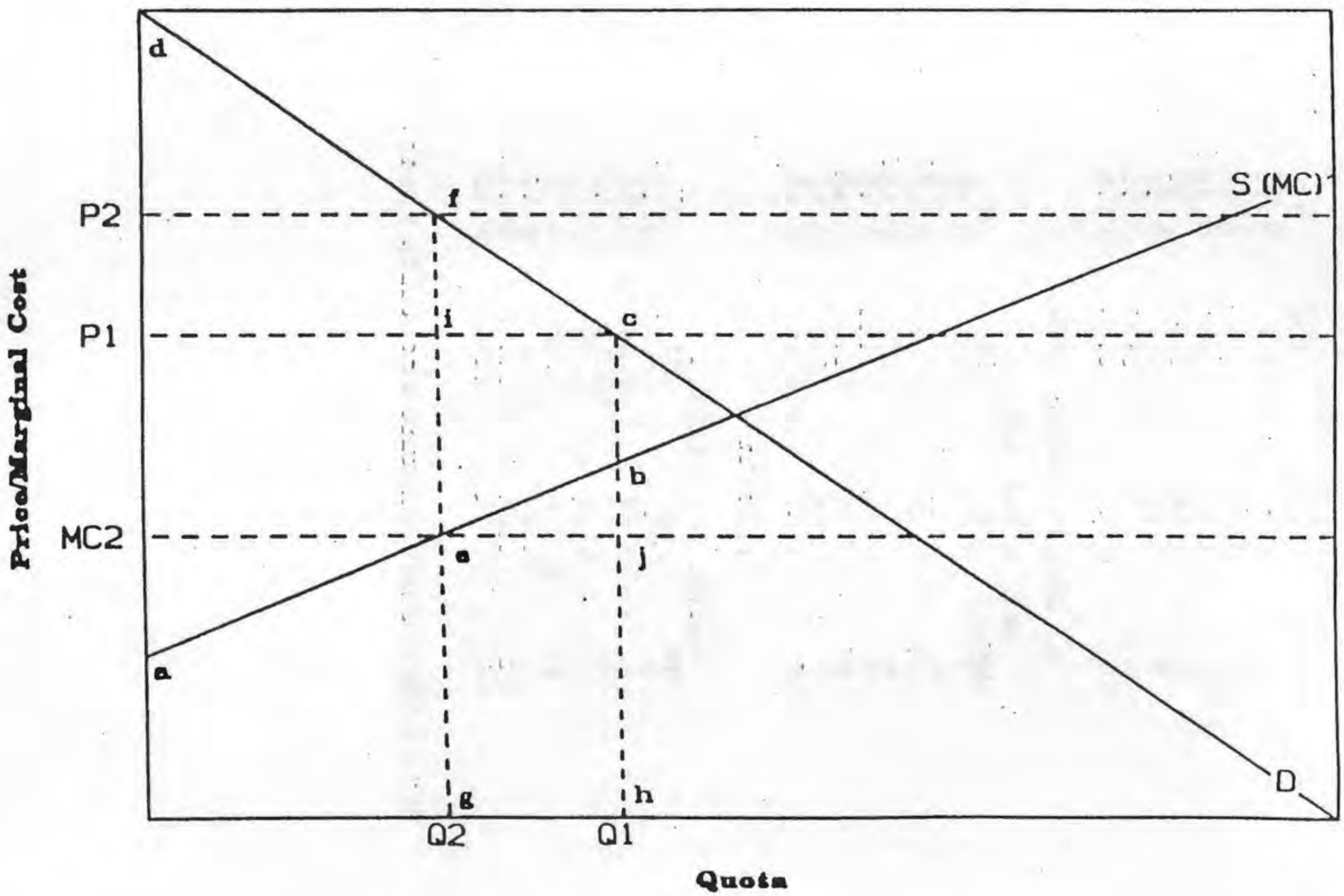

Table A2.1.1 Biological parameters used in estimating the potential impact cost of bycatch.

Red King Crab

age	weight per crab kg	lbs	M
3	0.32	0.70	0.36
4	0.49	1.07	0.36
5	0.83	1.82	0.36
6	1.18	2.61	0.36
7	1.54	3.39	0.36
8	1.94	4.27	0.36
9	2.41	5.32	0.36
10	2.83	6.24	0.36

C. bairdi Tanner crab

age	weight per crab kg	lbs	M
3	0.06	0.14	0.45
4	0.14	0.31	0.45
5	0.26	0.57	0.45
6	0.43	0.95	0.45
7	0.59	1.31	0.45
8	0.75	1.66	0.45
9	0.94	2.08	0.45
10	1.12	2.46	0.45

Halibut

age	weight per halibut kg	lbs	M
4	1.03	2.27	0.18
5	3.99	8.80	0.18
6	7.32	16.13	0.18
7	9.07	20.00	0.18
8	10.70	23.60	0.18
9	13.30	29.33	0.18
10	16.08	35.47	0.18
11	19.23	42.40	0.18

"M" is the annual natural mortality rate.

Table A2.1.2 Exvessel prices used in estimating the potential impact cost of bycatch.

1988 Exvessel Prices ($/lb.)	
king crab	5.10
bairdi	2.17
halibut	0.92*

* The average exvessel price in 1988 was $1.23 per pound dressed weight; with a round to dressed recovery rate of 75%, this is comparable to a round weight exvessel price of $0.92.

Note: The estimates in this appendix were adjusted using 1990 prices of $5 for king crab and $2.20 for bairdi prior to being used to compare the effects of the three alternatives. If this method were used for halibut, the estimates could be adjusted using a 1990 price of $1.51.

Table A2.1.3 Estimated potential reduction in crab catch and discounted exvessel value per 1,000 crab of bycatch mortality for different average bycatch weights, target catch ages, and discount rates.

Red King Crab with a Target Catch Age of 8

			Impact			
			Catch	Discounted Exvessel Value ($)		
kg/crab	age	years	(lbs)	(0%)	(5%)	(10%)
0.32	3	5	332	1693	1327	1051
0.49	4	4	553	2822	2322	1928
0.83	5	3	922	4704	4063	3534
1.18	6	2	1537	7840	7111	6479
1.54	7	1	2562	13066	12444	11878
1.94	8	0	4270	21777	21777	21777

Red King Crab with a Target Catch Age of 10

			Impact			
			Catch	Discounted Exvessel Value ($)		
kg/crab	age	years	(lbs)	(0%)	(5%)	(10%)
0.32	3	7	175	891	633	457
0.49	4	6	291	1485	1108	838
0.83	5	5	485	2475	1939	1537
1.18	6	4	809	4124	3393	2817
1.54	7	3	1348	6874	5938	5165
1.94	8	2	2246	11457	10392	9468
2.41	9	1	3744	19094	18185	17359
2.83	10	0	6240	31824	31824	31824

"Years" is the number of years between bycatch age and target catch age.

In 1988 the average weight of male red king crab taken as bycatch in the BSAI joint venture fishery was 1.60 kg. A crab of that weight is about 7 years old.

Notes: The estimates in this appendix were adjusted using 1990 prices of $5 for king crab and $2.20 for bairdi prior to being used to compare the effects of the three alternatives.

The estimate of natural mortality of red king crab used in generating this table was somewhat higher (0.4) than presented in Table A2.1.1. Consequently, the impact costs will increase upon revision.

Table A2.1.3 continued

Bairdi with a Target Catch Age of 8

		Impact				
		Catch	Discounted Exvessel Value ($)			
kg/crab	age	years	(lbs)	(0%)	(5%)	(10%)
0.06	3	5	17	37	29	23
0.14	4	4	43	92	76	63
0.26	5	3	106	231	199	173
0.43	6	2	266	577	523	477
0.59	7	1	665	1443	1374	1311
0.75	8	0	1662	3607	3607	3607

Bairdi with a Target Catch Age of 10

		Impact				
		Catch	Discounted Exvessel Value ($)			
kg/crab	age	years	(lbs)	(0%)	(5%)	(10%)
0.06	3	7	4	9	6	4
0.14	4	6	10	22	16	12
0.26	5	5	25	55	43	34
0.43	6	4	63	137	112	93
0.59	7	3	157	342	295	257
0.75	8	2	393	854	774	706
0.94	9	1	984	2134	2033	1940
1.12	10	0	2459	5336	5336	5336

"Years" is the number of years between bycatch age and target catch age.

In 1988 the average weight of male bairdi Tanner crab taken as bycatch in the BSAI joint venture fishery was 0.29 kg. A crab of that weight is about 5 years old.

Notes: The estimates in this appendix were adjusted using 1990 prices of $5 for king crab and $2.20 for bairdi prior to being used to compare the effects of the three alternatives.

The estimate of natural mortality of C. bairdi Tanner crab used in generating this table was higher (0.6) than presented in Table A2.1.1. Consequently, impact costs will increase upon revision.

Table A2.1.4 Estimated potential reduction in halibut catch and discounted exvessel value per metric ton of halibut bycatch mortality for different average bycatch weights, target catch ages, and discount rates.

Halibut with a Target Catch Age of 8

			Impact			
			Catch	Discounted Exvessel Value ($)		
kg/halibut	age	years	(lbs)	(0%)	(5%)	(10%)
1.03	4	4	10316	9490	7808	6482
3.99	5	3	3245	2986	2579	2243
7.32	6	2	2162	1989	1804	1644
9.07	7	1	2130	1960	1867	1782
10.70	8	0	2205	2029	2029	2029

Halibut with a Target Catch Age of 11

			Impact			
			Catch	Discounted Exvessel Value ($)		
kg/halibut	age	years	(lbs)	(0%)	(5%)	(10%)
1.03	4	7	10171	9358	6650	4802
3.99	5	6	3200	2944	2197	1662
7.32	6	5	2132	1961	1537	1218
9.07	7	4	2100	1932	1590	1320
10.70	8	3	2174	2000	1728	1503
13.30	9	2	2136	1966	1783	1624
16.08	10	1	2158	1986	1891	1805
19.23	11	0	2205	2029	2029	2029

"Years" is the number of years between bycatch age and target catch age and "Catch" is in round weight.

In 1988 the average weight of halibut taken as bycatch in the BSAI joint venture fishery was 1.62 kg. A halibut of that weight is about 4 years old.

Note: If this method were used for halibut, the estimates could be adjusted using a 1990 price of $1.51.

APPENDIX 2.2

Overview of Bycatch Monitoring Programs
in Alaskan Groundfish Fisheries
1988 - 1989

This paper summarizes Alaska Region NMFS' experience with special bycatch monitoring programs. Its purpose is to give insight into administrative, operational and statistical aspects of proposals for future bycatch monitoring programs. It includes the 1988 Industry/NMFS Joint Venture Bycatch monitoring program; the 1989 Port Moller Scientific Data Collection Program; and the 1989 Gulf of Alaska Halibut Bycatch monitoring program.

1988 Industry/NMFS Crab Bycatch Monitoring Program

Background: Under Amendment 10 of the Bering Sea and Aleutian Islands Fisheries Management Plan, caps were established for bycatches of red king crab and C. bairdi tanner crab in certain areas of the Bering Sea. These caps applied to both joint venture (JV) groundfish fisheries and domestic (DAP) fisheries.
JV fisheries were monitored using bycatch data collected by observers, whereas until 1990 DAP fisheries' bycatches were estimated using historical JV rates.

The JV industry as a whole was concerned that "dirty fishing" (i.e. excessive crab bycatch) by a relatively few individual boats would prematurely close key groundfish areas when crab caps were reached. The industry devised a program by which individual JV companies would be monitored and closed out of an area if dirty fishing occurred. NMFS implemented it by attaching the program as a permit condition on all foreign processing vessels which participated in the 1988 JV fisheries.

Program Elements: The program established, for each crab cap, checkpoints of 20%, 40%, 60% and 80% of the cap. At each checkpoint, each company was evaluated against both a fixed and an industry average rate. Any operation whose rate exceeded both the fixed rate and 150% of the industry average rate was forced to leave the zone. A grace period was instituted for the first checkpoint that any operation encountered; if the rate was more than 200% of the industry average, it was forced to leave, but if the rate was between 151% and 200% it only had to leave for 10 days. Closure was accomplished by notice from RD to company representative.

Scope and duration: The program affected 34 companies, and was in effect from January 15 to May 14, when the last cap was reached. Daily monitoring of two different crab caps was in effect for most of that period.

Personnel: NMFS Regional Office had a full-time staffer assigned to the project, but she put in up to 60-hour work weeks and worked weekends for most of the duration of the program. NMFS Observer Program had two staffers each spending 20 hours per week in daily data editing/control, as well as one in data entry (10 hours/week) and one providing programming support (10 hours total). At-sea observers took an additional half-hour to formulate and send messages (a total of 2,000 hours which would have otherwise been spent sampling).

In addition, the industry hired a full-time coordinator to collect data independently. This accomplished two things; cross-checking of NMFS data, and providing comprehensive releasable data

to industry (NMFS-collected company data is confidential to all but the company itself).
Results: In the Zone 1 fishery, the 20% checkpoint was reached rapidly because of high bycatches in rock sole operations, but because the industry average itself was so high, no company was excluded. Later, 3 companies were excluded at the 40% checkpoint and 2 at the 60%. In the Zone 2 fishery, 2 were excluded at each of the 20%, 40% and 60%, and one at the 80% checkpoint. The overall rate of red king crab in Zone 1 was .5 crab per mt, as compared to .87 the prior year and 1.17 the following year. However, the 80,000 crab cap was overshot by 10,000 crab, which was mostly taken in the last 3 days of fishing. A total of 99,800 mt of groundfish were taken in Zone 1 before it closed, compared to only 74,000 mt in 1987.

There were several complaints from companies that they had been unfairly excluded. In one case, the exclusion was based on a single tow - the first one of that particular operation - which happened to encounter a crab ball. Because the operation had begun shortly before a checkpoint, it did not have time to make additional tows which might have lowered its rates, but was evaluated and excluded nonetheless. Similarly, several companies were narrowly excluded which, if the checkpoint had fallen a day earlier or later, would have "passed" the criteria; basically, these companies had the bad luck to have tows with high crab bycatches just prior to checkpoints. The checkpoints, due to considerable fluctuations in the daily crab data, were not anticipatable by either NMFS or industry more than two days in advance.

Conclusions: The program was successful in increasing groundfish catch in Zone 1 and lowering crab bycatch rates. It was not successful in preventing the crab cap from being exceeded, due to lack of constraints after the 80% checkpoint. The fairness of the exclusion procedure, although agreed upon by industry, was questionable given the large, unanticipatable, and apparently random nature of fluctuations in crab catches. The industry data coordinator position was important in providing data on occasions when NMFS observer messages were garbled or missing, and serving as provider of detailed information to the fleet.

PORT MOLLER PROGRAM, 1989

Background: Under Amendments 10 and 12a, area 512 was closed to trawling with the exception of domestic trawling for Pacific cod in an area generally referred to as the Port Moller area. Vessels in this fishery were required to fish in accordance with a data-gathering program designed to provide data about and prevent overfishing of prohibited species. There was also a cap of 12,000 red king crab applicable to that area. As conducted in 1987 and 1988 the program provided useful biological information but not until 1989 was the program design modified in a way (required area check-ins, reports and 100% observer coverage) which permitted in-season monitoring of the cap.

Program elements: Each vessel had to apply to the program through the Regional Director, and agree to the conditions of the Program. These included carrying an observer, notifying the R.D. of starting and stopping times, and making all data public. Closures were accomplished by notification of R.D. to applicant.

Scope and duration: Eight vessels applied, although only six vessels participated in the program, the first beginning on June 5. The area was closed and the program terminated on July 14. Weekly monitoring of catch was in effect.

Personnel: A Regional staffer was responsible for final design of the data collection program, managing applications, and closing the fishery. Estimated time spent in these activities was 40 hours. An observer program staffer collected, edited and extrapolated the weekly observer data; estimated time spent in these activities was 20 hours per week or about 120 hours.

Results: A total of 5,600 mt of groundfish was taken during the program, including 2,800 mt of Pacific cod. Over 400 mt was unobserved or incompletely sampled because of problems with observer logistics (for example, airline lost sampling gear going to Dutch Harbor). The red king crab catch was 13,940, exceeding the cap by almost 2,000 crabs.

Conclusions: Monitoring even a small fishery can be very labor-intensive. Theoretical "100%" observer coverage never really is achieved, which requires some level of extrapolation by knowledgeable statisticians. Weekly monitoring is inadequate for precise monitoring of quotas in short-term fisheries, even with few participants.

1989 Gulf of Alaska Special Bottom Trawl Fishery

Background: Under Gulf of Alaska regulations, a cap was set on bycatch of Pacific halibut caught by trawls. When this cap was reached, bottom trawling was closed except for vessels participating in a special observer program, which was in effect until an additional 36 mt of halibut mortality was reached.

Program Elements: The observer plan required 100% coverage. All vessels were eligible to participate. The required target species was flounder. If a vessel's halibut bycatch rate reached or exceeded 4.5 percent during the first week, or 3.0 percent during any subsequent week, it was excluded from the fishery for the remainder of the year. Closures were accomplished by notice from R.D. to vessel captain.

Scope and duration of program: Only three vessels participated in the program, which began November 12. Two vessels experienced bycatch rates in excess of 4.5 percent in the first week each fished, and were excluded from the fishery. The other vessel kept its rates low for three weeks and remained in the fishery until it voluntarily ceased in early December. There was a two-day period required for data receipt/analysis before a closure notice could be sent. Weekly monitoring was in effect.

Personnel: A Regional staffer was responsible for design of the observer plan and informing each vessel of its closure; estimated time spent 6 hours. An observer program staffer was responsible for data collection/verification; estimated time, 10 hours.

Results: A total of 178 mt of groundfish was taken during the program, with an estimated halibut mortality of 5.7 mt.

Conclusions: Sample size is too small to be conclusive, but suggests that one week may be too short a period for many boats to adjust fishing in order to lower bycatch.

Administrative and Personnel Aspects of Bycatch Control Options

Options include PSC caps, incentive programs, and time/area closures, or some combination of the three. Any variation of PSC caps and time/area closures, or combination thereof, WITHOUT incentive programs or individual monitoring of any kind, can probably be handled by Regional staff levels expected by the end of 1990. During short intensive fisheries or periods of daily monitoring, one individual must be dedicated to each fishery or quota being monitored, and be prepared to work weekends.

Any kind of individual monitoring or incentive program changes the picture radically. Experience suggests that one person working full time can be responsible for 20 entities if daily monitoring is required; this would be a 40 hour a week job. It does NOT follow that the same person could handle 100 entities under weekly monitoring. If weekly data comes in all at once, and for the sake of equity all data must be analyzed/edited and closure decisions made within the same short time frame, the limit is still 20 entities per staffer. If the time frame were extended to two days, and half the data came in on each of two days, the limit would be 40 entities. This would be about a 20 hour a week job.

Staffing and logistics of observer program personnel present further difficulties. In order to provide scheduled training for observers, a minimum of two month's lead time and an accurate count of observers is required. This will be impossible to meet given the unpredictability associated with individual boat monitoring.

Furthermore, such monitoring puts tremendous pressure on individual observers. Under checkpoint schemes, it is possible that an observer's predetermined decision whether or not to sample an individual haul may dictate the future fishing ability, and perhaps economic viability, of the vessel. That in turn may affect the continued employment of that observer. The observer program works only because observers are trusted to be independent and unbiased, and not subject to outside influence; programs that could put this trust at risk could undermine the entire observer program.

Incentive program design

Staff needs would depend on the scope, complexity and duration of each incentive program, and whether one or more programs might be in effect simultaneously.

The scope, or number of vessels affected, would be a function of the usual number of boats participating in a fishery as modified by any limitation imposed by a reserve system. For example, if 20 vessels usually fish for rock sole, but only 10 met the criteria to fish in a reserve system, one staff person would be needed during a rock sole reserve fishery with daily monitoring.

The complexity of the program is related to the natural irregularity of the data, (randomness and variability) and the observer coverage levels. At less than 100% coverage levels, considerable time is devoted to ensuring data are extrapolated correctly. At even "100%" coverage levels, some data will have to be estimated; irregular data, such as red king crab data, are more complicated to estimate.

The duration of the program affects whether daily or weekly monitoring is required. As a rule of thumb, at least four data points are required for accurate projections, so any season that is apt to be less than six weeks requires more-frequent-than weekly monitoring. This, practically, means daily monitoring, since weeks are not amenable to breaking into other increments.

Another factor that must be considered is the legal requirement of closing individual operations. Past programs required immediate closure on contact by the R.D. However, if closure requirements became more formal, (for example receipt by registered mail) or demanded a cooling-off period and a chance for individual to contest data, the process would be considerably more time-consuming.

Given the uncertainty about number and possible overlap of programs, and the design of any one program, it is impossible to estimate the number of additional Regional staff needed. It is at least clear that staff needs will be irregularly spaced throughout the year, which suggests that these jobs should be filled by short-term assignments. These could be persons on IPA's from other regions or even organizations. For example, the IPHC could provide a staff person for monitoring the Pacific halibut bycatch in the Gulf of Alaska, and a person from ADF&G's crab staff could be assigned red king crab catch in the rock sole fishery.

STATISTICAL ASPECTS

Monitoring of PSC caps is inherently different from monitoring groundfish quotas, and to date we have not developed a reliable methodology for doing the former. This means that schemes that require closure of a fishery at a precise percent of a PSC quota are unlikely to succeed.

While groundfish quota monitoring cannot be characterized as simple, given the large number of species/area quotas, variety of gear types, and ability of vessels to switch target species without notification, the basic procedures of using catch and effort data to make quota projections have been used successfully for a decade in foreign, then joint venture and domestic fisheries. Using this system managers are usually able to "call" groundfish quotas within plus or minus a few percent. These same procedures cannot be effectively used for PSC quotas, because catch and effort data lose meaning in the latter context. Managers can assume that groundfish catch rates for each vessel class in a certain area will fall within a certain fairly narrow range; there is a maximum amount of groundfish that an individual trawler will be able to catch in one week in area 515. Groundfish rates do not vary much throughout a season for any individual vessel. Factors that can affect the magnitude of groundfish catches, mainly weather and movement of target species, affect all vessels proportionately. These assumptions go out the window with bycatch species; bycatch amounts can and do vary by orders of magnitude from vessel to vessel in the same area and in one vessel over time. Furthermore, the variation is unpredictable and to date we have not been able to establish a reliable connection with external factors.

Similarly, managers can safely assume fishermen are attempting to maximize their groundfish catch. However, reduction of PSC catch is at best a secondary goal to fishermen and one not consistently applied (if at all) across the fleet at any one time or by an individual boat throughout the season. As a result, there is a not a reliable relationship between groundfish and PSC catch. As an example, managers assume that a doubling of effort (number of vessels) in a an area by vessels targeting on a certain species will result in an approximate doubling of catch, and reaching that species quota by a readily calculable earlier date. The manager cannot assume, however, that bycatch catch will similarly double. The amount of increase will be related to such intangibles as the experience of the new vessels in avoiding bycatch and their commitment to bycatch avoidance as a goal. The manager can assume some trends - that bycatch rates of new vessels will be higher (perhaps only for a short period until gear is tuned) and that increased competition will cause vessels to "go for the groundfish" rather than minimize bycatch - but these are not quantifiable trends. The manager must therefore wait for hard information before making a decision. In a daily monitoring mode, there is currently a two day minimum period for receipt and analysis of observer data; verification of questioned data requires another two days. Given that several points (days) are needed to firmly establish a trend, the likelihood of the quota being overshot is high.

Individual vessel monitoring has been proposed as a panacea for both overshooting quotas and avoiding "dirty fishing." However, there are some aspects that should be thoroughly investigated before committing to any such a system. A major problem is that the effects of sampling error are magnified when the basic data unit is an individual vessel. Given that our information system will never be perfect or real time, errors that might have no effect over a fleet or an entire season are critical in the context of one vessel and a short time frame. This is illustrated in attached tables which illustrate the type of data that would be received in a daily individual vessel monitoring scheme. The data closely resemble real crab bycatch data.

Table 1 shows data from two vessels, the first a "clean" vessel with a season's catch of .8 crab/mt, the second a "dirty" vessel with a rate 25% higher. Assume the monitoring program evaluates vessels at certain checkpoints and eliminates vessels whose cumulative rates fall above .8 crab/mt. Checkpoints happen to fall on days 5, 10 and 18. Table 1 illustrates that the "clean" vessel, or vessel 1, is eliminated on day 5, whereas the "dirty vessel" is not eliminated until day 18, partly because it happened to start right after a checkpoint.

Table 2 shows the effect of incorrect or incomplete sampling. On day 9, vessel 1's observer was sick. The cumulative catch rate through day 8 was .7 crab/mt, and this rate was substituted in that cell. However, that put the cumulative rate on checkpoint day 10 at .9, and the vessel would be "unfairly" eliminated. Similarly, on day 17, the observer data from vessel 2 was scrambled and a message sent for clarification. The cumulative catch rate through day 16 was .8, which was temporarily substituted in that cell. On checkpoint day 18, vessel 2 was allowed to continue fishing. Not until a corrected observer message was received could vessel 2 be eliminated. Note that if the incorrect message had been a wrong number within the range of .4 to 2.4, rather than obviously scrambled, the data manager would not have identified it and the error would have remained in the data base until the return of the observer to Seattle.

It is imperative that any proposed incentive scheme be tested with real data from the fishery. However, the test should go further than using data that has been "cleaned up" and finalized but attempt to create a realistic data set, one that at any one time will include missing and incorrect cells.

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TABLE 1.

	VESSEL 1						VESSEL 2					
DAY	GF	CUM. GFSH	CRAB RATE	CRAB	CUM. CRAB	CUM. CRAB RATE	GF	CUM. GFSH	CRAB RATE	CRAB	CUM. CRAB	CUM. CRAB RATE
1	10	10	0.5	5	5	0.5	0	0	0	0	0	ERR
2	12	22	0.4	5	10	0.4	0	0	0	0	0	ERR
3	14	36	0.3	4	14	0.4	0	0	0	0	0	ERR
4	16	52	0.8	13	27	0.5	0	0	0	0	0	ERR
5	15	67	2.1	32	58	0.9	0	0	0	0	0	ERR
6	13	80	0.6	8	66	0.8	9	9	1.6	14	14	1.6
7	12	92	0.4	5	71	0.8	14	23	1.1	15	30	1.3
8	14	106	0.6	8	79	0.7	12	35	0.6	7	37	1.1
9	16	122	0.5	8	87	0.7	13	48	0.5	7	44	0.9
10	15	137	1.8	27	114	0.8	10	58	0.4	4	48	0.8
11	13	150	0.8	10	125	0.8	9	67	0.7	6	54	0.8
12	7	157	0.2	1	126	0.8	8	75	0.9	7	61	0.8
13	0	157	0.0	0	126	0.8	0	75	1.0	0	61	0.8
14	0	157	0.0	0	126	0.8	7	82	1.1	8	69	0.8
15	12	169	1.3	16	142	0.8	9	91	0.7	6	75	0.8
16	14	183	0.8	11	153	0.8	15	106	0.5	8	83	0.8
17	16	199	0.7	11	164	0.8	16	122	1.8	29	111	0.9
18	15	214	0.6	9	173	0.8	13	135	0.8	10	122	0.9
19	13	227	0.8	10	184	0.8	12	147	1.6	19	141	1.0
20	12	239	0.6	7	191	0.8	14	161	0.9	13	154	1.0

TABLE 2.

	VESSEL 1						VESSEL 2					
DAY	GF	CUM. GFSH	CRAB RATE	CRAB	CUM. CRAB	CUM. CRAB RATE	GF	CUM. GFSH	CRAB RATE	CRAB	CUM. CRAB	CUM. CRAB RATE
1	10	10	0.5	5	5	0.5	0	0	0	0	0	ERR
2	12	22	0.4	5	10	0.4	0	0	0	0	0	ERR
3	14	36	0.3	4	14	0.4	0	0	0	0	0	ERR
4	16	52	0.8	13	27	0.5	0	0	0	0	0	ERR
5	15	67	2.1	32	58	0.9	0	0	0	0	0	ERR
6	13	80	0.6	8	66	0.8	9	9	1.6	14	14	1.6
7	12	92	0.4	5	71	0.8	14	23	1.1	15	30	1.3
8	14	106	0.6	8	79	0.7	12	35	0.6	7	37	1.1
9	16	122	0.7	11	91	0.7	13	48	0.5	7	44	0.9
10	15	137	1.8	27	118	0.9	10	58	0.4	4	48	0.8
11	13	150	0.8	10	128	0.9	9	67	0.7	6	54	0.8
12	7	157	0.2	1	129	0.8	8	75	0.9	7	61	0.8
13	0	157	0.0	0	129	0.8	0	75	1.0	0	61	0.8
14	0	157	0.0	0	129	0.8	7	82	1.1	8	69	0.8
15	12	169	1.3	16	145	0.9	9	91	0.7	6	75	0.8
16	14	183	0.8	11	156	0.9	15	106	0.5	8	83	0.8
17	16	199	0.7	11	167	0.8	16	122	0.8	13	95	0.8
18	15	214	0.6	9	176	0.8	13	135	0.8	10	106	0.8
19	13	227	0.8	10	187	0.8	12	147	1.6	19	125	0.8
20	12	239	0.6	7	194	0.8	14	161	0.9	13	138	0.9

3.0 OVERFISHING DEFINITIONS FOR THE GOA AND BSAI

(Author's note: This chapter employs a number of technical concepts and analytical methods. Because of the complexity of the material, an overview is provided to help the nontechnical reader. It should be noted that small amounts of accuracy and precision have been sacrificed in the overview for the sake of simplicity.)

3.1 Nontechnical Overview

In 50 CFR Part 602, the National Oceanic and Atmospheric Administration (NOAA) presented its Guidelines for Fishery Management Plans (the "602 Guidelines"), which require each FMP to include an objective and measurable definition of overfishing for each stock or stock complex under management.

The 602 Guidelines make a clear distinction between the prevention of overfishing and the achievement of optimum yield. Thus, the task of specifying an overfishing definition should not be confused with an attempt to articulate an optimal harvest policy. The overfishing definition is to be used as a constraint, not as a target. (This does not mean that the two can never coincide in practice; it does mean, however, that the purposes of an overfishing definition and an optimal harvest policy are distinctly different.)

3.1.1 Overview of Terminology

Stock A population of fish. When "population" is used in a biological sense, it refers to a group of individuals, all of whom are members of the same species. Sometimes several stocks are grouped together to form a "stock complex" (often referred to as a "species complex").

Management category Any stock or stock complex for which the Council sets an ABC.

Biomass (B) The combined weight of a group (usually a stock) of fish. Sometimes a stock is measured in terms of the number of individuals it contains, and other times it is measured in terms of their combined weight.

Pristine biomass The long-term average biomass that would be observed (under current environmental conditions) if there were no fishing. This value may be different than the earliest recorded biomass level if environmental conditions have changed, or if a significant fishery had already developed by the time the earliest biomass level was recorded.

Threshold The biomass level below which the Secretary will close the fishery. If the Council sets a threshold for a particular stock, all fishing on that stock must cease if its biomass falls below the threshold level.

Recruitment The portion of a stock that becomes available to the fishery during the course of a year. Usually, the very youngest age groups are not recruited to the fishery. Older age groups may be either partially or fully recruited, though most simple fishery models assume that all fish become recruited at a single age (e.g., age 3 in the case of Pacific cod in the GOA).

Biomass-per-recruit ratio The ratio of biomass to recruitment. This ratio can take on different values, depending on the level of fishing mortality. For example, suppose that there were no fishing at all on a particular stock, and that fish in this stock recruit at age 3. Suppose further that 1000 recruits in this stock would survive and grow according to the following (purely hypothetical) table, where biomass is the product of numbers and weight:

Age	Numbers	Weight	Biomass
3	1000	0.5	500
4	670	0.6	402
5	449	0.7	314
6	301	0.8	241
7	202	0.9	182
8	135	1.0	135
9	91	1.1	100
10	61	1.2	73
11	41	1.3	53
Total	2950	---	2000

In this example, the biomass-per-recruit ratio is 2.0, obtained by dividing total biomass (2000) by the number of recruits (1000). Now, suppose that when the stock is fished at a rate equal to the natural mortality rate, the above table changes to the following:

Age	Numbers	Weight	Biomass
3	1000	0.5	500
4	449	0.6	269
5	202	0.7	141
6	91	0.8	73
7	41	0.9	37
8	18	1.0	18
9	8	1.1	9
10	4	1.2	5
11	2	1.3	3
Total	1815	---	1055

Now the biomass-per-recruit ratio is 1.055 (1055 divided by 1000). In other words, the biomass-per-recruit ratio has been reduced to a fraction of its pristine (unfished) value. This fraction is 1.055/2.0 = 0.5275. Other levels of fishing mortality would result in other values for this fraction; the higher the level of fishing mortality, the smaller the fraction.

Stock-recruitment relationship The relationship between stock size and future recruitment level. To know the stock-recruitment relationship means to know the recruitment levels that are most likely to be generated by each stock size within a wide range of stock sizes. The most common types of stock-recruitment relationships used in fishery models are called "Beverton-Holt," "Cushing," and "Ricker" curves (named after the scientists who developed them).

Yield The same as catch or harvest. Yield is usually measured as the combined weight of the fish that are caught during a year.

Maximum sustainable yield (MSY) The largest catch which the stock can withstand, on average, over a long period of time (given current environmental conditions). Estimation of this quantity is often difficult, since it requires having an estimate of the stock-recruitment relationship.

Yield variability The percentage by which a given catch might deviate from the long-term average, plus or minus. For example, if yield variability were 10%, most catches would be within plus or minus ten percent of the long-term average.

Catch per unit effort (CPUE) The ratio between catch and fishing effort. It is usually expected that CPUE will be highest when biomass is highest. If a stock is fished hard, biomass may be driven down, thereby causing CPUE to fall as well.

B_{MSY} The long-term average biomass level that would be observed (under current environmental conditions) if the annual catch were set consistently at the MSY level.

Natural mortality rate (M) A term that describes the proportion of the stock that is removed (per unit time) as a result of non-fishery causes (e.g., predation, disease, old age). The natural mortality rate is usually expressed as an "instantaneous" rate, which is analogous to the "continuous compounding of interest" concept sometimes used in financial computations (mortality can be thought of as negative interest).

Fishing mortality rate (F) A term that describes the proportion of the stock that is removed (per unit time) by the fishery. Like the natural mortality rate, the fishing mortality rate is usually expressed as an instantaneous rate.

F_{MSY} The fishing mortality rate that would yield MSY if stock biomass had been at the B_{MSY} level for a long time.

F_{MAX} The fishing mortality rate that maximizes yield per recruit. This quantity is easier to calculate than F_{MSY}, because it does not require an estimate of the stock-recruitment relationship. However, using F_{MAX} as a management strategy is sometimes considered dangerous, since it does not consider the possibility that recruitment could be reduced at low stock sizes. Usually, F_{MSY} is less than F_{MAX} (exceptions to this rule can occur when a "Ricker" type of stock-recruitment relationship is used to calculate F_{MSY}).

$F_{0.1}$ The fishing mortality rate where an additional unit of effort provides a catch equal to one-tenth of the CPUE that would be observed if stock biomass were at its pristine level (i.e., the highest possible CPUE). The $F_{0.1}$ rate is usually calculated under the assumption that future recruitment does not depend on stock size. The $F_{0.1}$ rate is always less than F_{MAX}. Since F_{MSY} is also usually less than F_{MAX}, $F_{0.1}$ is sometimes close to F_{MSY}.

Objective function A mathematical formulation of what the Council is trying to accomplish. The Council may wish to make management decisions (e.g., setting ABC or TAC levels) on the basis of a formally stated objective. This objective might take a relatively simple form, for example maximization of a single quantity such as long-term average yield. On the other hand, the Council might have several objectives it wishes to accomplish simultaneously. For example, the Council might wish to maximize long-term average yield and minimize yield variability. Unfortunately, it is sometimes impossible to accomplish competing objectives simultaneously. To illustrate, consider the following (purely hypothetical) situation:

Management strategy	Average yield	Yield variability
A	100	10.0%
B	98	8.8%
C	92	7.6%
D	82	6.4%

The column labeled "management strategy" lists four strategies (A, B, C, and D). Each strategy is expected to result in a particular long-term average yield (e.g., Strategy A is expected to result in a long-term average yield of 100). At the same time, each strategy is expected to result in a particular level of yield variability (e.g., Strategy A is expected to result in a yield variability of 10%). Notice that if the Council's management strategy were simply to maximize average yield, it would choose Strategy A, since the average yield for all other strategies is less. On the other hand, if the Council's management strategy were simply to minimize yield variability, it would choose Strategy D, since the yield variability for all other strategies is greater. However, it is impossible for the Council to accomplish both objectives simultaneously, since the Council cannot choose both Strategy A and Strategy D.

This is where the idea of an objective function comes into play. In order to get around the problem of accomplishing competing objectives, the Council could "weight" its various objectives, thereby providing an indication of which objectives are most important. Returning to the above example, the Council might decide that it is much more important to maximize long-term average yield than to minimize yield variability. Suppose the Council decided that the importance of maximizing long-term average yield is three times as great as the importance of minimizing yield variability. In other words, the Council's weighting factor for long-term average yield is 3, and its weighting factor for yield variability is 1. Here, then, is how the Council could go about making its decision: First, it could "standardize" the expected results of the management strategies, so that average yield and yield variability are measured in comparable terms (otherwise the Council would be adding apples and oranges). This could be done by dividing the result in each column by the result corresponding to Strategy A, as follows:

Management strategy	Average yield	Yield variability
A	100 ÷ 100 = 1.00	10.0 ÷ 10.0 = 1.00
B	98 ÷ 100 = 0.98	8.8 ÷ 10.0 = 0.88
C	92 ÷ 100 = 0.92	7.6 ÷ 10.0 = 0.76
D	82 ÷ 100 = 0.82	6.4 ÷ 10.0 = 0.64

Next, the Council could determine the "total benefit" of each strategy by applying the weights (3 and

1, respectively) to the second and third columns, then taking the difference (the term for yield variability is subtracted--not added--because the Council wishes to minimize--not maximize--this quantity):

Management strategy	Average yield		Yield variability		Total Benefit
A	1.00 x 3	-	1.00 x 1	=	2.00
B	0.98 x 3	-	0.88 x 1	=	2.06
C	0.92 x 3	-	0.76 x 1	=	2.00
D	0.82 x 3	-	0.64 x 1	=	1.82

The above table indicates that the Council would choose Strategy B, since it gives the greatest total benefit (as computed by the Council's objective function). Of course, other outcomes could be achieved if the Council were to assign different weights to the two variables. Also, long-term average yield and yield variability are not the only variables that the Council might wish to incorporate in its objective function. Other possible variables might include CPUE, average size of fish in the catch, stock biomass, and total industry profit. The number of possible objective functions is infinite.

3.1.2 Overview of the Alternatives

A number of different options are available to the Council under the 602 Guidelines. However, all of them involve two basic concepts: thresholds and maximum fishing mortality rates (these are two different concepts: a threshold corresponds to a biomass level that the Council does not want to go below, and a maximum fishing mortality rate corresponds to a harvest level that the Council does not want to go above).

To aid in the description of the alternatives, suppose that the Council is required to manage three stocks: Stock A is severely depressed, Stock B is slightly depressed, and Stock C is high in abundance. Specifically, suppose that these stocks exhibit the following characteristics (to make things easy, it has been assumed that all stocks exhibit the same values for all quantities except current biomass):

Stock	Pristine biomass	Current biomass	B_{MSY}	F_{MSY}	F_{MAX}
A	100,000	10,000	25,000	0.20	0.35
B	100,000	22,500	25,000	0.20	0.35
C	100,000	100,000	25,000	0.20	0.35

The following discussion describes each of the seven alternatives, and shows how overfishing would be defined for each of the three stocks in the above table. Figure 3.1 can also be used to examine how management of these stocks would be constrained by the various alternatives. (Note: the following discussion of the alternatives is considerably simplified relative to the discussion in the main text. In the main text, each of the alternatives is shown to incorporate a number of suboptions. Different suboptions are used depending on availability of data. The suboptions will not be discussed in this overview, except in the context of the description of Table 3.1 in Section 3.1.4.1).

Alternative 1 Status quo. The FMPs currently do not satisfy the 602 Guidelines' requirement for an objective and measurable definition of overfishing. All three stocks in the above example could be exploited at any level without being classified as overfished.

Alternative 2 Threshold biomass level. Under this alternative, fishing would not be allowed on any stock whose biomass is below its threshold level. One way (though not the only way) to define a threshold is to set it at 20% of pristine biomass. In the above example, this would result in the threshold being set at 20% x 100,000 = 20,000. Using this threshold, Stock A would be classified as overfished under any level of fishing, since the current biomass level of 10,000 is less than the threshold value of 20,000. However, since the current biomass levels for Stocks B and C are both above 20,000, they would not be classified as overfished under any level of fishing that kept them above the threshold.

Alternative 3 Constant fishing mortality rate--no threshold. Under this alternative, the fishing mortality rate on any stock would never be allowed to exceed F_{MSY}. In this case, none of the stocks in the above example would be classified as overfished so long as the Council did not allow them to be harvested at fishing mortality rates greater than 0.20.

Alternative 4 (Preferred) Variable fishing mortality rate--no threshold. Under this alternative, the fishing mortality rate on any stock would never be allowed to exceed a specified maximum level, but this maximum level would be different at different stock sizes (though it would have an upper limit equal to F_{MSY}). In this case, none of the stocks in the above example would be classified as overfished so long as the Council did not allow them to be harvested at fishing mortality rates greater than the following:

Stock	Maximum rate
A	0.08
B	0.18
C	0.20

Note that Stocks A and B could still be exploited, but not at the full F_{MSY} rate. Since Stock A is severely depressed, its maximum fishing mortality rate is lower than the maximum rate for Stock B (which is only slightly depressed). Stock C, which is at a high level of abundance, could be exploited at the full F_{MSY} rate.

Alternative 5 Constant fishing mortality rate with threshold. This alternative combines Alternatives 2 and 3. Under this alternative, Stock A would be classified as overfished under any level of fishing, since its current biomass (10,000) is below the threshold (20,000). Stocks B and C would not be classified as overfished so long as the Council did not allow them to be harvested at fishing mortality rates greater than 0.20.

Alternative 6 Variable fishing mortality rate with threshold--F_{MSY} version. This alternative combines Alternatives 2 and 4. Under this alternative, Stock A would be classified as overfished under any level of fishing, since its current biomass (10,000) is below the threshold (20,000). Stocks B and C would not be classified as overfished so long as the Council did not allow them to be harvested at fishing mortality rates greater than the following:

Stock	Maximum rate
B	0.10
C	0.20

Note that Stock B could still be exploited (because it is only slightly depressed), but not at the full F_{MSY} rate. Stock C, which is at a high level of abundance, could be exploited at the full F_{MSY} rate.

Alternative 7 Variable fishing mortality rate with threshold--F_{MAX} version. This alternative is like Alternative 6, except that the upper limit on the maximum fishing mortality rate would be F_{MAX} instead of F_{MSY}. Under this alternative, Stock A would be classified as overfished under any level of fishing, since its current biomass (10,000) is below the threshold (20,000). Stocks B and C would not be classified as overfished so long as the Council did not allow them to be harvested at fishing mortality rates greater than the following:

Stock	Maximum rate
B	0.10
C	0.35

In terms of the example, the only difference between Alternatives 6 and 7 is that Stock C could be exploited at the F_{MAX} level under Alternative 7 (since it is at such a high level of abundance), whereas F_{MSY} is the maximum fishing mortality rate allowed under Alternative 6.

3.1.3 Overview of Biological and Physical Impacts

Since the reason for developing an objective and measurable definition of overfishing is to protect the groundfish stocks, it is anticipated that adoption of any of the alternatives (except Alternative 1) would result in positive impacts on these stocks and on their predators. The relative merits of Alternatives 2-7, however, are difficult to evaluate on biological grounds alone. Perhaps the most that can be said is that Alternative 5 (constant fishing mortality rate with threshold) should provide more protection than Alternatives 2 (threshold) or 3 (constant fishing mortality rate--no threshold), and Alternative 6 (variable fishing mortality rate with threshold--F_{MSY} version) should provide the most protection of all. Still, it is impossible to guarantee that any of the alternatives will provide an absolute safeguard against stock collapse. If the Council's only objective were to minimize this risk, overfishing would probably have to be defined as any fishing at all. In considering the relative merits of the various alternatives, the benefits gained by reducing the risk of true overfishing must be weighed against any costs incurred by placing additional constraints on the fishery. In other words, the socioeconomic impacts must be considered as well as the biological impacts.

3.1.4 Overview of Socioeconomic Impacts

The choice of alternatives will be made easier if it turns out that the additional constraints imposed by the overfishing definition turn out to be nonbinding in practice. In fact, since the overfishing definition is intended to provide a failsafe rather than a target, it is quite conceivable that properly managed fisheries will never be impacted by the overfishing definition. Alternative 3 (constant fishing mortality rate--no threshold) can be considered as an example: Given that the Council already treats F_{MSY} or $F_{0.1}$ as an upper limit to fishing mortality, the analysis contained in this chapter indicates that Alternative 3 should not place any new constraints on the fishery.

More specifically, the impacts of each of the alternatives can be examined in the context of current stock conditions and management strategies by examining Tables 3.1, 3.2, and 3.3.

3.1.4.1 Overview of Tables Summarizing Current Conditions

Table 3.1 (Note: the legend for Table 3.1 defines all symbols used therein.) Table 3.1 examines the different suboptions of Alternative 3 (constant fishing mortality rate--no threshold) as they relate to all of the management categories used by the Council. Alternative 3 contains three main suboptions. In order of preference, these suboptions would set the maximum fishing mortality rate at the following levels: a) at F_{MSY}, b) at the level that sets the biomass-per-recruit level at 30% of its pristine value, and d) at the natural mortality rate (actually, there are four suboptions, but (b) and (c) are very similar). Table 3.1 contains six columns. The first column lists the management categories used by the Council in each management area. The second column lists the Council's apparent management strategy for each category. The third column lists the fishing mortality rate corresponding to ABC for each management category. The fourth column lists F_{MSY} for each management category. The fifth column lists the fishing mortality rate that sets the biomass-per-recruit level at 30% of its pristine value for each management category. The sixth column lists the natural mortality rate for each management category. When available data are insufficient to estimate any of the quantities in this table, the symbol "n/a" (for "not available") appears.

As an example, consider the Bering Sea (BS) pollock management category (this is the first management category listed in Column 1 under the "Bering Sea and Aleutian Islands" heading). The Council is currently managing the pollock stock according to an $F_{0.1}$ management strategy, as shown in Column 2. The fishing mortality rate corresponding to this management strategy is 0.31, as shown in Column 3. If Alternative 3 were in place, suboption (a) would set F_{MSY} as the upper limit on fishing mortality. The value of F_{MSY} also happens to be 0.31, as shown in Column 4 (recall that F_{MSY} and $F_{0.1}$ are sometimes close; here, they are identical). Alternative 3's suboption (b) uses the fishing mortality rate that sets the biomass-per-recruit level at 30% of its pristine value. This is the suboption that would come into play if the Council decided that the F_{MSY} estimate of 0.31 was not reliable. The fishing mortality rate under this suboption is 0.49, as shown in Column 5. Alternative 3's suboption (d) sets the maximum fishing mortality rate equal to the natural mortality rate. This suboption would come into play if the only data available to the Council were current biomass and the natural mortality rate. The natural mortality rate for BS pollock is 0.3, as shown in Column 6.

Of the 27 groundfish stocks or stock complexes currently under Council management, the Council sets F_{ABC} values for 24. Table 3.1 shows that Alternative 3 would constrain F_{ABC} in only one of these cases. This is the case of GOA Pacific cod, where the Council's F_{ABC} exceeds F_{MSY} by about 58%.

Table 3.2 For each management category (Column 1), Table 3.2 compares the fishing mortality rate used to obtain ABC (Column 2) with the maximum fishing mortality rates resulting from each alternative except status quo (Columns 3-8). Since some of the alternatives require more data than others, and since these additional data are sometimes unavailable, the entries for certain management categories are blank under certain alternatives.

As an example, consider again the case of BS pollock (the first entry in Column 1 under "Bering Sea and Aleutian Islands"). The fishing mortality rate currently used to compute ABC is 0.31, as shown in Column 2. A threshold can be computed for this stock under Alternative 2 (threshold), but the maximum allowable fishing mortality rate is unknown, as indicated by the question mark (?) in Column 3. Under Alternative 3 (constant fishing mortality rate--no threshold), overfishing would be defined as exceeding a fishing mortality rate of 0.31, as shown in Column 4. Under Alternative 4 (variable fishing mortality rate--no threshold), overfishing would be defined as exceeding a fishing mortality rate of 0.30, as shown in Column 5. Under Alternative 5 (constant fishing mortality rate with threshold), overfishing would be defined in the same way as under Alternative 3, namely as exceeding a fishing mortality rate of 0.31, as shown in Column 6. Under Alternative 6 (variable fishing mortality rate with threshold--F_{MSY} version), overfishing would be defined as exceeding a fishing mortality rate of 0.28, as shown in Column 7. Under Alternative 7 (variable fishing mortality rate with threshold--F_{MAX} version), overfishing would be defined in the same way as under Alternative 6, namely as exceeding a fishing mortality rate of 0.28, as shown in Column 8.

Note that overfishing cannot be defined for most management categories except under Alternative 3 (constant fishing mortality rate--no threshold). This does not mean that alternatives other than Alternative 3 cannot be chosen (since all of the other alternatives eventually default to Alternative 3 when data are scarce enough); it just means that the relative merits of most of the alternatives are currently of little practical importance for most management categories. However, it is anticipated that future research might improve this situation. That is, as more data become available, other alternatives might be applicable to a broader range of management categories.

Table 3.2 also indicates that none of the alternatives is particularly constraining when applied to current stock conditions using parameter estimates presently available. As in Table 3.1, GOA Pacific cod provides an exception (though not under every alternative; note that the current harvest strategy for this stock would not be constrained under Alternative 7). Also, BSAI pollock and BSAI Pacific ocean perch would be constrained slightly under Alternatives 4, 6, and 7.

Table 3.3 (Note: the legend for Table 3.3 defines all symbols used therein.) For each management category (Column 1), Table 3.3 summarizes the available data, including F_{MSY} (Column 2), the natural mortality rate (Column 3), pristine biomass (Column 4), B_{MSY} (Column 5), current biomass (Column 6), the ratio of B_{MSY} to pristine biomass (Column 7), and the ratio of current biomass to pristine biomass (Column 8). When the available data for a management category are insufficient to estimate certain quantities in this table, the symbol "n/a" (for "not available") appears. When the available data for a management category are insufficient to estimate either F_{MSY}, B_{MSY}, or pristine biomass, the phrase "data are insufficient to estimate main parameters" appears. Note that of the 27 categories currently managed by the Council, there are only 12 for which data are currently sufficient to estimate at least one of the main parameters (F_{MSY}, B_{MSY}, or pristine biomass).

Once again, BS pollock (the first entry in Column 1 under "Bering Sea and Aleutian Islands") can be considered as an example. The value of F_{MSY} for this management category is 0.31, as shown in Column 2. The natural mortality rate is 0.3, as shown in Column 3. Pristine biomass is 13.830 million metric tons, as shown in Column 4. The value of B_{MSY} is 6.120 million metric tons, as shown in Column 5. Current biomass is 5.844 million metric tons, as shown in Column 6. The ratio of B_{MSY} to pristine biomass is 0.44, as shown in Column 7, and the ratio of current biomass to pristine biomass is 0.42, as shown in Column 8. This last figure (0.42) is particularly helpful in that it allows the reader to determine the extent to which current biomass exceeds a threshold set at 20% of pristine biomass. In the case of BS pollock, current biomass would have to be reduced by about half (20% is about half of 42%) to reach a threshold so defined.

3.1.4.2 Overview of Possible Future Socioeconomic Impacts

None of the alternatives seem to present immediate potential for severely constraining the fishery. This is because, as shown in Tables 3.1-3.3, current harvest strategies tend to be at or below F_{MSY} and current biomass levels tend to be near or above B_{MSY}. However, it is also important to look at possible future impacts, since even a well managed stock can occasionally fall below B_{MSY} if recruitment fails. This fact has important implications for Alternatives 2 (threshold), 4 (variable fishing mortality rate--no threshold), and 5 (constant fishing mortality rate with threshold), and particularly for Alternatives 6 (variable fishing mortality rate with threshold--F_{MSY} version) and 7 (variable fishing mortality rate with threshold--F_{MAX} version).

It should be emphasized that it is extremely difficult either to analyze or to estimate the likelihood of each possible scenario within the full range of futures that might be imagined for each of the Council's 27 management categories. Nevertheless, to get at least a glimpse of how recruitment variability might impact fishery management under the various alternatives, two simulation studies are described in this chapter. The first simulation examines a hypothetical stock exhibiting parameters thought to be typical of groundfish in general. The second simulation examines sablefish in particular. Both incorporate random variability in recruitment.

Unfortunately, it was difficult to analyze Alternatives 1, 2, and 7 in these simulations, because the Council's apparent policy of not exceeding F_{MSY} means that Alternative 1 (status quo) is indistinguishable from Alternative 3 (constant fishing mortality rate--no threshold), Alternative 2 (threshold) is indistinguishable from Alternative 5 (constant fishing mortality rate with threshold), and Alternative 7 (variable fishing mortality rate with threshold--F_{MAX} version) is indistinguishable from Alternative 6 (variable fishing mortality rate with threshold--F_{MSY} version.

Both simulation studies found that the various alternatives should result in very similar long-term average yields, with Alternative 3 faring the best, followed in order by Alternatives 5, 4, and 6. Both studies also concluded that the differences in yield variability were more significant than the differences in average yield, with the ranking of the alternatives remaining roughly the same as above.

One difference, however, is that the sablefish simulation also addressed the direct performance of the stock, instead of focusing all of its attention on average yield and yield variability. The reason for addressing this issue is that the Council might feel that low biomass levels are undesirable in their own right, not just because they result in low catches. When examined in terms of average biomass and biomass variability, the performance of the alternatives in the sablefish simulation was generally the opposite of their performance when measured in terms of average yield and yield variability: Alternative 6 performed the best, followed in order by Alternatives 4, 5, and 3.

If the Council decides to incorporate biomass as well as catch considerations into its objective function, the results of the sablefish simulation imply that the relative merits of the alternatives depend completely on the weights the Council assigns to the different factors. Whether the increased protection provided by the more conservative alternatives outweighs the gains in average yield and decreased yield variability obtainable under some of the others is impossible to evaluate in a general sense.

3.1.5 Overview of Commonly Asked Questions

Is the Council limited to the overfishing definitions contained in the alternatives, or may it choose a more conservative definition? The Council may choose a more conservative definition. The main requirement of the 602 Guidelines is that the definition must protect the stock's long-term capacity to produce MSY. The 602 Guidelines thus establish a minimum, not a maximum, level of conservatism.

If the goal is to protect the stock's productive capacity, why not just choose the most conservative definition possible? The most conservative definition possible would be to prohibit fishing altogether. However, such a definition would clearly require the Council to abdicate its responsibility for achieving optimum yield. In backing off from this extreme case, the Council must weigh the costs of reduced conservatism against the benefits of increased (or less variable) harvests.

What would happen if the Council chose to define overfishing in terms of a threshold, and the stock happened to fall below the threshold level? Generally, fishing on that stock (including bycatch mortality) would have to cease. There are only two cases where continued fishing would be allowed. The first is the case where the Council is able to demonstrate that the stock's low abundance level cannot be alleviated by a reduction in fishing mortality. The second is the case where the stock in question constitutes a minor component of a multispecies fishery, and the Council is able to demonstrate that a net loss of benefits to the nation would result if any fishery taking that stock were eliminated.

What definitions of overfishing have been approved by NMFS so far? Only one overfishing definition has been approved by NMFS so far: the definition for red drum in the Gulf of Mexico. The red drum definition requires that the biomass-per-recruit ratio be maintained at a value no lower than 20% of the pristine value. This is less conservative than the minimum 30% figure contained in some of the alternatives here.

Why should the Council fish a stock so hard that it falls to 20% of its pristine biomass, or so hard that its biomass-per-recruit ratio falls to 30% of its pristine level? Nothing in the chapter indicates that the Council should fish a stock in this manner. It is important to remember that overfishing is something to avoid, not something to achieve. It is quite possible that the Council's responsibility to achieve optimal yield will require a more conservative harvest policy (though not necessarily a more conservative overfishing definition) than those addressed here.

When the alternatives talk about setting a threshold at 20% of pristine biomass or setting a maximum fishing mortality rate at the value that reduces the biomass-per-recruit ratio to 30% of its pristine value, are these figures arbitrary, or do they have some objective basis? These figures are not arbitrary. They have an objective basis, as discussed in the chapter. However, it should be remembered that other values may be more appropriate in specific cases. The values mentioned here are "safety net" values to be used when data are insufficient to identify more appropriate values.

Will adoption of any of the alternatives (except status quo) guarantee that no stock will ever collapse? No. The phenomenon of stock collapse is highly complex, and scientists are still struggling to understand it. One thing that does seem clear, however, is that recruitment is dependent not only on stock size, but on a number of other factors as well, many of which (e.g., currents, weather patterns) are completely out of the Council's control. Thus, no definition of overfishing can provide an absolute guarantee against stock collapse.

If the biomass-per-recruit ratio is maintained at 30% of its pristine value, will this keep the stock's biomass above the threshold? Not necessarily. It is always possible for a sufficiently long series of recruitment failures to drive a stock below any threshold that might be set.

Is it possible for a stock to recover to B_{MSY} after falling to a level less than 20% of pristine biomass, and if so, why should the threshold be set at the 20% level? First of all, the Council does not have to set a threshold level. It may, for example, choose Alternative 3 (constant fishing mortality rate--no threshold) or Alternative 4 (variable fishing mortality rate--no threshold). Second, even if the Council chooses an alternative that makes use of a threshold, the threshold would be set at the 20% level only when the best available scientific information is inadequate to identify a more appropriate level. Third, it may indeed be possible for a particular stock to recover to B_{MSY} after falling below the 20% level, but that is not the point. The point is to protect those stocks that may not be able to recover from such a low level. In other words, the overfishing definition should protect all of the stocks, not just the most resilient ones.

If the Council adopts any of the alternatives suggested in the chapter, will the subject of overfishing be closed once and for all? Probably not. As noted above, this is an area where scientific understanding is far from complete. As advancements in understanding continue, it is conceivable that future refinements in the overfishing definition will be necessary.

3.2 Description of the Problem and Need for Action

The Magnuson Fishery Conservation and Management Act (MFCMA) contains a set of "national standards" with which all fishery management plans (FMPs) and implementing regulations must be consistent. The first national standard states, "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."

Thus, the MFCMA places a high priority on the prevention of overfishing. However, nowhere in the MFCMA is overfishing defined. In 50 CFR Part 602, the National Oceanic and Atmospheric Administration (NOAA) presented its Guidelines for Fishery Management Plans (the "602 Guidelines"), which contain the following general definition:

"Overfishing is a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis."

Because of the generality of this definition, NOAA felt that it would be difficult to apply unambiguously. Therefore, the 602 Guidelines also contain the following directive:

"Each FMP must specify, to the maximum extent possible, an objective and measurable definition of overfishing for each stock or stock complex covered by that FMP, and provide an analysis of how the definition was determined and how it relates to reproductive potential."

The "objective and measurable definition" mentioned here is not intended to take the place of the general definition given earlier, but is to constitute a specific method of implementing that general definition. Whereas the general definition is qualitative, the implementing definitions are to be quantitative. Since the GOA and BSAI Groundfish FMPs contain no such definitions, the plans must be amended. The deadline for submission of these amendments is November 23, 1990.

As the above quotation indicates, the 602 Guidelines require overfishing definitions to be objective and measurable, and they require the method for arriving at those definitions to be objective as well. However, some latitude is granted in extreme cases:

"In cases where scientific data are severely limited, the Councils' informed judgment must be used, and effort should be directed to identifying and gathering the needed data."

Also, the 602 Guidelines allow certain limited exceptions to the requirement to prevent overfishing:

"There are certain limited exceptions to the requirement of preventing overfishing. Harvesting the major component of a mixed fishery at its optimum level may result in the overfishing of a minor (smaller or less valuable) stock component in the fishery. A Council may decide to permit this type of overfishing if it is demonstrated by analysis ... that it will result in net benefits to the Nation, and if the Council's action will not cause any stock to require protection under the Endangered Species Act (ESA)."

Note that this exception is not automatic; it requires an analysis demonstrating that positive net benefits to the Nation will result and that protection under the ESA will not result. Therefore, this exception clause should not be viewed as a means of circumventing the intent of the 602 Guidelines' requirements regarding the prevention of overfishing.

Another factor to keep in mind is that the 602 Guidelines make a clear distinction between the prevention of overfishing and the achievement of optimum yield. Thus, the task of specifying an overfishing definition should not be confused with an attempt to articulate an optimal harvest policy. The overfishing definition is to be used as a constraint, not as a target. (This does not mean that the two can never coincide in practice; it does mean, however, that the purposes of an overfishing definition and an optimal harvest policy are distinctly different.)

3.3 The Alternatives

The 602 Guidelines provide a wide range of possibilities for defining overfishing. For example, the 602 Guidelines allow, but do not require, the specification of a minimum spawning biomass level ("threshold"). A threshold can be used to define overfishing by requiring that fishing cease whenever a stock falls below its threshold. The 602 Guidelines also allow, but do not require, the specification of a maximum fishing mortality rate (F), which can be formulated in a variety of ways. Thresholds and maximum F policies can be used either individually or in combination.

Seven alternatives have been identified for this amendment proposal, and are described below. With most of these alternatives, suboptions need to be specified because of discrepancies in the amounts of information available for the various stocks. Suboptions are listed here in order of preference (most to least), which is also the approximate order of data requirements (most to least). For each alternative except "status quo," the minimum information requirement is an estimate of current stock biomass and the natural mortality rate. In the event that even these minimal data requirements cannot be satisfied for a particular stock (the "extreme cases" referred to in Section 3.2), it is anticipated that the Council will define overfishing as exceeding the average catch for that stock calculated over the years since implementation of the MFCMA. Whatever alternative is chosen, it is assumed that the suboption used to define overfishing for any particular stock will be upgraded as data availability improves.

Not only do suboptions vary in terms of their data requirements, but the alternatives themselves vary in the same respect. Therefore, the alternatives have been designed so that when scarcity of data precludes implementation of a particular alternative, that alternative defaults to another (related) alternative with less stringent data requirements.

To aid in the description of the alternatives, one suboption for each (except status quo) is illustrated in Figure 3.1. Along with illustrating the alternatives, this figure depicts reference points at B_{MSY} and at the ratio between F_{MAX} and F_{MSY}. Because Figure 3.1 is intended only as an illustration, the values indicated for these reference points are purely arbitrary (they happen to correspond to parameter values $K''=4.932$ and $q=0.201$ in a model described by Thompson (1990)).

3.3.1 Alternative 1: Status Quo

The only overfishing definition currently contained in the FMPs is a qualitative one similar to the general definition found in the 602 Guidelines. The FMPs contain no objective or measurable criteria for implementing this definition.

3.3.2 Alternative 2: Threshold Biomass Level

Under this alternative, fishing would not be allowed on any stock whose biomass is below its threshold level, where the threshold is computed as follows (suboptions are listed in order of preference):

a) Data available: Objective function coefficients, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters. The threshold will be set at the value that maximizes a Council-specified objective function, where any such objective function will assign at least 50% of its total weight to long-term average yield.

b) Data available: Pristine spawning biomass. The threshold will be set at 20% of pristine spawning biomass (Figure 3.1a).

c) Data available: Pristine exploitable biomass. The threshold will be set at 20% of pristine exploitable biomass.

d) Default to Alternative 3.

3.3.3 Alternative 3: Constant Fishing Mortality Rate--No Threshold

Under this alternative, the fishing mortality rate on any stock would not be allowed to exceed a density-independent maximum level, where this level is computed as follows (suboptions are listed in order of preference):

a) Data available: Stock-recruitment, fecundity, maturity, growth, and mortality parameters. The maximum allowable fishing mortality rate will be set at F_{MSY} (Figure 3.1a).

b) Data available: Fecundity, maturity, growth, and mortality parameters. The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine level. (Figure 3.2 shows an example based on a model presented by Thompson (1990) and an assumption that $F_{0.1}$ equals the natural mortality rate, where $F_{0.1}$ is defined as the fishing mortality rate at which the slope of the yield-per-recruit curve is 10% of the slope at the origin.)

c) Data available: Growth and mortality parameters. The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine level.

d) Data available: Natural mortality rate. The maximum allowable fishing mortality rate will be set equal to the natural mortality rate.

3.3.4 Alternative 4: (Preferred) Variable Fishing Mortality Rate--No Threshold

Under this alternative, the fishing mortality rate on any stock would not be allowed to exceed a biomass-dependent maximum level, where this level is computed as follows (suboptions are listed in order of preference):

a) Data available: Stock-recruitment, fecundity, maturity, growth, and mortality parameters. The maximum allowable fishing mortality rate will be set at F_{MSY} for all biomass levels in excess of B_{MSY}. For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the origin and increasing to a value of F_{MSY} at B_{MSY} (Figure 3.1b).

b) Default to Alternative (3), suboption (b), and following.

3.3.5 Alternative 5: Constant Fishing Mortality Rate with Threshold

This alternative combines Alternatives 2 and 3, where thresholds and maximum fishing mortality rates are computed as follows (suboptions are listed in order of preference):

a) Data available: Objective function coefficients, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters. The threshold will be set at the value that maximizes a Council-specified objective function, where any such objective function will assign at least 50% of its total weight to long-term average yield. In addition, for all values of B above the threshold, the maximum allowable fishing mortality rate will be set at F_{MSY}.

b) Data available: Pristine spawning biomass, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters. The threshold will be set at 20% of pristine spawning biomass. In addition, for all values of B above the threshold, the maximum allowable fishing mortality rate will be set at F_{MSY} (Figure 3.1c).

c) Data available: Pristine spawning biomass, along with fecundity, maturity, growth, and mortality parameters. The threshold will be set at 20% of pristine spawning biomass. In addition, for all values of B above the threshold, the maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine level.

d) Data available: Pristine exploitable biomass, along with growth and mortality parameters. The threshold will be set at 20% of pristine exploitable biomass. In addition, for all values of B above the threshold, the maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine level.

e) Default to Alternative (3), suboptions (c) and following.

3.3.6 Alternative 6: Variable Fishing Mortality Rate with Threshold--F_{MSY} Version

This alternative combines Alternatives 2 and 4, where thresholds and biomass-dependent maximum fishing mortality rates are computed as follows (suboptions are listed in order of preference):

a) Data available: Objective function coefficients, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters (also requires that B_{MSY} exceed the threshold). The threshold will be set at the value that maximizes a Council-specified objective function, where any such objective function will assign at least 50% of its total weight to long-term average yield. In addition, the maximum allowable fishing mortality rate will be set at F_{MSY} for all biomass levels in excess of B_{MSY}. For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the threshold and increasing to a value of F_{MSY} at B_{MSY}.

b) Data available: Pristine spawning biomass, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters (also requires that B_{MSY} exceed the threshold). The threshold will be set at 20% of pristine spawning biomass. In addition, the maximum allowable fishing mortality rate will be set at F_{MSY} for all biomass levels in excess of B_{MSY}. For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the threshold and increasing to a value of F_{MSY} at B_{MSY} (Figure 3.1d).

c) Default to Alternative (5), suboptions (c) and following.

3.3.7 Alternative 7: Variable Fishing Mortality Rate with Threshold--F_{MAX} Version

This alternative combines the protection of Alternative 6 at low and intermediate stock levels with a less conservative fishing mortality constraint at high stock levels, where thresholds and biomass-dependent maximum fishing mortality rates are computed as follows (suboptions are listed in order of preference):

a) Data available: Objective function coefficients, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters (also requires that B_{MSY} exceed the threshold). The threshold will be set at the value that maximizes a Council-specified objective function, where any such objective function will assign at least 50% of its total weight to long-term average yield. In addition, the maximum allowable fishing mortality rate will vary linearly with spawning biomass as follows: for biomass levels below B_{MSY}, the maximum allowable fishing mortality rate will increase from a value of zero at the threshold to a value of F_{MSY} at B_{MSY}; for biomass levels above B_{MSY}, the maximum allowable fishing mortality rate will increase from a value of F_{MSY} at B_{MSY} through a value of F_{MAX} at pristine biomass.

b) Data available: Pristine spawning biomass, along with stock-recruitment, fecundity, maturity, growth, and mortality parameters (also requires that B_{MSY} exceed the threshold). The threshold will be set at 20% of pristine spawning biomass. In addition, the maximum allowable fishing mortality rate will vary linearly with spawning biomass as follows: for biomass levels below B_{MSY}, the maximum allowable fishing mortality rate will increase from a value of zero at the threshold to a value of F_{MSY} at B_{MSY}; for biomass levels above B_{MSY}, the maximum allowable fishing mortality rate will increase from a value of F_{MSY} at B_{MSY} through a value of F_{MAX} at pristine biomass. (Figure 3.1d).

c) Default to Alternative (5), suboptions (c) and following.

3.4 Biological and Physical Impacts

The task of providing an objective and measurable definition of overfishing has been a major field of research within the discipline of fisheries science. Usually, attempted solutions have implicitly defined overfishing as any harvest above the optimal level. The optimal rate of fishing has usually been specified as the rate corresponding to maximum sustainable yield, maximum sustainable rent, maximum discounted rent, or other value that maximizes some specified objective function.

This approach is very different from the one contemplated in the 602 Guidelines. Implicitly, at least, the 602 Guidelines deal with the overfishing question not in terms of deviating from some optimum point (such as the MSY level), but in terms of jeopardizing a stock's long-term capacity to return to the MSY level. As noted in Section 3.2, the overfishing definition is to provide a constraint that keeps the stock from falling below a point of no return; it is not intended to substitute for an optimal harvest policy. However, the overfishing definition may be a component of such a policy, or the two may happen to coincide. Along these lines, the Council always has the option of specifying a more conservative standard than the one required by the 602 Guidelines. All the Council has to do is demonstrate that its overfishing definition is at least as conservative as the one contemplated by the 602 Guidelines.

Since the 602 Guidelines define overfishing in terms of the stock's long-term capacity to achieve MSY, one way to implement the definition in an objective and measurable way would be to require that the fishing mortality rate never exceed F_{MSY} (as in Alternative 3). However, estimation of F_{MSY} requires information that is often unavailable, e.g., stock-recruitment parameters.

Even when sufficient information is available to calculate F_{MSY}, constraining F by this value may not be adequate to prevent a collapse when the stock is sufficiently depressed. (This assertion is purely theoretical; it has proven difficult to find an example of a stock that has collapsed when consistently exploited at its F_{MSY} rate.) An additional degree of safety can be obtained by specifying a stock-specific threshold level below which fishing (on that stock) would cease altogether. Ideally, determination of such a threshold would be based on detailed knowledge of stock and ecosystem dynamics, along with some Council-specified objective function that allocates most of its weight to long-term average yield (e.g., Quinn et al. in press). However, the Council has not yet specified such an objective function. Furthermore, determining a threshold in this manner would undoubtedly also require the same type of information needed to calculate F_{MSY}, which, as has already been noted, is often unavailable.

Thus, the problem of specifying an objective and measurable means of implementing the general overfishing definition found in the 602 Guidelines becomes, at least in part, one of justifying a second- or third-best standard when the best standard cannot be calculated. It is important to remember in this context that the 602 Guidelines require a demonstration that the Council's overfishing definition will insure the preservation of a stock's long-term reproductive capacity. Therefore, every reasonable effort should be made to avoid definitions that are arbitrary or that do not address the problem.

Appendix I describes a pair of constraints that can be used to define overfishing when data are unavailable to define F_{MSY} or a stock-specific threshold. Importantly, these constraints relate directly to the problem of long-term reproductive capacity, and they are scientifically defensible. The constraints, which are built into the alternatives listed in Section 3.3, are as follow:

> For a definition based on a threshold biomass level: When an estimate of pristine biomass is available, fishing should cease whenever the stock falls to a level less than about 20% of this estimate.
>
> For a definition based on a constant fishing mortality rate: When estimates of the relevant life history parameters are available, the fishing mortality rate should be set so as to maintain the biomass-per-recruit ratio at a level no less than about 30% of the pristine level.

The above constraints are mathematically derivable from three plausible assumptions (explained more precisely in Appendix I): First, it is assumed that the stock-recruitment relationship can be described by a particular generalization of the curve presented by Beverton and Holt (1957). Second, it is assumed that natural selection acts to keep the most productive part of the stock-recruitment curve above the threshold. Finally, it is assumed that growth and mortality parameters are independent of stock size. It should be emphasized that the constraints are dependent only on these assumptions; they do not depend on particular parameter values.

Because they are explicitly derivable from a small number of qualitative assumptions regarding population dynamics, the above constraints pose two significant advantages over some other measures that have been suggested: 1) they avoid the problem of requiring types or amounts of data that are often unavailable, and 2) they avoid the problem of being critically dependent on arbitrarily chosen parameter values.

In addition, it is significant that the above constraints compare favorably to management measures that have been suggested by a number of authors. For example, the 20% figure used to define a threshold corresponds exactly to the figure employed by Beddington and Cooke (1983). It is within the range of 20%-30% derived by Quinn et al. (in press) for BS pollock, and the 20%-50% range derived by Clark (1990). The 30% figure used to define a maximum fishing mortality rate is close to the 35% figure derived by Clark. The robustness of these results is augmented by the fact that the authors were using different models and objectives: Beddington and Cooke used a stochastic yield-per-recruit model to maximize yield without entering the domain where recruitment was thought to depend on stock size, Quinn et al. used an age-structured model with two stock-recruitment assumptions to maximize an objective function involving average yield and yield variability, and Clark used an age-structured model to maximize catch (relative to MSY) across a wide range of stock-recruitment assumptions.

In cases where scientific information is severely limited, the baseline suboption for all of the alternatives (except status quo) is to set the maximum allowable fishing mortality rate equal to the natural mortality rate. This can be justified in a number of ways. First, Appendix I indicates that setting the fishing mortality rate at 80% of the natural mortality rate should keep the fishing mortality rate below the value that sets the biomass-per-recruit ratio equal to 30% of the pristine value, even in extreme situations. Since the 30% figure is already a conservative value (i.e., designed to protect stocks even in extreme situations), it might be appropriate to relax the 80% figure somewhat, e.g., by rounding to 100%. Second, several studies have suggested that the natural mortality rate is a reasonable approximation of either F_{MSY} or $F_{0.1}$ in the absence of more detailed information (e.g., Alverson and Pereyra 1969, Shepherd 1982, Deriso 1987, Kimura 1988, Clark 1990). Third, the 602 Guidelines state that ABC may safely be calculated by setting the fishing mortality rate equal to the natural mortality rate. Given that an appropriately specified ABC can never result in overfishing (see response to Comment 22 in the "Comments and Response" section of the 602 Guidelines), this lends some official support to the idea of using the natural mortality rate to define overfishing.

Since the reason for developing an objective and measurable definition of overfishing is to protect the groundfish stocks, it is anticipated that adoption of any of the alternatives (except Alternative 1) would result in positive impacts on these stocks and on their predators. The relative merits of Alternatives 2-7, however, are difficult to evaluate on biological grounds alone. Perhaps the most that could be said is that Alternative 5 should provide more protection than Alternatives 2 or 3, and Alternative 6 should provide the most protection of all. Still, it is impossible to guarantee that any of the alternatives will provide an absolute safeguard against stock collapse. If the Council's only objective were to minimize this risk, overfishing would probably have to be defined as any fishing at all. In considering the relative merits of the various alternatives, the benefits gained by reducing the risk of true overfishing must be weighed against any costs incurred by placing additional constraints on the fishery.

3.5 Socioeconomic Impacts

The choice of alternatives will be made easier if it turns out that the additional constraints imposed by the overfishing definition turn out to be nonbinding in practice. In fact, since the overfishing definition is intended to provide a failsafe rather than a target, it is quite conceivable that properly managed fisheries will never be impacted by the overfishing definition. Alternative 3 can be considered as an example: Given that the Council already tends to treat F_{MSY} as an upper limit to fishing mortality, Alternative 3 would not place any new constraints on fisheries for which an estimate of F_{MSY} is available. In cases where estimates of F_{MSY} are unavailable, Alternative 3 (suboption (b)) sets the maximum fishing mortality rate at the value that results in the biomass-per-recruit ratio falling to 30% of its pristine level. However, in such cases the Council already tends to treat $F_{0.1}$ as an upper limit to fishing mortality, and according to a model described in Appendix I, an upper limit set according to Alternative 3's suboption (b) can never constrain an $F_{0.1}$ harvest strategy. Thus, on theoretical grounds at least, it appears that Alternative 3 would be unlikely to impose any new (binding) constraints on the fishery.

3.5.1 Impacts Under Current Stock Conditions

The possible impacts of the alternatives can be explored further by examining them in the context of current stock conditions. Continuing to use Alternative 3 as an example, Table 3.1 lists the fishing mortality rate corresponding to the Council's 1990 acceptable biological catch (F_{ABC}) for each groundfish stock or stock complex managed in the BSAI and GOA, along with maximum allowable fishing mortality rates under the various suboptions. To compute the fishing mortality rate at which the biomass-per-recruit ratio is reduced to 30% of its pristine value, the following approaches were used (square brackets enclose the list of management categories to which each approach was applied):

1) Age-specific schedules of maturity, weight, and selectivity [BSAI--pollock, GOA--pollock].
2) Beverton and Holt's (1957) "simple" model [BSAI--yellowfin sole, arrowtooth flounder, other flatfish (using male Alaska plaice parameters), and Atka mackerel; GOA--deep flatfish (using flathead sole parameters), shallow flatfish (using rock sole parameters), arrowtooth flounder, demersal shelf rockfish (using male yelloweye rockfish parameters), and thornyhead].
3) Deriso's (1980, generalized by Schnute 1985) delay-difference model [BSAI--Greenland turbot, sablefish, and Pacific ocean perch; GOA--Pacific cod, sablefish, and slope rockfish (using Pacific ocean perch parameters)].
4) Thompson's (1990) dynamic pool model [BSAI--Pacific cod and rock sole].

Of the 27 groundfish stocks or stocks complexes currently under Council management (not counting those with separate Aleutian Islands quotas), the Council sets F_{ABC} values for 24. Table 3.1 shows that Alternative 3 would constrain F_{ABC} in only one case: GOA Pacific cod, where the Council's F_{ABC} exceeds F_{MSY} (suboption (a)) by about 58%.

Table 3.2 generalizes Table 3.1 to include all of the alternatives (except status quo). Although Table 3.2 indicates that none of the alternatives except Alternative 3 can be applied to more than 35% of the stocks under management (without defaulting to suboptions of other alternatives), it is important to realize that this table was constructed entirely from information contained in the Council's Stock Assessment and Fishery Evaluation Reports (except for Bering Sea pollock, where results from Quinn et al. (in press) were also used). As new information becomes available, any given alternative's range of applicability could increase.

Table 3.2 indicates that none of the alternatives is particularly constraining when applied to current stock conditions using parameter estimates presently available. As in Table 3.1, GOA Pacific cod provides an exception (though not under every alternative; note that the current harvest strategy for this stock would not be constrained under Alternative 7). Also, BSAI pollock and BSAI Pacific ocean perch would be constrained slightly under Alternatives 4, 6, and 7.

While none of the alternatives seem to present immediate potential for severely constraining the fishery, it is also important to look at possible future impacts. There are two principal means by which the proposed alternatives might have future impacts on the fishery: 1) Depending on parameter values, it is possible for a threshold set at 20% of pristine biomass to exceed B_{MSY}; this is important for Alternatives 2, 5, 6, and 7. 2) Because the population dynamics of fish stocks usually contain a major stochastic component, even a well managed stock can fall below B_{MSY}; this is important for Alternatives 2, 4, and 5, and particularly for Alternatives 6 and 7.

3.5.2 Impacts Resulting from the Threshold Exceeding B_{MSY}

The 1989 SAFE documents for BSAI and GOA groundfish contain F_{MSY} or pristine biomass estimates for twelve stocks, as shown in Table 3.3. Of the nine stocks for which estimates of pristine biomass are available, Table 3.3 indicates that a threshold set at 20% of pristine biomass poses no obvious constraint on the fishery, either in terms of current biomass levels or biomass at MSY. The stocks with the greatest potential for falling beneath the suggested threshold appear to be the Pacific ocean perch stocks. Current biomass and B_{MSY} for these two stocks are estimated to fall between 24% and 29% of pristine biomass (it should be noted that the figures for Pacific ocean perch are based on subjective estimates of stock-recruitment parameters).

Appendix I evaluates the conditions under which a threshold set at 20% of pristine biomass might exceed B_{MSY}. Basically, the analysis shows that the threshold will exceed B_{MSY} only when F_{MSY} exceeds the natural mortality rate by more than about 50%. According to Table 3.3, of the three stocks for which estimates of pristine biomass are unavailable but estimates of F_{MSY} are available, the ratios of F_{MSY} to M range from 0.62 to 1.00, well below the 1.5 figure that would place B_{MSY} close to the suggested threshold.

Appendix I also evaluates some of the consequences that might be suffered should B_{MSY} fall below the suggested threshold. The main conclusion is that the amount of yield forgone by constraining the fishery in this manner is likely to be very small, and in no case should exceed 20% of MSY.

3.5.3 Impacts Resulting from Stochasticity in Stock Dynamics

In Appendix I, a model is described in which B_{MSY} is about 23% of pristine biomass if the conventional wisdom equating F_{MSY}, $F_{0.1}$, and the natural mortality rate holds. While this is higher than the 20% threshold suggested in suboptions of several of the proposed alternatives, it is close enough that a reasonable degree of stochasticity in population dynamics could cause the stock to fall below the threshold even if an F_{MSY} harvest policy were faithfully followed.

To investigate this possibility more fully, a stochastic model was developed and used to simulate the stock and harvest dynamics of a "typical" groundfish under the various alternatives (Appendix II). The results of this simulation showed that long-term average yield would be expected to differ only slightly between the various alternatives. Alternative 3 performed best in this regard, followed in order by Alternatives 5, 4, and 6. (Alternatives 1, 2, and 7 were not included because the Council's de facto policy of not exceeding F_{MSY} means that Alternative 1 is indistinguishable from Alternative 3, Alternative 2 is indistinguishable from Alternative 5, and Alternative 7 is indistinguishable from Alternative 6.) The fact that all of the alternatives performed similarly in terms of long-term average yield indicates that the threshold suggested in Alternatives 5 and 6 had little effect in this regard.

The simulation also examined the performance of the various alternatives in terms of yield variability. Here, the order of preference between the alternatives remained the same, except that Alternative 4 equaled or outperformed Alternative 5 when recruitment variability was extremely high. However, the relative differences were much greater than those observed in regard to average yield. The fact that Alternative 3 outperformed the three alternatives that incorporate some sort of reduction in fishing mortality at low stock sizes (Alternatives 4, 5, and 6) indicates that harvests were being constrained in the latter. The relative performances of Alternatives 4 and 5 indicate that the proportionate reduction in fishing mortality suggested in the former was more constraining than the threshold suggested in the latter, at least until recruitment variability reached a very high level. Finally, the fact that Alternative 6 fared the worst indicates that the combination of a threshold with reduced fishing mortality at intermediate stock sizes was the most constraining, as would be expected.

It should be noted that these results are somewhat different from those obtained by Quinn et al. (in press), who conducted a simulation experiment to determine the optimal combination of threshold level and fishing mortality rate for Bering Sea pollock. Quinn et al. concluded that Alternative 5 should result in greatly increased average yield relative to Alternative 3, while yield variability should increase only slightly. One explanation for the difference in results is that Quinn et al. assumed that the population had been reduced to 5-15% of pristine biomass at the start of each simulation. In contrast, the model in Appendix II assumed that the population was at B_{MSY} (29% of pristine biomass) at the start of each simulation, which seems to reflect more accurately the current status of most groundfish stocks under management by the Council (Table 3.3).

Of course, all of the results in Appendix II are contingent on the assumptions of the model and the parameter values employed. Since the parameter values used in Appendix II were chosen only to reflect those of a "typical" groundfish, there is no guarantee that the results will correspond exactly to those obtained for any given groundfish stock managed by the Council. To help determine the generality of these results, it is useful to draw on results of a second simulation that employed parameter values for sablefish (Appendix III). Although this simulation used slightly different methods and harvest strategies, for purposes of discussion the following equivalencies will be assumed:

Appendix III Strategy	Alternative
"constant rate" =	Alternative 3
"variable rate" =	Alternative 4
"constant rate with threshold" =	Alternative 5
"variable rate$_1$ with threshold" =	Alternative 6
"variable rate$_2$ with threshold" =	Alternative 7

The sablefish study described in Appendix III generated many of the same conclusions contained in the generic study described in Appendix II. Both studies found that the various alternatives should result in very similar long-term average yields, with Alternative 3 faring the best, followed in order by Alternatives 5, 4, and 6 (Appendix III also showed Alternative 7 outperforming Alternative 6 in this category). Both studies also concluded that the differences in yield variability were more significant than the differences in average yield, with the ranking of the alternatives remaining roughly the same as above (the exception being that Appendix III showed Alternative 4 consistently outperforming Alternative 5 in this category, with Alternative 7 faring the worst).

A significant difference, however, is that the sablefish simulation also addressed the direct performance of the stock, instead of focusing all of its attention on average yield and yield variability. The implication is that low biomass levels might be undesirable in their own right, not just because they result in low catches. When examined in terms of average biomass, biomass variability, lowest biomass, and frequency of sub-threshold biomass, the performance of the alternatives in Appendix III was as follows: Alternative 6 performed the best, followed in order by Alternatives 7, 4, 5, and 3 (the one exception was biomass variability, where Alternative 7 outperformed Alternative 6).

It should be emphasized that both Appendices II and III assume that the Council will fish at the maximum allowable rate under each alternative. (This assumption was made because each alternative--except Alternatives 1 and 7--is at least as conservative as the Council's de facto target strategy of harvesting at F_{MSY}, not because the alternatives themselves supply a target harvest strategy.) However, if the Council adopts an alternative that involves a threshold (i.e., Alternatives 2, 5, 6, or 7), it is possible that the Council will also want to modify its existing target strategy so as to reduce the possibility that random recruitment failure might cause a stock to fall below its threshold. Since it is difficult to predict what form (if any) this modification would take, it is also difficult to predict how such a modification would affect the results given in Appendices II and III.

Given this caveat, it is possible to summarize the results of the simulation studies as follows: Alternative 3 performed the best in terms of long-term average yield and yield variability, and Alternative 6 performed the worst. The rankings of Alternatives 4 and 5 were ambiguous in this regard, with Alternative 5 outperforming Alternative 4 in Appendix II (except when recruitment variability was extremely high), and the order reversed in Appendix III. When biomass-related performances were considered, the rankings were generally the opposite of those based on yield-related performances. Alternative 6 (or 7) performed the best, and Alternative 3 performed the worst, with Alternative 4 and 5 intermediate. If the Council decides to incorporate biomass as well as catch considerations into its objective function, these results imply that the relative merits of the alternatives depend completely on the weights the Council assigns to the different factors. As noted at the conclusion of Section 3.4, Alternative 5 should provide more protection than Alternatives 2 or 3, and Alternative 6 should provide the most protection of all. Whether the increased protection provided by Alternative 6 (or perhaps Alternative 7) outweighs the gains in average yield and decreased yield variability under Alternatives 3, 4, or 5 is impossible to evaluate in a general sense.

3.5.4 Reporting Costs

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

3.5.5 Administrative, Enforcement, and Information Costs

No additional administrative or enforcement costs are anticipated under any of the alternatives. However, for a few stocks (e.g., BSAI "other" rockfish, BSAI squid and "other" species, GOA demersal shelf rockfish, and GOA "other" species) it appears that information is currently insufficient to satisfy the data requirements of the alternatives. For these stocks, the 602 Guidelines require that effort be directed to identifying and gathering the needed data. It is anticipated that the costs of gathering such information will be small in comparison to the benefits obtained by protecting these stocks against overfishing.

3.5.6 Distribution of Costs and Benefits

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

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Table 3.1. Current ABC harvest strategies and fishing mortality rates compared with three overfishing criteria.

Bering Sea (BS) and Aleutian Islands (AI)

Management category	Strategy	F_{ABC}	F_{MSY}	$F_{0.3}$	M
Pollock (BS)	$F_{0.1}$	0.31	0.31	0.49	0.30
Pollock (AI)	$F_{0.1}$	0.31	n/a	0.49	0.30
Pacific cod	F_{MSY}	0.18	0.18	0.31	0.29
Yellowfin sole	$F_{0.1}$	0.17	n/a	0.17	0.12
Greenland turbot*	F_{BYC}	0.02	0.07	0.19	0.18
Arrowtooth flounder	$F_{0.1}$	0.18	n/a	0.25	0.20
Rock sole	F_{MSY}	0.18	0.18	0.21	0.20
Other flatfish	F_{PRX}	0.18	n/a	0.23	0.20
Sablefish* (BS)	$F_{0.1}$	0.13	0.27	0.18	0.10
Sablefish* (AI)	$F_{0.1}$	0.13	0.27	0.18	0.10
Pacific ocean perch* (BS)	F_{MSY}	0.06	0.06	0.08	0.05
Pacific ocean perch* (AI)	F_{MSY}	0.06	0.06	0.08	0.05
Other rockfish (BS)	F_{PRX}	0.06	n/a	n/a	n/a
Other rockfish (AI)	F_{PRX}	0.06	n/a	n/a	n/a
Atka mackerel	$F_{0.1}$	0.27	n/a	0.33	0.20
Squid & other species	F_{HIS}	n/a	n/a	n/a	n/a

Gulf of Alaska

Management category	Strategy	F_{ABC}	F_{MSY}	$F_{0.3}$	M
Pollock	?	0.10	n/a	0.45	0.40
Pacific cod	?	0.19	0.12	0.31	0.29
Deep flatfish	$F_{0.1}$	0.20	n/a	0.26	0.20
Shallow flatfish	$F_{0.1}$	0.20	n/a	0.26	0.20
Arrowtooth flounder	$F_{0.1}$	0.17	n/a	0.22	0.22
Sablefish*	$F_{0.1}$	0.13	0.27	0.18	0.10
Slope rockfish*	M/2	0.03	0.08	0.10	0.05
Pelagic shelf rockfish	M	0.05	n/a	n/a	0.05
Demersal shelf rockfish	?	n/a	n/a	0.07	0.04
Thornyheads*	F_{HIS}	0.04	0.07	0.08	0.08
Other species	?	n/a	n/a	n/a	n/a

Legend (F = fishing mortality rate):

$F_{0.1}$ = F value at which the yield-per-recruit curve's slope is 10% of the slope at the origin
$F_{0.3}$ = F value at which the biomass-per-recruit ratio is reduced to 30% of its pristine value
F_{ABC} = F value used to calculate acceptable biological catch
F_{BYC} = F value that allows for bycatch only
F_{HIS} = F value that sets ABC equal to the historic average
F_{MSY} = F value corresponding to maximum sustainable yield
F_{PRX} = proxy target F adopted from the preceding species

M = natural mortality rate

Note: For species marked with an asterisk (*), F_{MSY} is based on subjective estimates of stock-recruitment parameters or B_{MSY}.

Table 3.2. Maximum fishing mortality rates under the various alternatives, compared to current ABC rates

Bering Sea (BS) and Aleutian Islands (AI)

Management category	F_{ABC}	Alternative 2	3	4	5	6	7
Pollock (BS)	0.31	?	0.31	0.30	0.31	0.28	0.28
Pollock (AI)	0.31		0.31				
Pacific cod	0.18		0.18	0.18			
Yellowfin sole	0.17		0.17				
Greenland turbot*	0.02	?	0.07	0.06	0.07	0.05	0.05
Arrowtooth flounder	0.18		0.25				
Rock sole	0.18		0.18				
Other flatfish	0.18		0.23				
Sablefish* (BS)	0.13	?	0.27	0.27	0.27	0.27	0.33
Sablefish* (AI)	0.13	?	0.27	0.27	0.27	0.27	0.35
P. ocean perch* (BS)	0.06	?	0.06	0.05	0.06	0.04	0.04
P. ocean perch* (AI)	0.06	?	0.06	0.05	0.06	0.04	0.04
Other rockfish (BS)	0.06						
Other rockfish (AI)	0.06						
Atka mackerel	0.27		0.33				
Squid & other species	n/a						
Subtotal (no. species)	15	6	13	7	6	6	6

Gulf of Alaska

Management category	F_{ABC}	Alternative 2	3	4	5	6	7
Pollock	0.10		0.45				
Pacific cod	0.19	?	0.12	0.12	0.12	0.12	0.33
Deep flatfish	0.20		0.26				
Shallow flatfish	0.20		0.26				
Arrowtooth flounder	0.17		0.22				
Sablefish*	0.13	?	0.27	0.27	0.27	0.27	0.33
Slope rockfish*	0.03	?	0.08	0.07	0.08	0.04	0.04
Pelagic shelf rockfish	0.05		0.05				
Demersal shelf rockfish	n/a		0.07				
Thornyheads*	0.04		0.07				
Other species	n/a						
Subtotal (no. species)	9	3	10	3	3	3	3
Grand total	24	9	23	10	9	9	9
Percent applicability	89	33	85	37	33	33	33

Notes:

1) An asterisk (*) indicates that satisfaction of some alternatives' data requirements depends on subjective estimates of stock-recruitment parameters or B_{MSY}.

2) A question mark (?) indicates that Alternative 2 can be applied, but the maximum F is currently unknown.

Table 3.3. Statistics relating to maximum sustainable yield and pristine biomass for various groundfish stocks.

Bering Sea (BS) and Aleutian Islands (AI)

Management Category	F_{MSY}	M	B_p	B_{MSY}	B(90)	β_1	β_2
Pollock (BS)	0.31	0.30	13.830	6.120	5.844	0.44	0.42
Pollock (AI)	data are insufficient to estimate main parameters						
Pacific cod	0.18	0.29	n/a	0.879	1.335	n/a	n/a
Yellowfin sole	data are insufficient to estimate main parameters						
Greenland turbot*	0.07	0.18	1.073	0.399	0.357	0.37	0.33
Arrowtooth flounder	data are insufficient to estimate main parameters						
Rock sole	0.18	0.20	n/a	n/a	1.194	n/a	n/a
Other flatfish	data are insufficient to estimate main parameters						
Sablefish* (BS)	0.27	0.10	0.083	0.018	0.033	0.21	0.39
Sablefish* (AI)	0.27	0.10	0.186	0.040	0.082	0.21	0.44
P. ocean perch* (BS)	0.06	0.05	0.267	0.076	0.068	0.29	0.26
P. ocean perch* (AI)	0.06	0.05	0.600	0.173	0.158	0.29	0.26
Other rockfish (BS)	data are insufficient to estimate main parameters						
Other rockfish (AI)	data are insufficient to estimate main parameters						
Atka mackerel	data are insufficient to estimate main parameters						
Squid & other spp.	data are insufficient to estimate main parameters						

Gulf of Alaska

Management Category	F_{MSY}	M	B_p	B_{MSY}	B(90)	β_1	β_2
Pollock	data are insufficient to estimate main parameters						
Pacific cod	0.12	0.29	0.695	0.272	0.505	0.39	0.73
Deep flatfish	data are insufficient to estimate main parameters						
Shallow flatfish	data are insufficient to estimate main parameters						
Arrowtooth flounder	data are insufficient to estimate main parameters						
Sablefish*	0.27	0.10	0.675	0.145	0.311	0.21	0.46
Slope rockfish*	0.08	0.05	1.391	0.383	0.329	0.28	0.24
Pelagic shelf rock.	data are insufficient to estimate main parameters						
Demersal shelf rock.	data are insufficient to estimate main parameters						
Thornyhead*	0.07	0.07	n/a	n/a	0.080	n/a	n/a
Other species	data are insufficient to estimate main parameters						

Legend: F_{MSY} = MSY fishing mortality rate, M = natural mortality rate, B_p = pristine biomass, B_{MSY} = biomass at MSY, B(90) = projected biomass in 1990, $\beta_1 = B_{MSY}/B_p$, $\beta_2 = B(90)/B_p$

Notes: 1) All biomass estimates are in millions of metric tons.

2) An asterisk (*) by a species indicates that the corresponding figures are based on subjective (as opposed to empirical) estimates of stock-recruitment parameters or B_{MSY}.

3) All information was taken from the final 1989 Stock Assessment and Fishery Evaluation (SAFE) reports, except for BS pollock. For this stock, B(90) was taken from the SAFE document and all other information was taken from Quinn et al. (1990).

4) For some stocks, the documents provide estimates based on several different model versions. In such cases, single values were chosen as follows: BS pollock--Beverton-Holt stock-recruitment version; BSAI and GOA sablefish--version tuned to point estimates from surveys; BSAI POP, GOA slope rockfish, and GOA thornyhead--versions that give 90% of pristine recruitment at 50% of pristine biomass.

5) Biomass figures for BSAI POP and GOA slope rockfish refer to Sebastes alutus only.

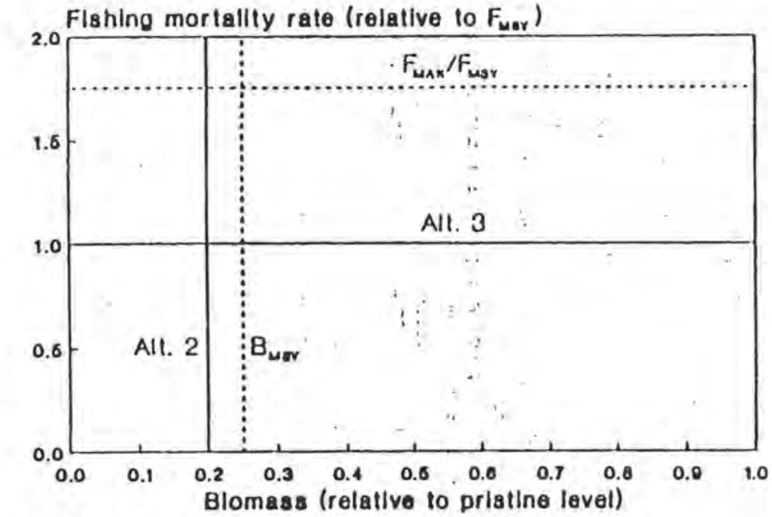

Figure 3.1a.

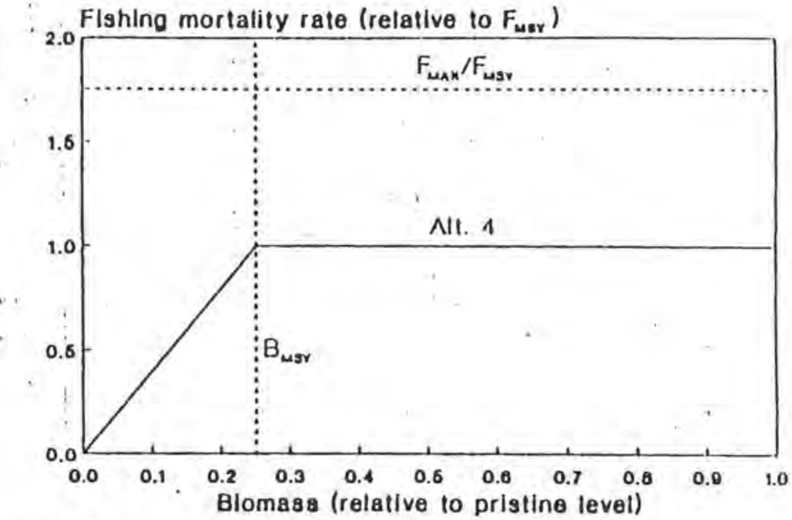

Figure 3.1b.

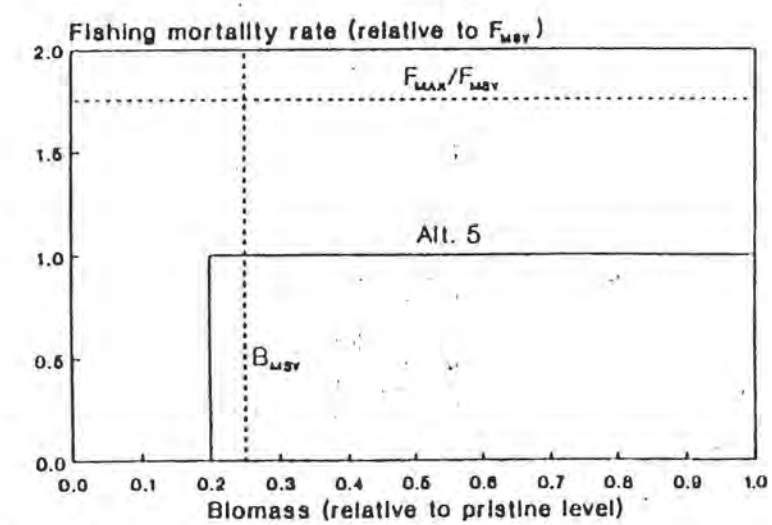

Figure 3.1c.

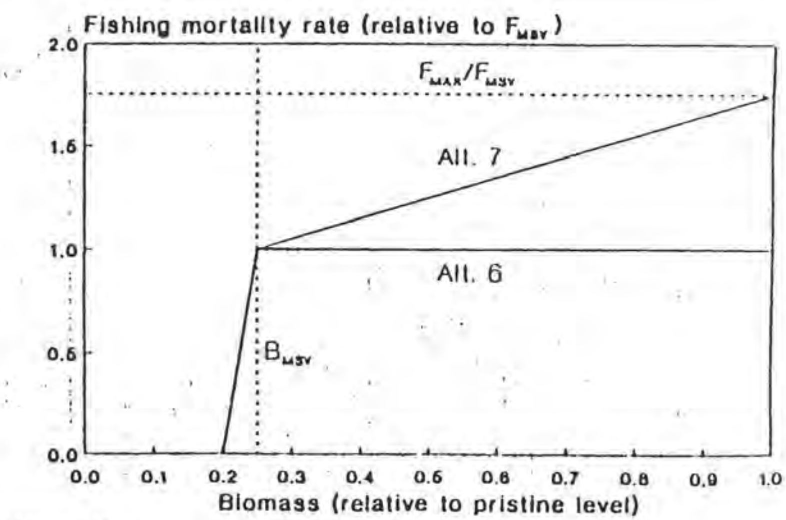

Figure 3.1d.

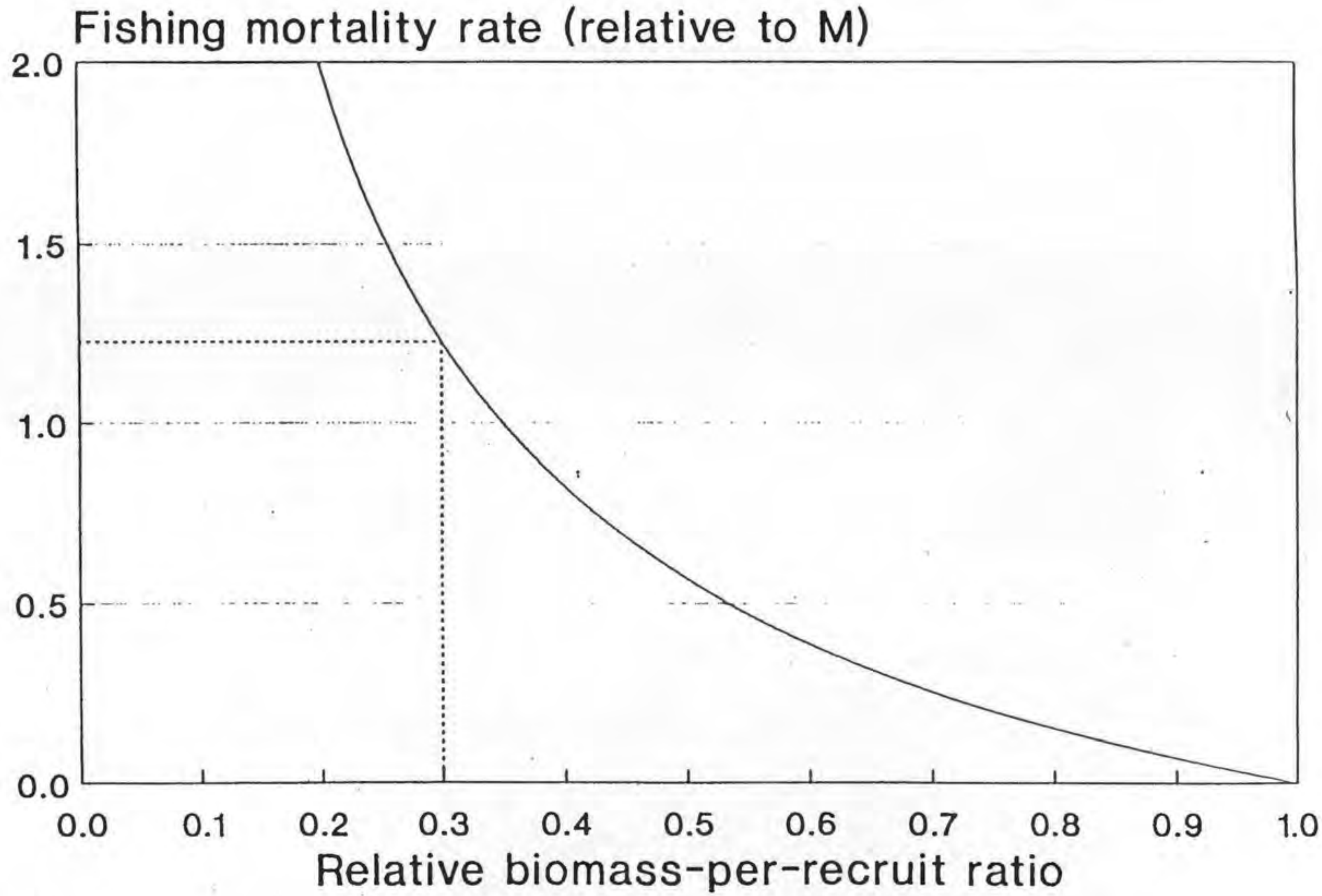
Fishing mortality rate (relative to M)
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Relative biomass-per-recruit ratio

Figure 3.2.

3.A.1 Appendix I: A proposal for a threshold stock size and maximum fishing mortality rate

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Abstract

Overfishing can be defined as any harvest policy that causes a stock to collapse. A generalized form of the Beverton-Holt stock-recruitment relationship is used here to develop a set of three constraints that can be employed to safeguard against overfishing. Given the assumptions of the model, the ability of these three constraints to prevent stock collapse is independent of the parameter values used in the stock-recruitment relationship. A general theoretical evaluation indicates that the constraints are unlikely to impose new restrictions on fisheries that are already managed for maximum sustainable yield. However, the constraints should insure against pursuit of overly aggressive harvest strategies when detailed biological information is lacking.

Introduction

Throughout the history of fisheries science, one of the central questions has been the question of overfishing: How much fishing is too much? Typically, attempted answers have defined "too much fishing" (at least implicitly) as any fishing above the optimal level. The optimal rate of fishing has usually been specified as the rate corresponding to maximum sustainable yield (MSY, e.g., Graham 1935), maximum sustainable rent (e.g., Gordon 1954), maximum discounted yield (e.g., Plourde 1970), maximum discounted rent (e.g., Clark 1973), or other value that maximizes some specified objective function. (Strategies associated with the first four objectives mentioned are compared by Thompson 1989.)

An alternative though more complicated approach deals with the overfishing question in terms of multiple equilibria, or bifurcations in stock dynamics. The theory behind this approach is outlined by Lewontin (1969), Holling (1973), and May (1977). In the multiple equilibrium approach, "too much fishing" could be defined as any fishing that causes the stock to fall below an undesirable point of no return. Although it is difficult to provide conclusive proof of the existence of multiple equilibria in natural systems (Connell and Sousa 1983), Table 1 lists some stocks that have been suggested to exhibit such behavior, in the sense of experiencing a severe decline and subsequently failing to recover despite a reduction in the fishing mortality rate.

In the simplest case, the multiple equilibrium approach defines overfishing as any harvest policy that causes the stock to collapse. Implicitly, at least, this is the approach endorsed by the National Oceanic and Atmospheric Administration, whose Guidelines for Fishery Management Plans (NOAA Guidelines, 50 CFR Part 602) contain the following general definition:

> "Overfishing is a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY on a continuing basis."

In other words, an optimal level of production (in this case, MSY) is not the object of concern. Rather, the object of concern is the stock's long-term productive capacity (Warren et al. 1979).

One problem with this approach to the overfishing question is that none of the models commonly used for quantitative stock assessment exhibit the requisite behavior, namely a critical point ("threshold") at which the stock moves from a favorable domain (such as the one containing the MSY point) to an unfavorable one (such as a domain of inevitable extinction). The purposes of this paper are to develop a model that does exhibit this behavior, to derive from this model a set of constraints that can be used to prevent overfishing, and to evaluate some of the likely impacts of imposing these constraints on a fishery insofar as such impacts can be assessed using deterministic models of stock dynamics.

Approach

A Generalized Beverton-Holt Stock-Recruitment Relationship

Typical stock-recruitment curves, such as those of Ricker (1954), Beverton and Holt (1957), and Cushing (1971), generate only two equilibria (one of which is at the origin) if growth and mortality parameters are independent of stock size. However, Ricker (1954) also pointed out that an appropriately drawn stock-recruitment curve can generate multiple (i.e., more than two) equilibria. The key attribute of such curves is an ability to account for depensatory mortality, in which relative losses decrease with stock size (Neave 1953). Basically, this means that the second derivative of the stock-recruitment curve must be positive over some range of stock sizes below the point (if any) where the curve reaches its peak.

Much of the work in the analysis of such curves has been qualitative (e.g., Ricker 1954, Paulik 1973, Clark 1974, Gulland 1977). However, a few formal equations describing such curves have been developed. These include three-equilibrium forms of the Ricker curve developed by Southwood and Comins (1976) and Parrish and MacCall (1978), four-equilibrium forms of the Ricker curve developed by May (1977) and Peterman (1977), an original three-equilibrium curve developed by DeAngelis et al. (1977), and a three-equilibrium form of the Cushing curve developed by Parrish and MacCall (1978).

Unfortunately, these studies have mostly been used to demonstrate the fact that stock collapse is at least a theoretical possibility, without generating much in the way of quantitative management advice. This may largely be due to the fact that the depensatory stock-recruitment curves suggested to date have been fairly complex (e.g., in none of the curves listed above is it possible to solve for stock size as an explicit function of recruitment). However, it is possible to specify a particular stock-recruitment relationship that is both sufficiently complex to allow for multiple equilibria and sufficiently simple to permit quantitative assessment. To begin development of such a curve, note that the Beverton-Holt stock-recruitment relationship can be written

$$R(B) = \frac{r_1}{1 + r_2 B^{-1}}, \tag{1}$$

where B = stock biomass, R = recruitment (lagged appropriately), and r_1 and r_2 are positive constants. The parameter r_1 gives the value of the recruitment asymptote as biomass approaches infinity, and r_2 is a shape parameter governing the degree of curvature in the relationship.

Equation (1) can be viewed as a special case of the following three-parameter function:

$$R(B) = \frac{r_1}{1 + r_2 B^{-r_3}}, \tag{2}$$

where r_3 is a positive constant. Figure 1 shows the behavior of Equation (2) for several values of r_3, including the special case of Beverton-Holt recruitment ($r_3 = 1$).

The first and second derivatives of Equation (2) are

$$\frac{dR}{dB} = \frac{r_2 r_3 R^2}{r_1 B^{r_3+1}}, \tag{3}$$

and

$$\frac{d^2R}{dB^2} = \frac{r_2 r_3 R^3 \left[r_2 (r_3 - 1) - (r_3 + 1) B^{r_3} \right]}{r_1^2 B^{2r_3+2}}. \tag{4}$$

Equations (2-4) are plotted in Figure 2 for particular values of r_2 and r_3.

Equations (2-4) attain their respective maxima at the critical points B_1, B_2, and B_3, which can be written

$$B_i = \left[\frac{r_2}{f_i(r_3)} \right]^{1/r_3}, \tag{5}$$

where

$$f_1(r_3) = 0, \tag{6}$$

$$f_2(r_3) = \frac{r_3+1}{r_3-1}, \tag{7}$$

and

$$f_3(r_3) = \frac{r_3+2}{2(r_3-1) - r_3\left[\frac{3(r_3-1)}{r_3+1}\right]^{1/2}}. \tag{8}$$

Note that a positive value of B_2 exists only for $r_3 > 1$, while a positive value of B_3 exists only for $r_3 > 2$. Critical points are indicated in Figure 2 by vertical dashed lines.

The recruitment levels corresponding to the critical points B_i are given by

$$R_i = \frac{r_1}{1 + f_i(r_3)}. \tag{9}$$

The Relationship Between Threshold and Pristine Biomass

A common assumption is that growth and mortality are density independent. If this is the case, then equilibrium stock biomass will be proportionate to recruitment, or

$$R = u(F)B, \tag{10}$$

where F is the instantaneous rate of fishing mortality and $u(F)$ describes the equilibrium ratio of recruitment to stock biomass.

Equilibrium stock biomass and recruitment will be determined by the intersection of Equations (2) and (10), as shown for various hypothetical values of $u(F)$ in Figure 3. Note that for values of $r_3 > 1$ and sufficiently low values of $u(F)$, two intersections will exist. When $F = 0$, the upper intersection corresponds to pristine biomass (B_p), while the lower one corresponds to threshold biomass (B_t). Setting $F = 0$ and solving Equations (2) and (10) simultaneously gives

$$B_p^{r_3} - \left[\frac{r_1}{u_p}\right]B_p^{r_3-1} + r_2 = 0, \tag{11}$$

where $u_p = u(0)$.

Unfortunately, Equation (11) cannot be solved explicitly except in the special cases where $r_3 = 1$ or $r_3 = 2$. However, Equation (11) can be simplified somewhat for another important special case. First, assume that B_t can be written in the form of Equation (5), in which case

$$r_2 = f(r_3)B_t^{r_3}. \tag{12}$$

Second, substitute B_t for B_p and Equation (12) for r_2 in Equation (11), giving

$$B_t^{r_3} - \left[\frac{r_1}{u_p}\right] B_t^{r_3-1} + f(r_3)B_t^{r_3} = 0. \tag{13}$$

Third, solve Equation (13) for the ratio r_1/u_p:

$$\frac{r_1}{u_p} = [1 + f(r_3)]B_t. \tag{14}$$

Fourth, substitute Equations (12) and (14) into Equation (11):

$$B_p^{r_3} - [1 + f(r_3)]B_t B_p^{r_3-1} + f(r_3)B_t^{r_3} = 0. \tag{15}$$

Fifth, define

$$\beta = \frac{B}{B_p} \tag{16}$$

for any value of B (e.g., β_t would represent B_t/B_p).

Sixth, use Equation (16) to substitute B_t/β_t for B_p in Equation (15), giving

$$\left[\frac{B_t}{\beta_t}\right]^{r_3} - [1 + f(r_3)]B_t\left[\frac{B_t}{\beta_t}\right]^{r_3-1} + f(r_3)B_t^{r_3} = 0. \tag{17}$$

Finally, eliminate B_t in Equation (17) and rearrange terms to yield

$$f(r_3)\beta_t^{r_3} - [1 + f(r_3)]\beta_t + 1 = 0. \tag{18}$$

Like the general case of Equation (11), Equation (18) has the difficulty of not being explicitly solvable, but it does have the advantages of eliminating all but one parameter (r_3) and employing the useful ratio β_t as the only variable. In other words, it indicates that in the special case described by Equation (12), the ratio of B_t to B_p is dependent only on r_3.

A Hypothesis Concerning Threshold Biomass

Equation (12) constitutes the critical assumption in deriving Equation (18). Is there any reason to think that B_t can be described in the form of Equation (5)? One possible rationale can be drawn by considering the problem in the context of life history theory. Equation (3) describes the instantaneous rate at which recruitment changes with respect to biomass. The area around B_2 (the peak of Equation [3]) is the region of greatest recruitment productivity, i.e., the region in which the greatest gains in recruitment are realized. It might be reasonable to assume that natural selection would tend to act in a manner that keeps the most productive portion of the stock-recruitment curve available for the stock's use. In other words, natural selection would not tend to generate a value of B_t so high that the most productive portion of the stock-recruitment curve is sacrificed (i.e., encountered only enroute to extinction).

If this is the case, the question then becomes one of defining the lower bound of the highly productive region that surrounds B_2. A natural choice in this regard is B_3 (the peak of Equation [4]). This biomass level defines the point at which the stock-recruitment curve begins to decelerate. Put another way, B_3 marks the place where recruitment productivity (Equation [3]) begins to level off. Assuming that B_3 does constitute the lower bound of the highly productive region surrounding B_2, and assuming that natural selection will tend to act so as to keep this region available for the stock's use, the following constraint will hold:

$$B_t \leq B_3. \qquad (19)$$

Given Equation (19), Equation (18) can be made more specific by setting $f(r_3) = f_3(r_3)$, in which case β_t now describes the upper limit to the ratio B_t/B_p. When this specification is made, the solution to Equation (18) takes the form shown in Figure 4, where the asymptote corresponds to the limit

$$\lim_{r_3 \to \infty} \beta_t = \frac{2-\sqrt{3}}{3-\sqrt{3}} \approx 0.211. \qquad (20)$$

Equation (20) indicates that so long as a stock's biomass is kept above about 20% of its pristine level, collapse is unlikely. While this result is dependent on Equations (2), (10), and (19), it is independent of all parameter values.

Minimum Safe Biomass-per-Recruit Ratio

As mentioned earlier, two equilibria exist in this model so long as $r_3 > 1$ and $u(F)$ is sufficiently low. As $u(F)$ increases from its pristine value, B_p and B_t become increasingly close, ultimately converging when $u(F)$ reaches a limiting value (u_e). For all values of $u(F)$ higher than u_e, the stock will go extinct. The stock biomass corresponding to u_e (B_e) is the value at which the tangent to the recruitment curve passes through the origin, or

$$B_e = [r_2(r_3-1)]^{1-r_3}. \qquad (21)$$

The recruitment at B_e (R_e) is given by

$$R_e = \frac{r_1(r_3-1)}{r_3}. \tag{22}$$

(Note that R_e is exactly twice R_2, regardless of parameter values). The ratio of R_e to B_e gives the value of u_e:

$$u_e = \frac{r_1(r_3-1)}{r_3[r_2(r_3-1)]^{1/r_3}}. \tag{23}$$

In cases where estimates of B_p are unavailable, Equation (18) does not provide much useful information, and specifying a value for B_t becomes highly problematic. As an alternative (or in addition to specifying a threshold biomass), it may be desirable to specify a limit to the amount by which the pristine biomass-per-recruit ratio ($1/u_p$) can be reduced without causing the stock to collapse (which occurs whenever $1/u(F)$ is sustained at a value less than $1/u_e$). In general, define

$$\alpha = \frac{u_p}{u(F)}, \tag{24}$$

so that the goal is to specify a maximum value for α_e ($= u_p/u_e$).
This can be done by using Equation (19) to set the ratio R_3/B_3 as an upper limit to u_p, giving

$$\alpha_e = \frac{r_3[(r_3-1)/f_3(r_3)]^{1/r_3}}{(r_3-1)[1+f_3(r_3)]} \tag{25}$$

as an upper limit to α_e. Equation (25) is plotted in Figure 5. Unlike β_t, α_e exhibits a maximum at a finite value of r_3. The α_e-maximizing value of r_3 is the solution to the following equation:

$$\left[\frac{1}{f_3(r_3)}+1-r_3\right]\left[\frac{df_3}{dr_3}\right] - \left[\frac{1+f_3(r_3)}{r_3}\right]\ln[(r_3-1)/f_3(r_3)] = 0, \tag{26}$$

where

$$\frac{df_3}{dr_3} = \left[\frac{f_3(r_3)}{r_3+2}\right]^2\left[\left(\frac{3r_3^2+2r_3-2}{r_3+1}\right)\sqrt{\frac{3}{r_3^2-1}} - 6\right]. \tag{27}$$

The value of r_3 that solves Equation (26) is about 3.776, which results in an α_e value of about 0.294. Thus, if the biomass-per-recruit ratio is kept above 30% of the pristine level, stock collapse would appear to be unlikely. Strictly speaking, this result holds necessarily only for stocks with biomass levels greater than B_e. For severely depressed stocks, a more conservative policy (i.e., higher biomass-per-recruit ratio) might be appropriate.

Maximum Safe Fishing Mortality Rate

The preceding section describes a minimum safe value for the biomass-per-recruit ratio. To convert this ratio into a measure of the maximum safe fishing mortality rate, it is necessary to assume some functional form for the ratio $u(F)$.

Thompson (in press) developed a dynamic pool model than can serve as a simple example. In terms of biomass per recruit, the model is basically the same as that of Hulme et al. (1947), where body weight is assumed to be a linear function of age. As configured by Thompson,

$$u(F) = \left[\frac{1}{M(1+F')}\right]\left[1 + \frac{K''}{1+F'}\right], \qquad (28)$$

where M is the instantaneous rate of natural mortality, $F' = F/M$, and K'' is the ratio of growth to recruitment in the pristine stock (which is determined in this model as the ratio of the weight-at-age slope to the product of M and size at recruitment).

Equation (28) can be used to compute the F level that results in u_p being reduced proportionately by the factor α:

$$F' = \frac{1 + \sqrt{1+4\alpha K''(1+K'')}}{2\alpha(1+K'')} - 1. \qquad (29)$$

Equation (29) attains an upper limit of $(1/\alpha)-1$ when $K''=0$. It also exhibits the following lower limit:

$$\lim_{K''\to\infty} F' = \frac{1}{\sqrt{\alpha}} - 1. \qquad (30)$$

If α is set at the level of 0.3 recommended in the previous section, this model indicates that F should range between about 0.826 and 2.333 times the natural mortality rate. Thus, if M is the only life history parameter for which an estimate is available, a fishing mortality rate set at or below about 80% of that estimate should keep the stock from collapsing.

Impacts on the Fishery: Theoretical Considerations

Threshold Biomass

It seems unlikely that any short-term economic benefits to be derived from overfishing (as defined here) would outweigh the corresponding costs of irreversible damage to the stock's productive capacity. In other words, the long-term economic impacts from avoiding overfishing should be positive. However, since the constraints listed in the preceding sections are limiting values derived from a particular model, it is not so clear that their long term economic impacts will be positive. For example, the biomass level associated with MSY (B_{MSY}) could conceivably fall well below the suggested threshold set at 20% of B_p. If fishing is halted whenever the stock falls below its threshold (as is required by the NOAA Guidelines), the threshold rule could result in some cost to the fishery, even in the case of a stock managed for MSY. Likewise, the fishing mortality rate that maximizes sustainable yield (F_{MSY}) could also be higher than the rate that sets α equal to 0.3.

Another way to approach the problem (using the model described in the preceding section) is to solve for those parameter combinations that result in a β_{MSY} value of 0.2. To facilitate estimation of MSY-related quantities, Thompson (in press) extended the model described in Equation (28) by incorporating the stock-recruitment relationship described by Cushing (1971):

$$R = pB(F)^q, \tag{31}$$

where $B(F)$ is the equilibrium stock biomass obtained under a fishing mortality rate of F, and p and q are constants, with $0 \leq q \leq 1$. In the limiting case of $q = 0$, recruitment is constant, while in the other limiting case of $q = 1$, recruitment is proportional to biomass.

The central results of Thompson's (in press) treatment of Equations (28) and (31) can be summarized by deriving equations for equilibrium stock biomass, equilibrium yield, and F_{MSY}. Substituting Equation (31) into Equation (28) and rearranging terms gives the following equation for equilibrium stock biomass:

$$B(F) = \left\{\left[\frac{p}{M(1+F')}\right]\left[1 + \frac{K''}{1+F'}\right]\right\}^{\frac{1}{1-q}}. \tag{32}$$

Multiplying both sides of Equation (32) by F then gives the equation for equilibrium yield $Y(F)$ shown below:

$$Y(F) = F\left\{\left[\frac{p}{M(1+F')}\right]\left[1 + \frac{K''}{1+F'}\right]\right\}^{\frac{1}{1-q}}. \tag{33}$$

Differentiating Equation (33) with respect to F and setting the resulting expression equal to zero gives the following equation for F_{MSY}:

$$\frac{F_{MSY}}{M} = \frac{-(q+1)K'' - (2q-1) + \sqrt{(q+1)^2K''^2 + 2(3q-1)K'' + 1}}{2q}. \tag{34}$$

Equations (32-34) can be used to examine the possible impacts of setting a threshold at 20% of B_p. Here, the ratio of B_{MSY} to B_p can range anywhere from 0 to $1/e$ ($\approx$0.368). While it is difficult to predict what percentage of stocks might have a B_{MSY} value less than 20% of B_p, one option is to assume the conventional wisdom (Clark in press) that equates F_{MSY}, M, and $F_{0.1}$ (Gulland and Boerema 1973). In the above model, this assumption holds only when $K''=1.5$ and $q=2/7$ (giving approximately 82% of pristine recruitment at 50% of B_p). Under these parameter values, B_{MSY} is approximately 23% of B_p.

Equation (32) can be manipulated to show that α and β are related as follows:

$$\beta = \alpha^{1/(1-q)}, \qquad (35)$$

Substituting Equation (35) into Equation (29) and solving the resulting expression simultaneously with Equation (34) yields the following polynomial in K'':

$$\begin{aligned}
&[\,4\beta_{MSY}^{2-2q} - (q^2+2q+1)\beta_{MSY}^{1-q}\,]K''^5 + \\
&[16\beta_{MSY}^{2-2q} - (3q^2+10q+3)\beta_{MSY}^{1-q}\,]K''^4 + \\
&[24\beta_{MSY}^{2-2q} - (3q^2+18q+2)\beta_{MSY}^{1-q} - q]K''^3 + \\
&[16\beta_{MSY}^{2-2q} - (q^2+14q-2)\beta_{MSY}^{1-q} - 3q]K''^2 + \\
&[\,4\beta_{MSY}^{2-2q} - (4q-3)\beta_{MSY}^{1-q} - 3q]K''^1 + \\
&[\,\beta_{MSY}^{1-q} - q]K''^0 = 0.
\end{aligned} \qquad (36)$$

Equation (36) has at most one positive root. This solution is plotted for $\beta_{MSY}=0.2$ in Figure 6, along with the loci at which the F_{MSY}/M ratio takes on various constant values. Note that the curve corresponding to $\beta_{MSY}=0.2$ is almost identical to the curve corresponding to $F_{MSY}/M=1.5$. Thus, so long as F_{MSY} does not exceed M by more than about 50%, B_{MSY} should not violate a threshold set at 20% of B_p.

Still another way to approach the problem is to look at the yield that might be forgone under a threshold set at 20% of B_p. The ratio of yield at F_β (Y_β) to MSY is given by

$$\frac{Y_\beta}{MSY} = \left[\frac{F'_\beta}{F'_{MSY}}\right]\left[\frac{(1+K''+F'_\beta)(1+F'_{MSY})^2}{(1+K''+F'_{MSY})(1+F'_\beta)^2}\right]^{\frac{1}{1-q}}, \qquad (37)$$

where $F'_\beta = F_\beta/M$ and $F'_{MSY}=F_{MSY}/M$.

For a given value of K'', Equation (37) reaches its lower bound at $q=0$, while for a given value of q, the lower bound is reached at $K''=0$. These two worst-case scenarios ($K''=0$ with q variable, $q=0$ with K'' variable) are shown for $b=0.2$ in Figure 7. Note that only those values to the left of the vertical dashed lines ($q=0.353$ and $K''=5$, respectively) are relevant, since the threshold does not constrain the fishery at values to the right. The main conclusion to be drawn from Figure 7 is that even when a threshold set at $0.2B_p$ does constrain the fishery, the loss in yield is probably very small (in no case exceeding 20%).

Minimum Safe Biomass-per-Recruit Ratio

The other problem to be considered here is whether constraining F by the value that sets $\alpha = 0.3$ might place undue hardship on the fishery. Equating the right-hand sides of Equations (29) and (34) gives the parameter values that set F_{MSY} equal to the F level corresponding to a given value of α:

$$K'' = \frac{2\alpha(\alpha - q) + \sqrt{\alpha(q-\alpha)\left[4\alpha(q-\alpha) - (q+1)^2 + 4\alpha\right]}}{\alpha\left[(q+1)^2 - 4\alpha\right]}. \tag{38}$$

Equation (38) is illustrated in Figure 8 for three different values of α. For (q,K'') combinations above and to the right of a given curve, an F_{MSY} harvest strategy will not be constrained by setting α at the associated value. Note that for $\alpha > 0.25$, a vertical asymptote exists at $q = 2(\alpha^{1/2}) - 1$. Thus, for $\alpha = 0.3$ and $q < 0.095$, an F_{MSY} harvest strategy will always be constrained, regardless of the value of K''. At higher values of q, the impact on the fishery will depend on the value of K''. For example, using the "conventional wisdom" parameters $K'' = 1.5$ and $q = 2/7$, the biomass-per-recruit ratio under an F_{MSY} harvest strategy is exactly 35% of the pristine value, so the constraint imposed by setting α equal to 0.3 would not be binding.

Of course, stocks are not always managed according to F_{MSY}. Another common strategy is to harvest the stock at the $F_{0.1}$ rate. The $F_{0.1}$ rate is the value at which the slope of the yield-per-recruit vs. F curve is one tenth of the value at the origin. Thompson (1989) showed that this rate could be computed as a special case of the following polynomial in F':

$$PF'^3 + 3PF'^2 + \left[3P + \frac{K''-1}{K''+1}\right]F' + P - 1 = 0, \tag{39}$$

where P is the slope of the yield-per-recruit curve relative to the slope at the origin ($P = 0.1$ in the case of $F_{0.1}$).

As noted earlier, the F value corresponding to α is bounded above by $(1/\alpha) - 1$ and below by Equation (30). Inserting these limiting values into Equation (39) and solving for α gives the following lower and upper bounds, respectively:

$$\alpha = \sqrt{P}, \tag{40}$$

and

$$4\alpha^3 - \alpha^2 - 2P\alpha - P^2 = 0. \tag{41}$$

For the special case of $P = 0.1$, Equations (40) and (41) give limits of $\alpha = 0.316$ and $\alpha = 0.393$, respectively. Thus, constraining F by the value that sets $\alpha = 0.3$ should not impact a fishery managed at the $F_{0.1}$ rate (a P value of 0.09 would be required to observe an α value as low as 0.3).

Discussion

The above sections developed a set of three constraints designed to insure against overfishing, where overfishing is defined as any harvest policy that causes a stock to collapse. These constraints (which can be used separately or in combination) are as follow:

A) When an estimate of pristine biomass is available, fishing should cease whenever the stock falls to a level less than about 20% of this estimate.

B) When estimates of the relevant life history parameters are available, the fishing mortality rate should be set so as to maintain the biomass-per-recruit ratio at a level no less than about 30% of the pristine level.

C) When the natural mortality rate is the only life history parameter for which an estimate is available, the fishing mortality rate should be set at a level no higher than about 80% of this estimate.

It should be emphasized that Constraints (A) and (B) are dependent only on Equations (2), (10), and (19). In addition to these three equations, Constraint (C) is dependent on Equation (28). The constraints are totally independent of the parameter values used in these equations. Because they are explicitly derivable from a small number of qualitative assumptions regarding population dynamics, the constraints pose two significant advantages over some other overfishing criteria that have been proposed: 1) they avoid the problem of requiring types or amounts of data that are often unavailable (e.g., stock-recruitment parameters required to compute F_{MSY}), and 2) they avoid the problem of being critically dependent on arbitrarily chosen parameter values (e.g., the "0.1" in $F_{0.1}$).

Perhaps the most tenuous of the assumptions used to derive the suggested constraints is Equation (19), which states that the threshold will never exceed the third critical point of the stock-recruitment relationship. Although it is not unassailable, Equation (19) does find support in the following arguments: 1) it is defensible in terms of life history theory, as discussed earlier; 2) ecological theory is beginning to find significance in analogous critical points (e.g., Fowler 1988); and 3) the resulting management implications are reasonable.

Expanding on this last point, it is interesting to note how well Constraints (A-C) conform to standards with which fishery scientists already seem to feel comfortable. As shown above, Constraints (A-C) are unlikely to impinge severely on some of the more common management measures recommended by fishery scientists, at least insofar as such impingements can be assessed using deterministic models of stock dynamics.

Other examples of concordance can be cited as well. For example, the 20% figure used to define a threshold corresponds exactly to the figure employed by Beddington and Cooke (1983). It is within the range of 20%-30% derived by Quinn et al. (in press) for BS pollock, and the 20%-50% range derived by Clark (in press). The 30% figure used to define a maximum fishing mortality rate is identical to the result obtained by Gabriel et al. (1989) for Georges Bank haddock (Melanogrammus aeglefinus), and it is close to the 35% figure derived by Clark. The robustness of these results is augmented by the fact that the authors were using different models and objectives: Beddington and Cooke used a stochastic yield-per-recruit model to maximize yield without entering the domain where recruitment was thought to depend on stock size, Quinn et al. used an age-structured model with two stock-recuitment assumptions to maximize an objective function involving average yield and yield variability, Gabriel et al. used an age-structured model to determine conditions necessary to maintain present stock size, and Clark used an age-structured model to maximize catch (relative to MSY) across a wide range of stock-recruitment assumptions.

The 80% figure in Constraint (C) is not far from the 100% value suggested in several studies as a reasonable approximation of either F_{MSY} or $F_{0.1}$ in the absence of more detailed information (e.g., Alverson and Pereyra 1969, Shepherd 1982, Deriso 1987, Kimura 1988, Clark in press).

Although analyses presented here have shown that Constraints (A) and (B) should impose few additional costs on fisheries that are already managed for MSY, such fisheries are not really the constraints' intended target. Rather, it is anticipated that the constraints' main benefit would accrue from applying them to fisheries where good estimates of F_{MSY} are not available. There, the suggested constraints should provide a relatively painless, objective, and scientifically defensible means of safeguarding against overly aggressive harvest strategies.

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Table 1. A sampling of stocks suggested to exhibit multiple equilibria.

Stock	Scientific name	Citation(s)
Great Lakes lake sturgeon	*Acipenser fulvescens*	Smith 1968, Holling 1973
Antarctic fin whale	*Balaenoptera physalus*	Jones and Walters 1976
California Dungeness crab	*Cancer magister*	Botsford 1981
North Sea herring	*Clupea harengus*	Ulltang 1980
Norwegian spring-spawning herring	*Clupea harengus*	Ulltang 1980
Georges Bank herring	*Clupea harengus*	Beddington 1986
Lake Huron lake whitefish	*Coregonus clupeaformis*	Smith 1968, Holling 1973
Lake Erie lake herring	*Leucichthys artedi*	Smith 1968, Holling 1973
British Columbia pink salmon	*Oncorhynchus gorbuscha*	Neave 1953, Ricker 1954, Peterman 1977
Lake Michigan yellow perch	*Perca flavescens*	Wells 1977, Botsford 1981
Lake Windermere (England) perch	*Perca fluviatilis*	Le Cren et al. 1972, Holling 1973
Pacific sardine	*Sardinops caerulea*	Murphy 1977, Beddington 1986

Figure Captions

1) A generalized Beverton-Holt stock-recruitment curve, shown for various values of the parameter r_3. Limiting cases corresponding to $r_3=0$ and $r_3=\infty$ are shown, along with six intermediate cases corresponding to $r_3=0.5$, 1, 2, 4, 8, and 16. The parameter r_2 has been fixed at a value of 1.0.

2) An example of the stock-recruitment curve *R(B)* along with its first and second derivatives [*R'(B)* and *R"(B)*, respectively]. Values of the stock-recruitment parameters r_2 and r_3 used to generate the curves were $r_2=8.932$ and $r_3=4.204$. Maxima are indicated by the vertical dashed lines.

3) Multiple equilibria as defined by different values of the biomass-per-recruit ratio *u(F)*. As the value of *u(F)* increases, the threshold and pristine biomass levels become closer, finally converging when $u(F)=0.343$. Values of the stock-recruitment parameters r_2 and r_3 used to generate the curves were $r_2=8.932$ and $r_3=4.204$.

4) Ratio of threshold to pristine biomass, plotted as a function of the stock-recruitment parameter r_3. The curve corresponds to the solution of Equation (18) when the threshold is set equal to the third critical point of the stock-recruitment curve. The horizontal dashed line denotes the asymptote of the curve as r_3 approaches infinity.

5) Critical biomass-per-recruit ratio as a proportion of the pristine biomass-per-recruit ratio, plotted as a function of the stock-recruitment parameter r_3. By setting the threshold equal to the third critical point of the stock-recruitment curve, Equation (25) describes the curve shown here. The horizontal dashed line extending all the way across the figure denotes the asymptote of the curve as r_3 approaches infinity. The horizontal dashed line extending only part way across the figure denotes the maximum value of Equation (25). The vertical dashed line denotes the value of r_3 that maximizes Equation (25).

6) Parameter combinations (K'', the pristine ratio of growth to recruitment, and q, the Cushing stock-recruitment exponent) at which the ratio of biomass at maximum sustainable yield (B_{MSY}) to pristine biomass (B_p) is 0.2 (solid curve). This locus is bounded by the values $K''=5$ and $q=0.353$. Also shown are parameter combinations at which the the fishing mortality rate (F) at maximum sustainable yield corresponds to fixed multiples (1.0, 1.5, and 2.0) of the natural mortality rate (M).

7) The ratio between yield (Y) at the suggested threshold (20% of pristine biomass, B_p) and maximum sustainable yield (MSY). The dashed lines indicate the parameter values at which the threshold corresponds to the biomass level (B) at MSY.

a) Relative yield when the pristine growth-to-recruitment ratio K'' is zero and the Cushing stock-recruitment exponent q is allowed to vary.

b) Relative yield when q is zero and K'' is allowed to vary.

8) Parameter combinations at which the fishing mortality rate at maximum sustainable yield sets the biomass-per-recruit ratio equal to three constant proportions (α) of its pristine value (0.2, 0.3, and 0.4). The vertical dashed lines indicate asymptotes for $\alpha=0.3$ and $\alpha=0.4$.

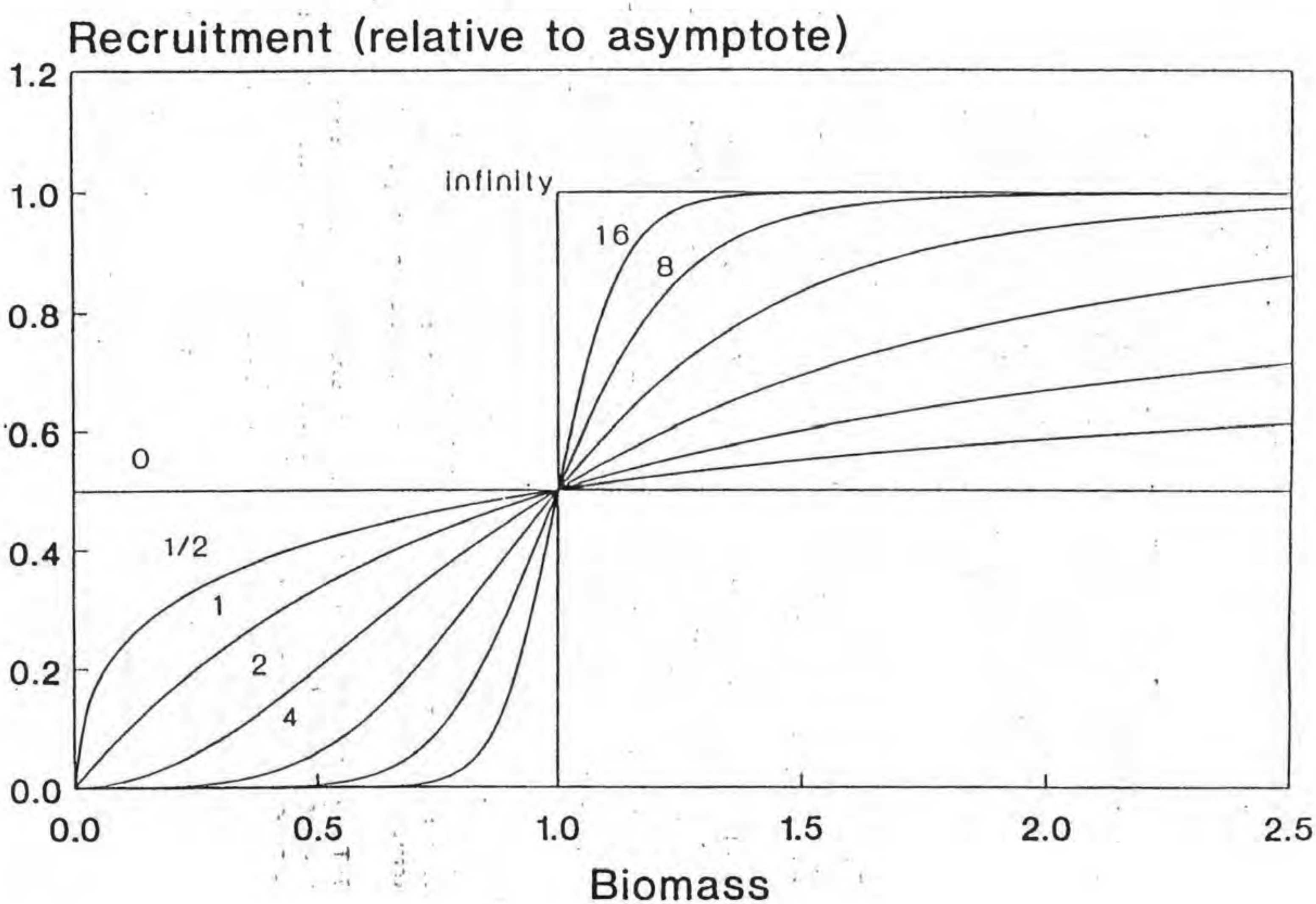
Recruitment (relative to asymptote)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
infinity
16
8
0
1/2
1
2
4
0.0
0.5
1.0
1.5
2.0
2.5
Biomass

Figure 1.

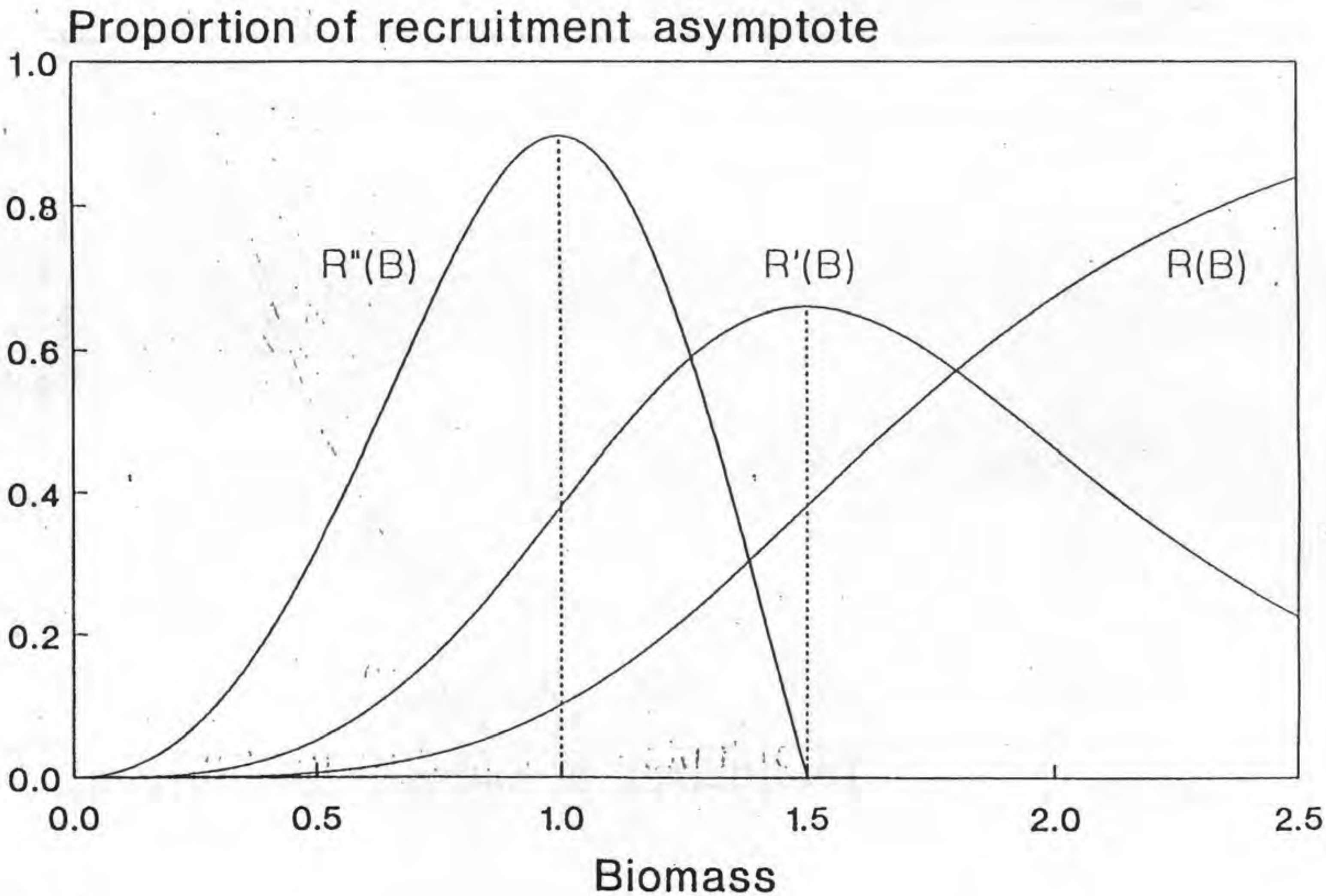
Proportion of recruitment asymptote
1.0
0.8
0.6
0.4
0.2
0.0
R"(B)
R'(B)
R(B)
0.0
0.5
1.0
1.5
2.0
2.5
Biomass

Figure 2.

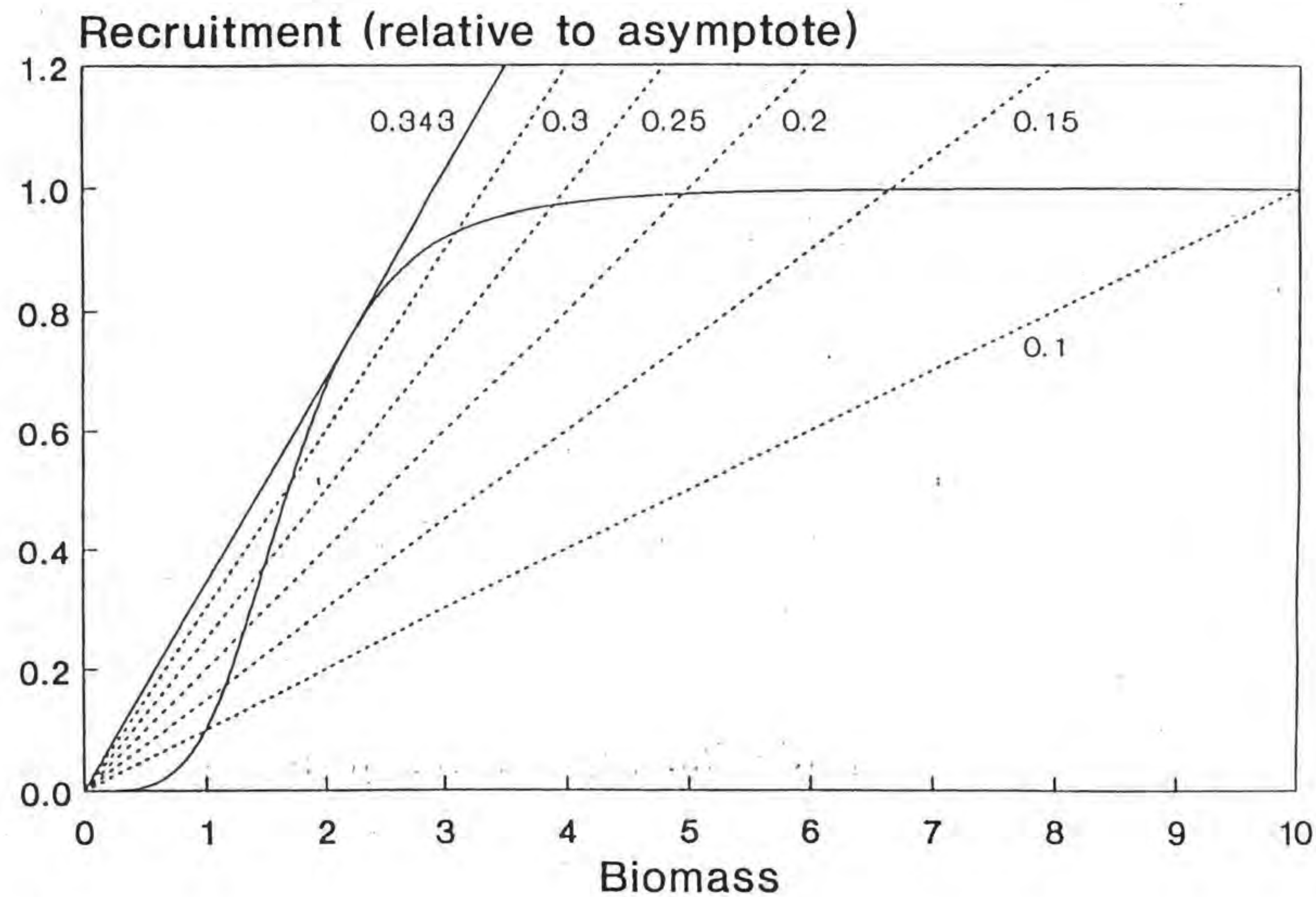
Recruitment (relative to asymptote)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.343
0.3
0.25
0.2
0.15
0.1
0
1
2
3
4
5
6
7
8
9
10
Biomass

Figure 3.

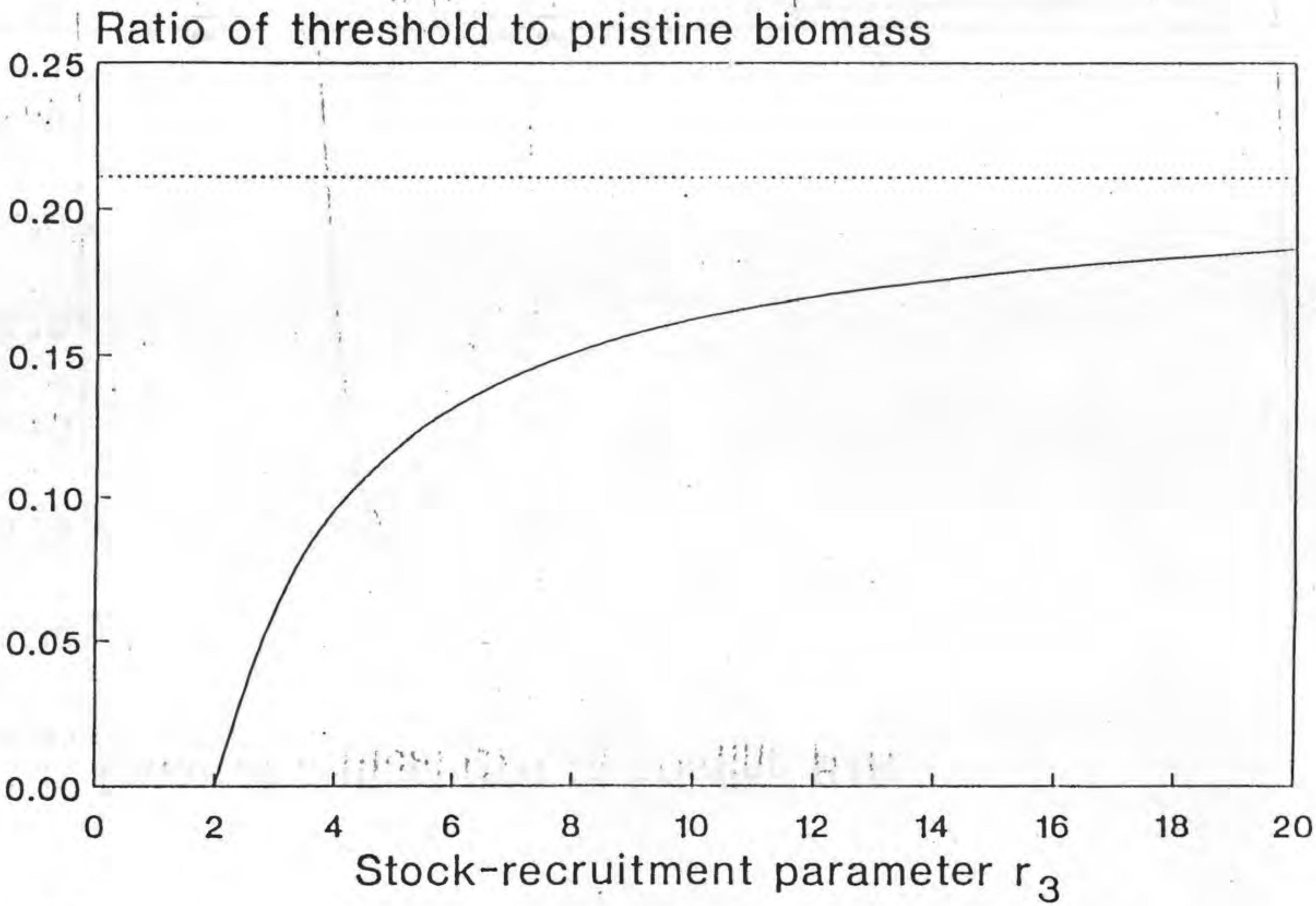
Ratio of threshold to pristine biomass
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14
16
18
20
Stock-recruitment parameter r3

Figure 4.

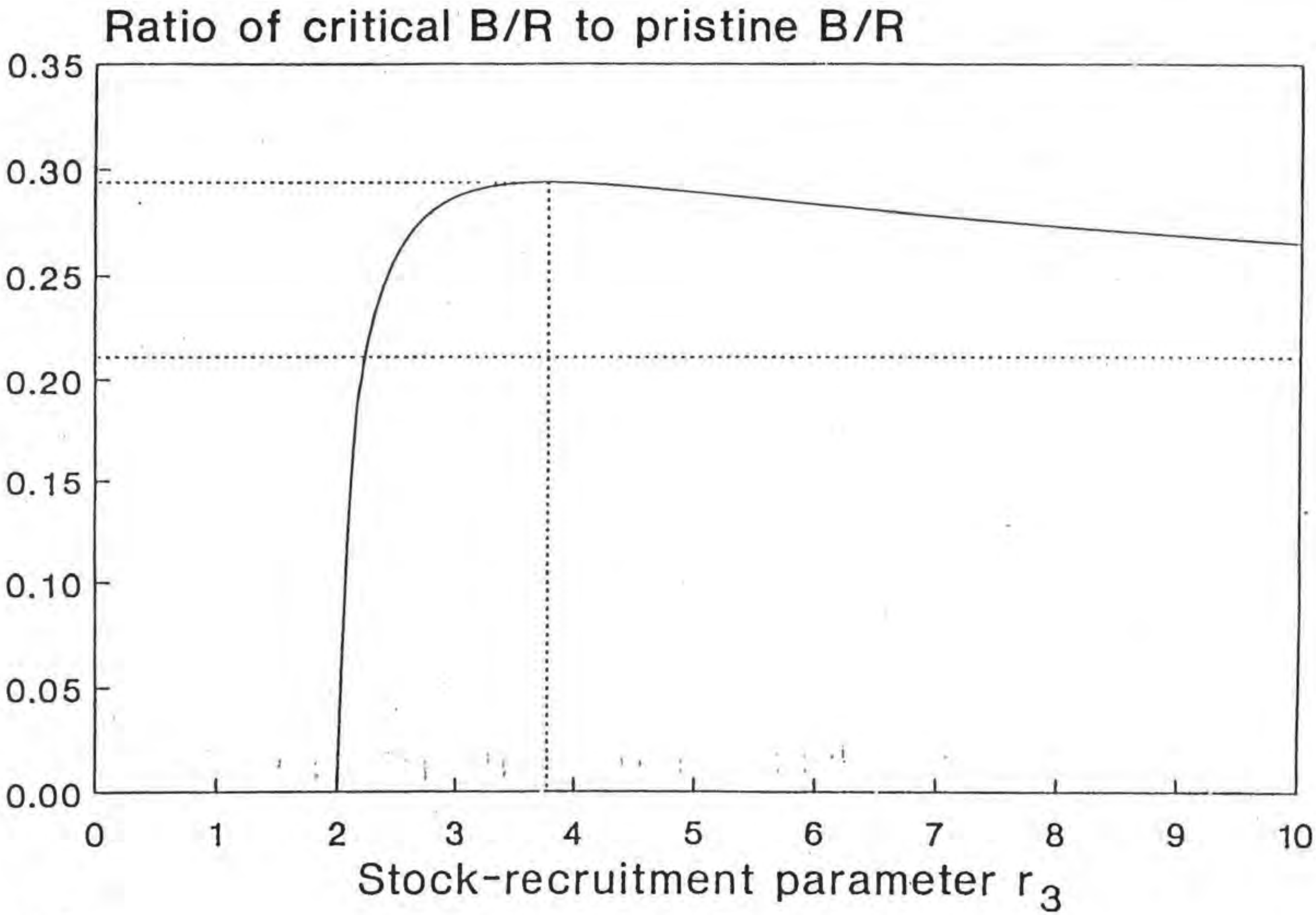
Ratio of critical B/R to pristine B/R
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
10
Stock-recruitment parameter r3

Figure 5.

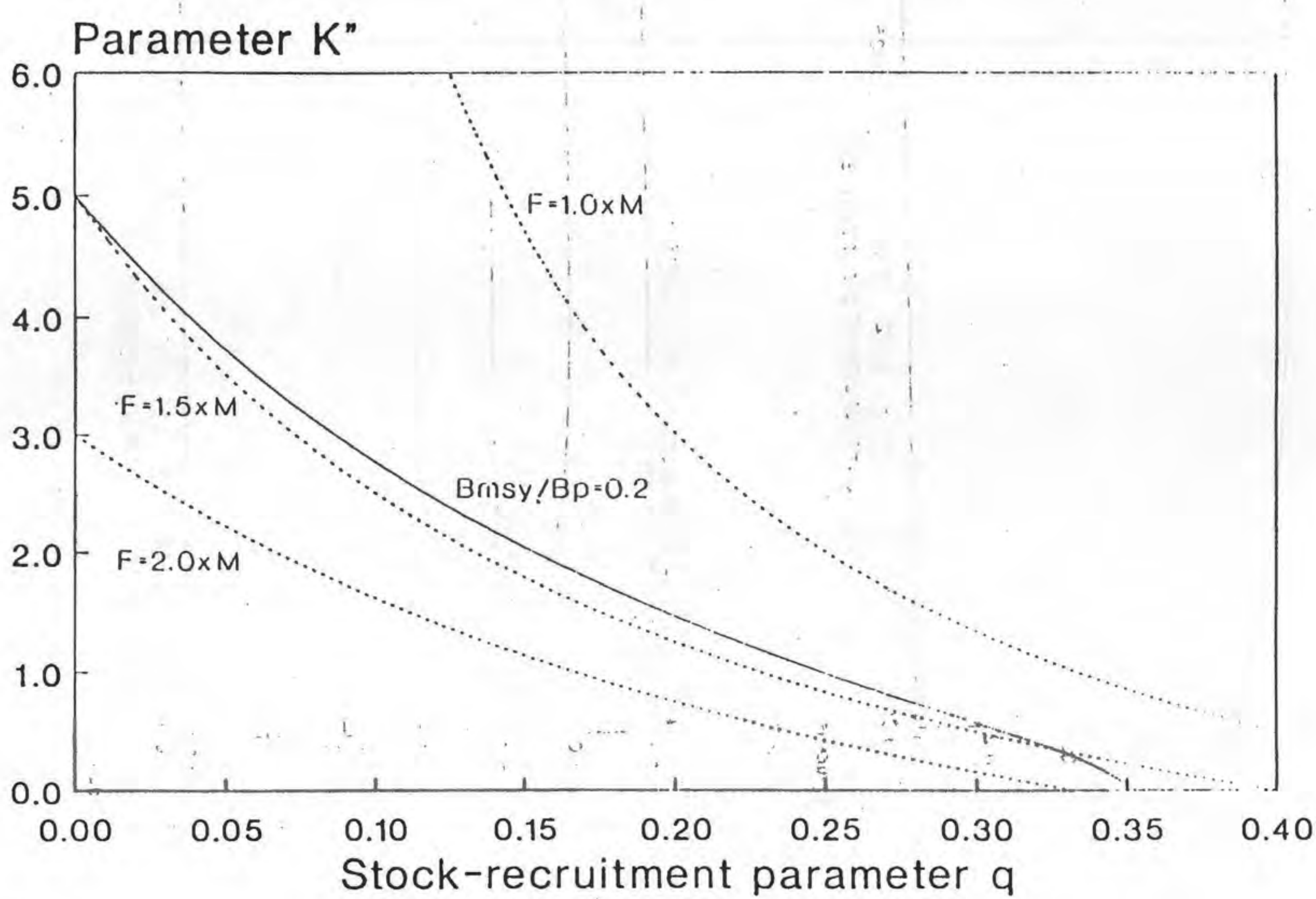
Parameter K"
6.0
5.0
4.0
3.0
2.0
1.0
0.0
F=1.0xM
F=1.5xM
Bmsy/Bp=0.2
F=2.0xM
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Stock-recruitment parameter q

Figure 6.

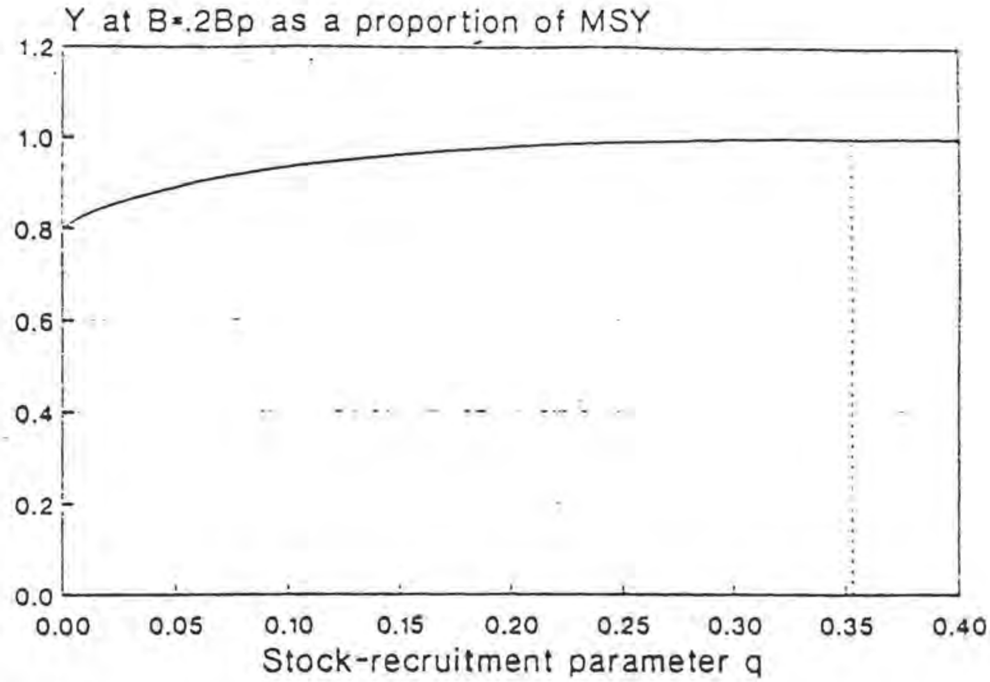

Figure 7a.

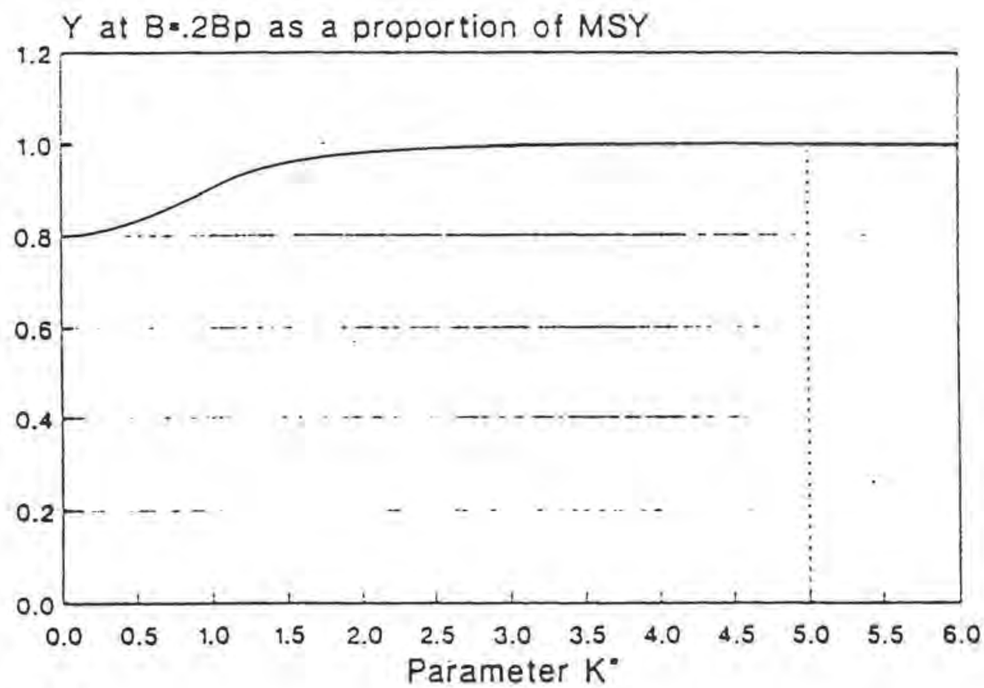

Figure 7b.

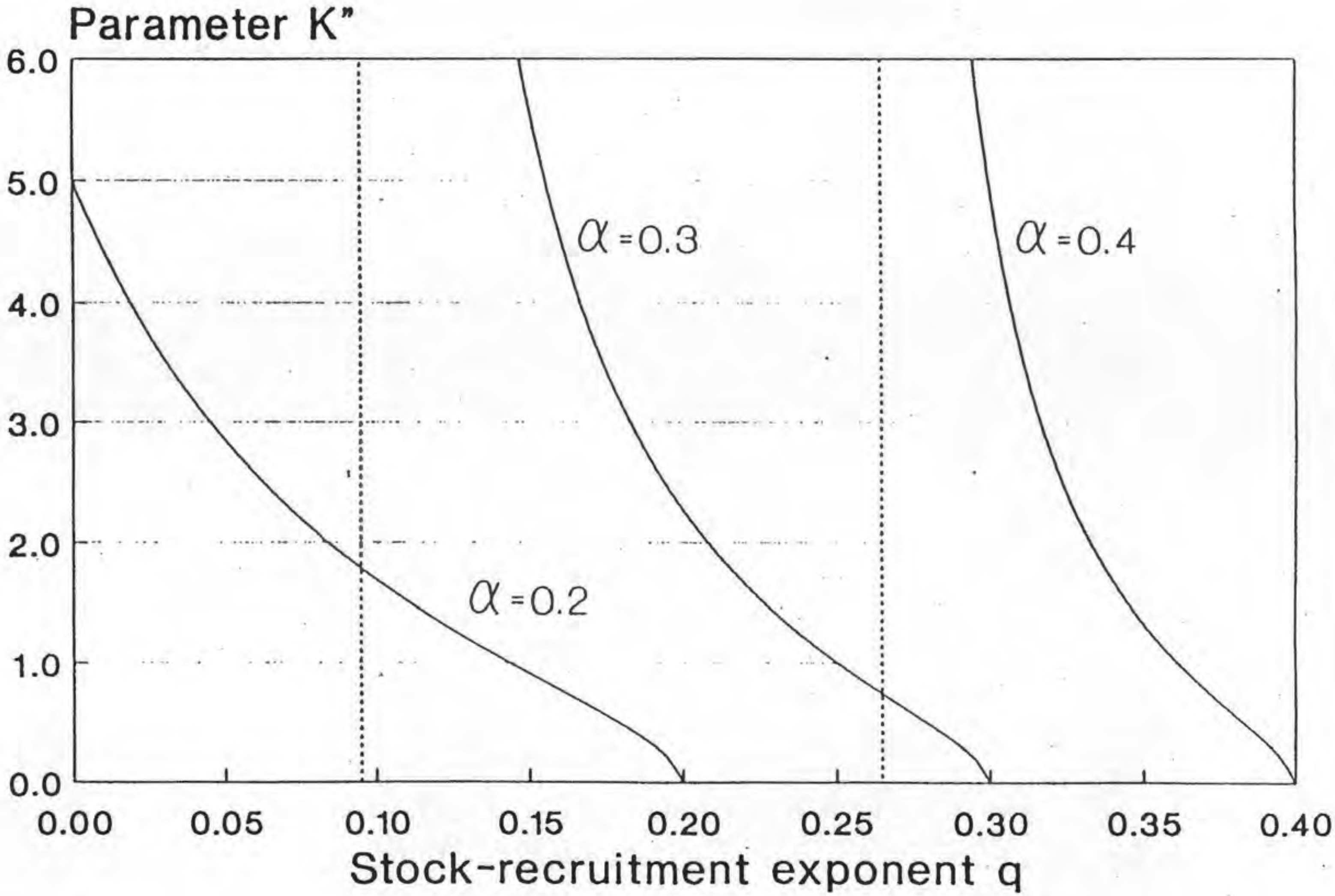
Parameter K"
6.0
5.0
4.0
3.0
2.0
1.0
0.0
α=0.2
α=0.3
α=0.4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Stock-recruitment exponent q

Figure 8.

3.A.2 Appendix II: Simulation of Stock and Harvest Dynamics Under Four Alternatives

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A stochastic fishery model was constructed to examine the relative impacts of the alternatives listed in Section 3.3. Technical specifications of the model were as follow: Basic stock dynamics were modeled according to the delay-difference equation of Deriso (1980, generalized by Schnute 1985), with a Beverton-Holt stock-recruitment relationship. Two series of simulations were performed, differing in the type of error structure assumed for the stock-recruitment relationship. One series of simulations incorporated a lognormal error term, and the other incorporated a uniform error term. The delay-difference equation was corrected to allow for continuous harvest as suggested by Thompson (1989). Values used for life-history parameters were those of the "typical" groundfish described by Clark (1990). The stock-recruitment relationship was parametrized to give 90% of pristine recruitment when biomass was reduced to 50% of the pristine level. Under these assumptions and parameter values, B_{MSY} is about 29% of pristine biomass.

The model was used to simulate stock and harvest dynamics under Alternatives 3, 4, 5, and 6. Alternatives 1, 2, and 7 were not explicitly included in the simulations because the Council already tends to treat F_{MSY} as an upper limit to fishing mortality, meaning that (in practice) Alternatives 1, 2, and 7 behave the same as Alternatives 3, 5, and 6, respectively. To examine the effects of increasing stochasticity, the magnitudes of the error terms were varied in a systematic fashion. For the series of simulations that used lognormal error, the standard deviation of the error term was increased from 0 to 1 in increments of 0.01 units. For the series of simulations that used uniform error, the maximum relative error was increased in the same pattern. In the uniform distribution, standard deviation of the error (SDE) is related to maximum relative error (MRE) by the following equation:

$$SDE = \left[\frac{2(MRE^3)}{3}\right]^{1/2}.$$

To give an idea of how the stock-recruitment relationship behaves under these alternative error assumptions, Figures 1a and 1b show the basic stock-recruitment curve along with 95% confidence intervals for three of the 101 different levels of stochasticity.

For type of error and each level of stochasticity, the fishery was simulated for 100 years under each alternative, and 100 such simulations were conducted. The stock was assumed to be in equilibrium at B_{MSY} at the start of each simulation, and the upper limit of fishing mortality (as defined for each alternative) was applied in every year. (Note: the upper limit of fishing mortality was applied because each alternative examined is at least as conservative as the Council's de facto target strategy of harvesting at F_{MSY}, not because the alternatives themselves supply a target harvest strategy.)

In terms of long-term average yield, Figures 2a and 2b show the results for Alternatives 4, 5, and 6 as proportions of the results for Alternative 3. Figure 2a shows the results for the series of simulations using lognormal error, and Figure 2b shows the results for the series of simulations using uniform error. Alternative 3, as the standard, is given a value of 1 for each level of stochasticity. Alternative 5 comes the closest to matching this standard, with identical results when the magnitude of the error term is small. Alternative 4 fares the next best, actually catching up with Alternative 5 when the magnitude of the error term becomes large. Alternative 6 fares the worst, particularly under the uniform error structure. However, it should be emphasized that all four alternatives are extremely close, as indicated by the scaling of the vertical axes. In no case does any of the alternatives give a long-term average yield less than 98% of the long-term average yield obtained with Alternative 3.

The differences shown in Figures 3a and 3b are more significant. These figures show the standard deviation of yield under the four alternatives (again, scaled relative to Alternative 3). As in Figures 2a and 2b, Alternative 3 performs the best. When the magnitude of the error term is small, Alternative 3 is followed in order by Alternatives 5, 4, and 6. However, when the magnitude of the error term becomes sufficiently large, Alternative 4 catches up with Alternative 5 in the lognormal case, and surpasses Alternative 5 in the uniform case.

Considering Figures 2 and 3 together, it can be seen that if the Council's objective function is a weighted combination of long-term average yield and standard deviation of yield, and if the magnitude of the error term is sufficiently small, the ranking of the four alternatives is unambiguous in terms of the "typical" stock examined here (the ranking would be 3, 5, 4, 6). On the other hand, if the magnitude of the error term is large, Alternative 4 might be preferable to Alternative 5, depending on the type of error structure and the relative weights that the Council assigns to average yield and standard deviation of yield.

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Schnute, J.
1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42:414-429.

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1989. Incorporating continuous harvest into the delay-difference model. Unpubl. manuscr., 11 p. Alaska Fish. Science Cent., 7600 Sand Point Way NE., Seattle, WA 98115.

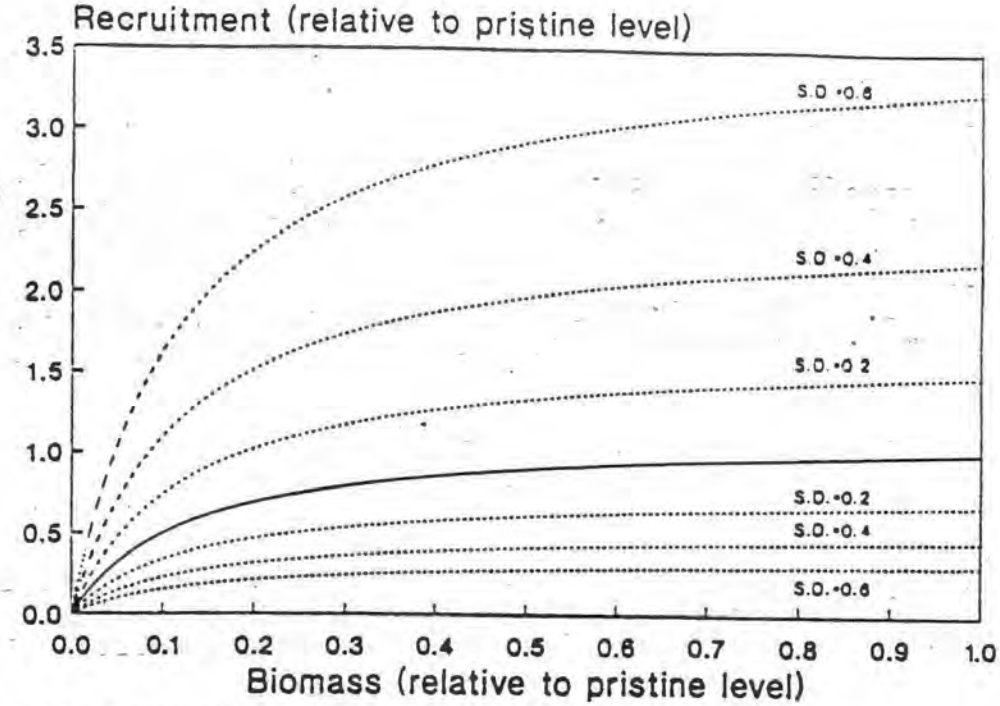

Figure 1a. Lognormal error

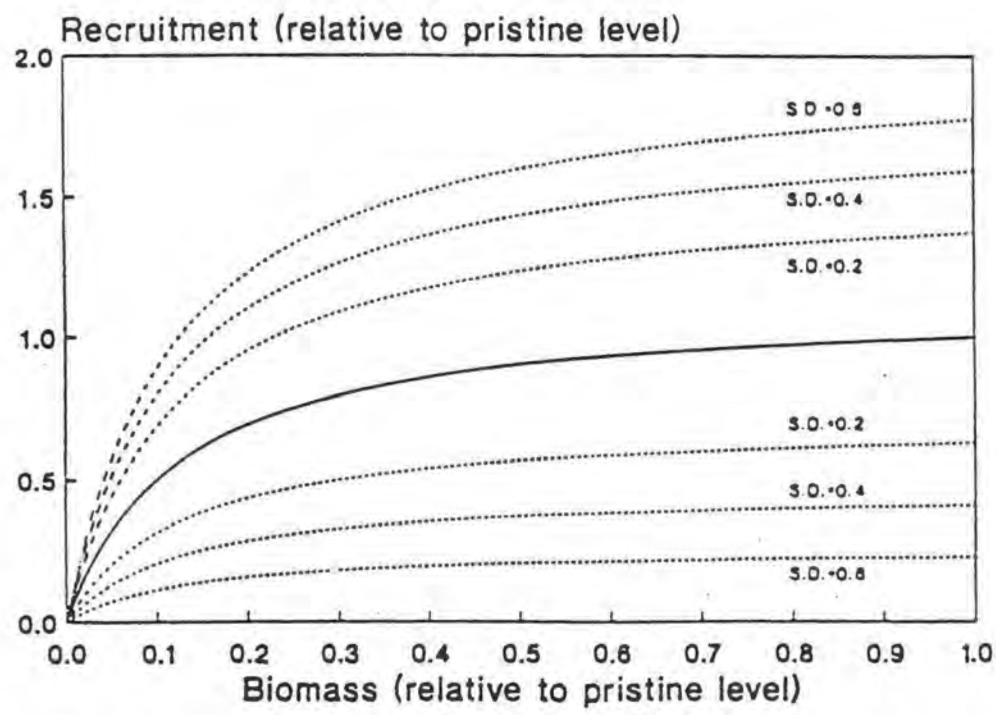

Figure 1b. Uniform error

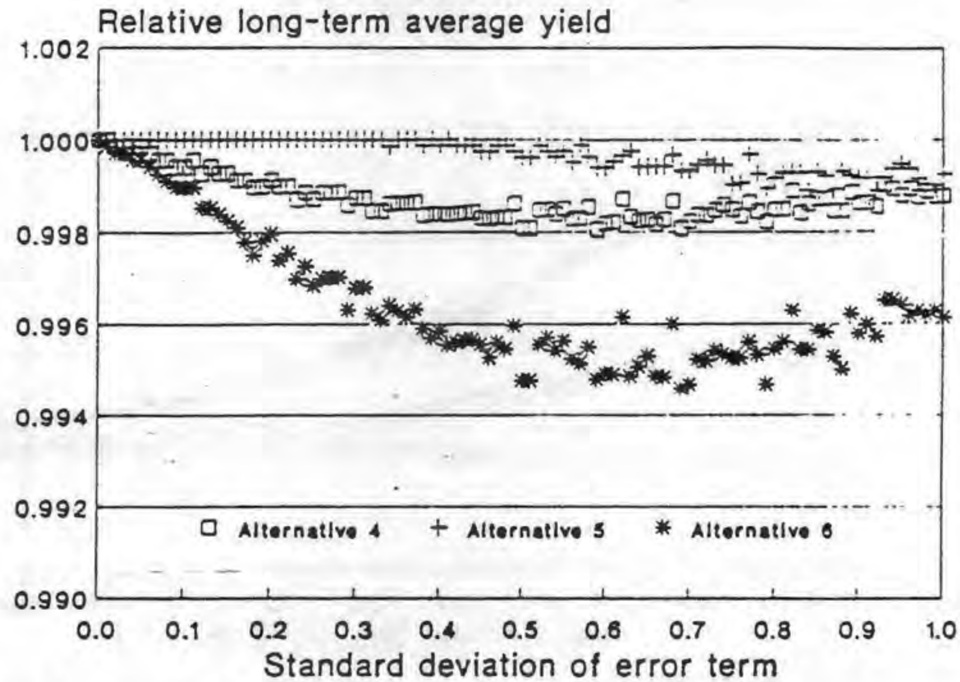

Figure 2a. Lognormal error

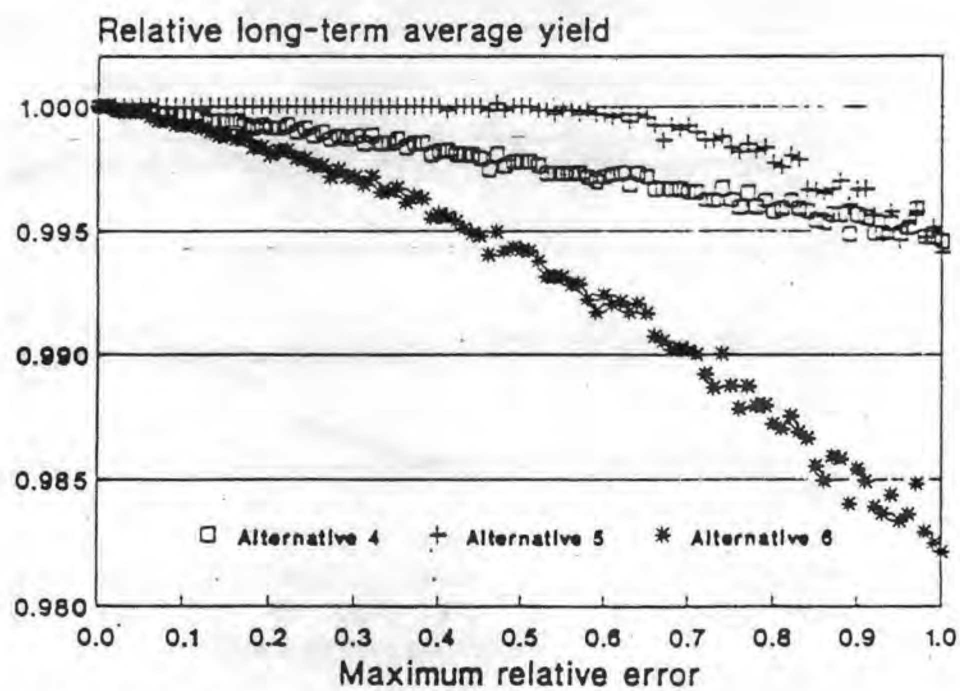

Figure 2b. Uniform error

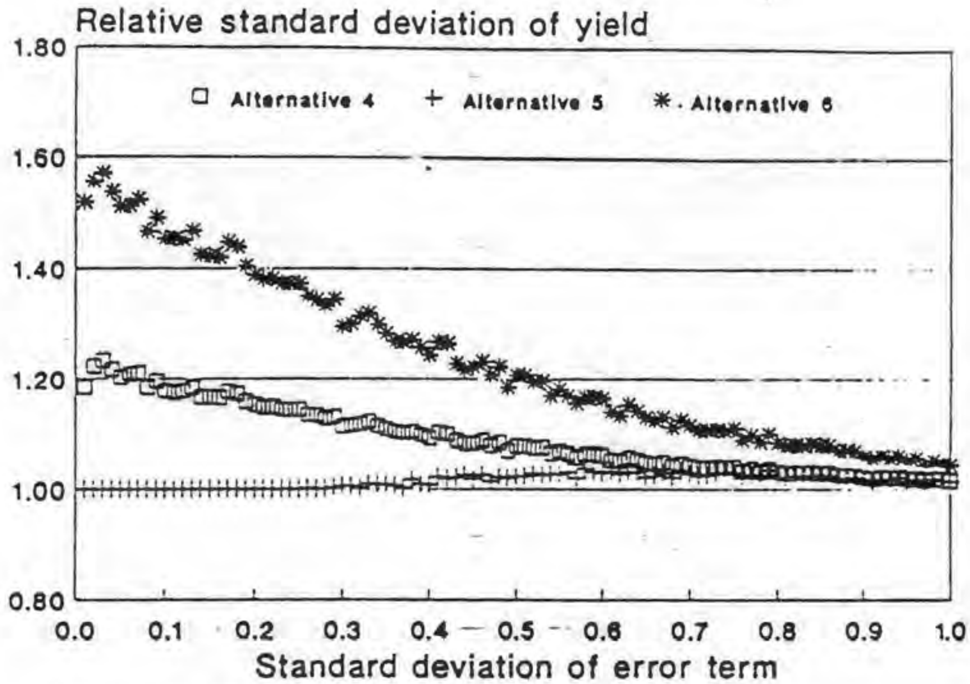

Figure 3a. Lognormal error

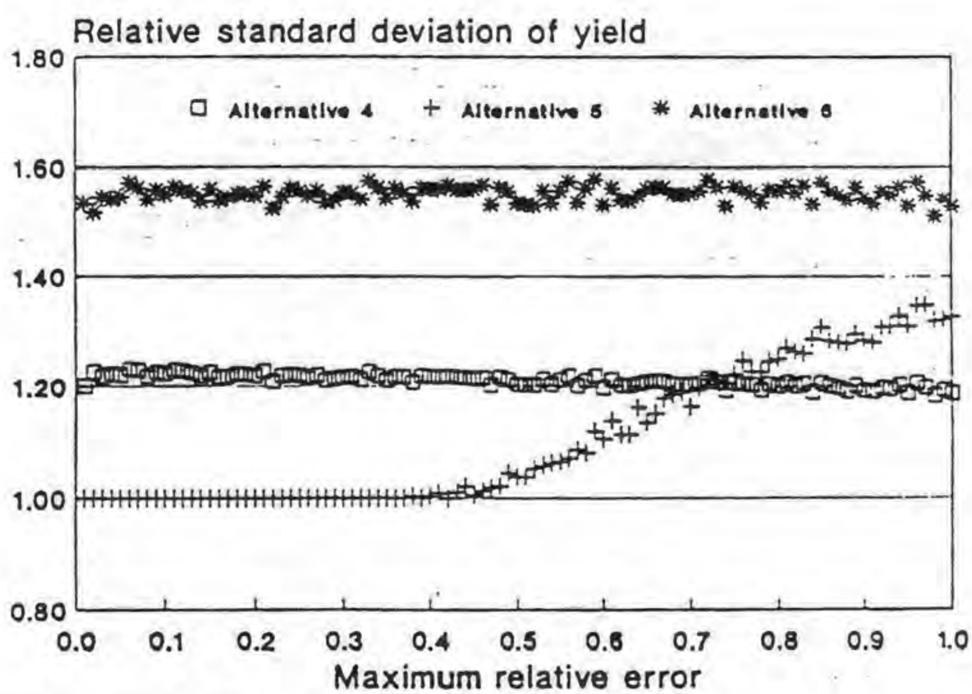

Figure 3b. Uniform error

3.A.3 Appendix III: A Comparison of Five Harvest Policies Applied to Sablefish in Alaskan Waters

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Introduction

Three variable rate harvest policies and two constant rate harvest policies are compared in a simulation of the management of sablefish. The simulation utilizes the model currently applied in the management of the sablefish stocks of the Gulf of Alaska, Bering Sea and Aleutian Islands. The model is biomass based and utilizes the Schnute delay difference equation as applied by Kimura (1985) in stock reduction analysis. Averages of yield, biomass, and fishing rate, standard deviations of yield and biomass, minimum biomass, and percentage of time population is below the all time observed low level are the values compared.

Three sources of uncertainty are incorporated in the study. Annual recruitment is considered independent of biomass and is sampled randomly from a set of previous recruitment estimates. Hypothetical bias and random error in the biomass estimate used to compute recommended harvest are added to the simulation.

Methods

The simulation consists of a population model, which represents the "true" population, and a management model which is the perception or estimate of the population model. Both are delay difference models as described by Kimura (1985) and are applied as in the 1989 SAFE documents for the Bering Sea-Aleutian Islands sablefish and the Gulf of Alaska sablefish. The parameters for growth, natural mortality, and age of recruitment are the same as in the SAFE documents. F_{max} and $F_{0.1}$ are 0.43 and 0.13 respectively. The population model is projected forward from 1989 a year at a time where recruitment for each projected year is randomly chosen from the 11 values calculated for the years 1979 to 1989. Annual biomass from the population model is input with a consistent error and a random error to the management model . The management model computes, for the following year, a recommended harvest, which is then input to the population model. The population model is projected another year and the process repeated for 400 years.

Yield results and population response are measured and the projection is repeated again with a different random seed 3 times. The same random seeds for the random recruitment and the biomass estimate error are used to compare the three harvest policies.

Population Model

The population model biomass is scaled to one half of the 1984 estimate. This scale is hypothetically set low to reflect the possibility that the trawl doors herd fish into the survey nets and that density of fish may be higher in trawlable areas than in untrawlable areas. These factors would cause the biomass estimate to be over optimistic. At this scale population biomass ranged from a low of 91,000 mt in 1980 to a high of 244,000 mt in 1985, and was at 224,000 mt at the beginning of 1989.

The computed recruitment for 1979 to 1989 under the half scale averaged 29,600 mt and ranged from 3,340 mt to 87,800 mt. Equilibrium yield at F_{max} and at $F_{0.1}$ equals 30,340 mt and 26,335 mt respectively.

Management Model

In the management model, the biomass, B_t, is estimated from the "true" biomass from the population model with a consistent 2X fold error plus a uniformly distributed random error of plus or minus 10%. Ie, $B_t = B_{t,true} \cdot 2 \cdot E_t$, where E is a uniformly distributed random variable from .9 to 1.1. The scale of B_t is equivalent to the 1984 GOA trawl survey biomass and lies between the range of scales given in the SAFE documents. This scale indicates that the population increased from a low of 180,000 mt in 1980, peaked at 484,000 mt in 1985, and was at 437,000 mt in 1989.

The management model estimate of annual recruitment for 1979 to 1989, ranged from 0[1] mt to 163,000 mt and averaged 40,540 mt. Equilibrium yield and biomass at F_{max} equals 41,600 mt and 124,000 mt respectively. Equilibrium yield and biomass at $F_{0.1}$ would equal 36,000 mt and 312,000 mt respectively.

Harvest Policies

The harvest policies applied here can be generalized from a formula found in Ruppert et al (1985), where the recommended catch equals:

$$C_t = G_t \cdot (B_t - T)^q \qquad (1)$$

where B_t is the estimated exploitable biomass level, T is a biomass level below which C would be zero and the exponent q is set equal to 1.0. This study sets T at the estimated 1980

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[1] A negative value actually is computed on two occasions, however, a zero is used as the estimate and the modeled population does not reach as low a level for those years as the longline survey had indicated.

biomass level, the historic measured low observed for Alaskan sablefish stocks, and attempts to manage the population at the $B_{0.1}$ level, thus substituting:

$$B_{MSY} = B_{0.1}, \text{ and } U_{MSY} = U_{0.1} \qquad (2)$$

Five policies are compared (note--for convenience in reference to the Overfishing Definition EA/RIR, that eqs 3 thru 7 define policies approximately equivalent to Alternatives 3 thru 7, respectively, in the EA/RIR):

A Constant Exploitation Rate policy, which is obtained by setting T equal to zero and G_t a constant equal to

$$G = U_{MSY} \qquad (3)$$

A Variable Exploitation Rate policy, is computed by setting T=0 and G_t equal to:

$$G_t = U_{MSY} \cdot B_t / B_{MSY} \quad \text{for } B_t < B_{MSY} \qquad (4a)$$

$$G_t = U_{MSY} \quad \text{for } B_t => B_{MSY} \qquad (4b)$$

A Constant Exploitation Rate with Threshold policy, is obtained by setting:

$$G = U_{MSY} / (B_t - T) \quad \text{for } B_t > T \qquad (5a)$$

$$G = 0 \quad \text{for } B_t <= T \qquad (5b)$$

A Variable Exploitation Rate with Threshold policy, where G_t is set to:

$$G = U_{MSY} \cdot B_{MSY} / (B_{MSY} - T) \quad \text{for } T < B_t < B_{MSY} \qquad (6a)$$

$$G = 0 \quad \text{for } B_t < T \qquad (6b)$$

$$G = U_{MSY} / (B_t - T) \quad \text{for } B_t > B_{MSY} \qquad (6c)$$

A second Variable Exploitation Rate with Threshold policy is obtained by setting G_t to:

$$G = U_{MSY} \cdot B_{MSY} / (B_{MSY} - T) \quad \text{for } B_t > T \qquad (7a)$$

$$G = 0 \quad \text{for } B_t < T \qquad (7b)$$

Recommended catch in relation to biomass is shown for these policies in figure 1. At B_{MSY} the recommended catch is $U_{MSY} \cdot B_{MSY}$ for all policies, while below B_{MSY} the catch decreases linearly to zero at $B_t = 0$ for the constant rate policy (eq. 3), and linearly to zero at $B_t = T$ for the variable exploitation rate with threshold policies (eqs. 6 and 7)[2]. In the constant rate with threshold policy (eq. 5), the catch decreases proportionately with B_t, but is set to zero when $B_t < T$. In the variable exploitation rate policy (eq. 4), the exploitation rate decreases linearly to zero at $B_t = 0$, and remains constant at U_{MSY} for B_t above B_{MSY}. The difference in the two variable rate with threshold polices, is the rate at which catch increases when $B_t > B_{MSY}$. In eq. 7, the catch increases in a greater proportion than does the biomass, while in the first policy the catch is in proportion to the biomass.

Prediction of B_t

In practice, the C_t is decided upon during year t-1 and B_t must be predicted. $B_{t,predicted}$ is obtained using the delay difference equation, given a guess of recruitment for year t.

$$B_{t,predicted} = x_{t-1} \cdot B_{t-1} - y_{t-1,t-2} \cdot B_{t-2} - z_{t-1} \cdot \dot{R}_{t-1} + R_{guess}. \qquad (8)$$

R_{guess} is set equal to zero to be conservative. The x, y, and z coefficients contain growth and mortality as appropriate in the delay difference equations. Recruitment at time t-1 is estimated as the estimated biomass at time t-1 less biomass in existence the previous year projected to time t-1, i.e.:

$$\dot{R}_{t-1} = B_{t-1} - B_{t-1,predicted} + R_{guess} \qquad (9)$$

$$\dot{R}_{t-1} = 0 \text{ if } B_{t-1,predicted} > B_{t-1} + R_{guess} \qquad (10)$$

Results

The averages and standard deviations of catch and biomass, the minimum biomass, the proportion of time the biomass was below the 1980 biomass level, average fishing mortality rate, and relative catch per effort are shown for the five harvest policies in table 1. Each comparison is repeated 4 times. Biomass is expressed in the assumed scale in all cases, where the "true" population size is equal to half the assumed scale.

Biomass Response

Compared to the constant rate policies (eqs. 3 and 5) the variable rate policies (eqs. 4, 6, and 7) provide greater protection to the population. Under the constant rate policy (eq. 3) the biomass dropped as low as 92,000 mt, barely half of the all time measured low of 180,000 mt observed in 1980. The lowest biomass levels reached under the variable rate policies were 53, 78 and 75 percent higher, respectively for eqs. 4, 6, and 7, than the level reached under the constant rate policy (eq. 3). The lowest biomass level reached under the constant rate

[2] In this analysis the F is set at .01 for $B_t < T$ in the policies with thresholds (eqs. 5,6, and 7).

with threshold policy (eq. 5) was 30 percent greater than under eq. 3.

The probability of being below the 1980 biomass would be less under the variable rate policies than under the constant rate policies. At no time using the variable rate with threshold policies (eqs. 6 and 7) did the population drop below that level. The population dropped below only 1 percent of the time under the variable rate without threshold policy (eq. 4), and dropped below the 1980 level 3.7 and 9.2 percent of the time under the constant rate policies with and without a threshold, respectively.

The average biomass level for the variable rate policies were higher than for the constant rate polices. Average biomass was 10.8, 16.5, 11.6, and 5.7 percent greater for eqs. 4, 6, 7, and 5 respectively, than for eq. 3.

The variability of the population was slightly higher under the constant fishing rate policies compared to the variable rate policies.

Yield

There is little measurable difference in the long term yield between all five harvest policies. The lowest average yield which occurred under a variable rate with threshold policy (eq. 6) was only 3 percent less than the highest average yield which occurred under the constant rate policy (eq. 3).

Annual harvest varied least under the constant rate policy (eq. 3) and varied the most under the variable rate with threshold policy (eq. 7).

Fishing Mortality/Catch per Effort

The average of the instantaneous fishing mortality rate necessary to catch the recommended catch, was lowest under the variable rate policies and highest in the constant rate policies. The average catch per average effort under a variable rate with threshold policy (eq. 6) was 23 per cent greater than under the constant rate policy (eq. 3).

Discussion

Recruitment Uncertainty

Little is known about the recruitment of sablefish. Since the late 70's we have estimates of recruitment, which appears to have no relationship to stock size. We therefore estimate long term yield expectations as if recruitment is independent of stock size and simulate future populations using randomly resampled values from observed recruitment estimates. However, we do not have estimates of recruitment from stock sizes less than the level measured in 1980, when the population index was about 38%

of current values and therefore do not know if the recruitment assumption is valid below that level.

Not only don't we have recruitment estimates from stock levels below the 1980 level, we don't have estimates or indices of stock size below that level. Nor do we even know if the population had ever been lower than the 1980 level and therefore, cannot say for certain whether the population had ever recovered from levels that low. Although we might suspect that it had, or could, we know nothing about the time or ecological circumstances necessary to recover.

Biomass Uncertainty

While annual longline surveys of sablefish stocks in Alaskan waters provide relative abundance measurements which are considered reliable, area swept estimates of absolute biomass from trawl surveys are difficult to defend. Area swept estimates assume that any fish that are herded into the net path by the trawl doors and cables are balanced by fish that escape the path of the net. Observations of catch rate from trawlable habitat are extrapolated over untrawlable habitat which may have quite different fish densities. The risk of overfishing is greater if our assumed biomass is greater than the true biomass. This uncertainty is reflected in the hypothetical bias in the biomass estimate simulated in this study.

Prevention of Overfishing

Since we have no information of how recruitment might be affected or how sablefish population dynamics might be altered by population levels below the 1980 level, the prudent strategy is to reduce the occurrences and extent to which the population drops below that level. So long as the biomass remains above that level, we needn't be concerned that, at some lower level, the stock-recruitment relationship might be depensatory, or that grenadiers will take over sablefish habitat left vacant.

I suggest that to decrease the probability of overfishing of sablefish we should decrease P, the proportion of time the population is below the 1980 level, and decrease the amount which the biomass drops below the 1980 level. The results of this study indicate that this can done without any measurable decrease in long term average catch by using a variable fishing rate with a threshold in place of a constant fishing rate policy. This would not only result in a smaller P and a larger minimum biomass, but a larger average biomass, an average catch that is only very slightly smaller, and greater catch per effort. The only possible disadvantage of the sliding scale policy is that the catch will be more variable as the fishing rate responds to changes in population level.

The above discussion suggests reasonable strategies to avoid overfishing without actually defining it, or saying when it will occur. Implied in the strategies is that overfishing could occur if the biomass drops below the biomass level observed in 1980. The 1980 biomass level is an objective and measurable value and could be treated as a threshold, but it is difficult to defend as the true threshold biomass. The absence of this parameter in the variable rate policy without a threshold (eq. 4), would avoid the question of whether any biomass level needs to be proven as a true threshold before it could be used in an overfishing definition for sablefish in Alaskan waters.

The variable rate fishing policies are measurable and objective formulae designed to ensure the maintenance of the stock's productive capacity. They are defined in a way to enable evaluation of the condition of the stock relative to the definition. As applied in this example some appropriate considerations of risk and uncertainties have been taken into account. The variable rate policies provide courses of action for a range of stock conditions.

Literature Cited

Kimura, D. K. 1985. Changes to stock reduction analysis indicated by Schnute's general theory. Can. J. Fish. Aquat. Sci. 42:2059-2060.

Ruppert, D., et al. 1985. A stochastic population model for managing the Atlantic menhaden. Can. J. Fish. Aquat. Sci. 42:1371-1379.

Table 1. Catch and biomass results (1,000 mt.) of five harvest policies compared under four random recruitment sequences. P is proportion of time biomass is below all time measured low. F is instantaneous fishing mortality rate.

Constant Rate (eq. 3):

	Catch		Biomass					
seq	ave	S.D.	ave	S.D.	min	P	F	C/F
1	28.4	9.62	284	84	127	0.100	0.239	118.9
2	29.4	10.22	294	91	102	0.090	0.239	122.9
3	31.3	9.79	313	86	92	0.060	0.239	130.8
4	27.9	10.12	278	90	114	0.118	0.239	116.5
avg.	29.2	9.94	292	87	109	0.092	0.239	122.3

Variable Rate (eq. 4):

	Catch		Biomass					
seq	ave	S.D.	ave	S.D.	min	P	F	C/F
1	27.8	12.15	317	77	176	0.003	0.200	138.7
2	28.8	12.77	325	83	167	0.013	0.202	142.4
3	30.8	12.36	339	80	151	0.015	0.210	147.0
4	27.2	12.58	312	82	171	0.010	0.198	137.3
avg.	28.7	12.47	323	81	166	0.010	0.203	141.4

Constant Rate w/Threshold (eq. 5):

	Catch		Biomass					
seq	ave	S.D.	ave	S.D.	min	P	F	C/F
1	28.1	12.99	301	79	148	0.038	0.216	130.0
2	29.1	13.60	312	84	142	0.040	0.215	134.9
3	31.1	12.03	323	81	131	0.030	0.226	137.9
4	27.5	13.71	298	84	144	0.040	0.213	129.1
avg.	28.9	13.08	308	82	141	0.037	0.218	133.0

Variable $Rate_1$ w/Threshold (eq. 6):

	Catch		Biomass					
seq	ave	S.D.	ave	S.D.	min	P	F	C/F
1	27.4	14.78	334	75	205	0.000	0.185	148.4
2	28.5	15.29	342	80	189	0.000	0.187	152.2
3	30.5	14.60	353	78	188	0.000	0.197	154.9
4	26.8	15.18	330	79	194	0.000	0.182	147.4
avg.	28.3	14.96	340	78	194	0.000	0.188	150.7

Variable $Rate_2$ w/Threshold (eq. 7):

	Catch		Biomass					
seq	ave	S.D.	ave	S.D.	min	P	F	C/F
1	27.6	19.40	322	71	205	0.000	0.193	142.7
2	28.8	20.10	327	75	189	0.000	0.198	145.2
3	30.8	19.92	337	75	182	0.000	0.208	147.6
4	27.0	19.49	318	74	187	0.000	0.190	142.5
avg.	28.5	19.73	326	74	191	0.000	0.197	144.5

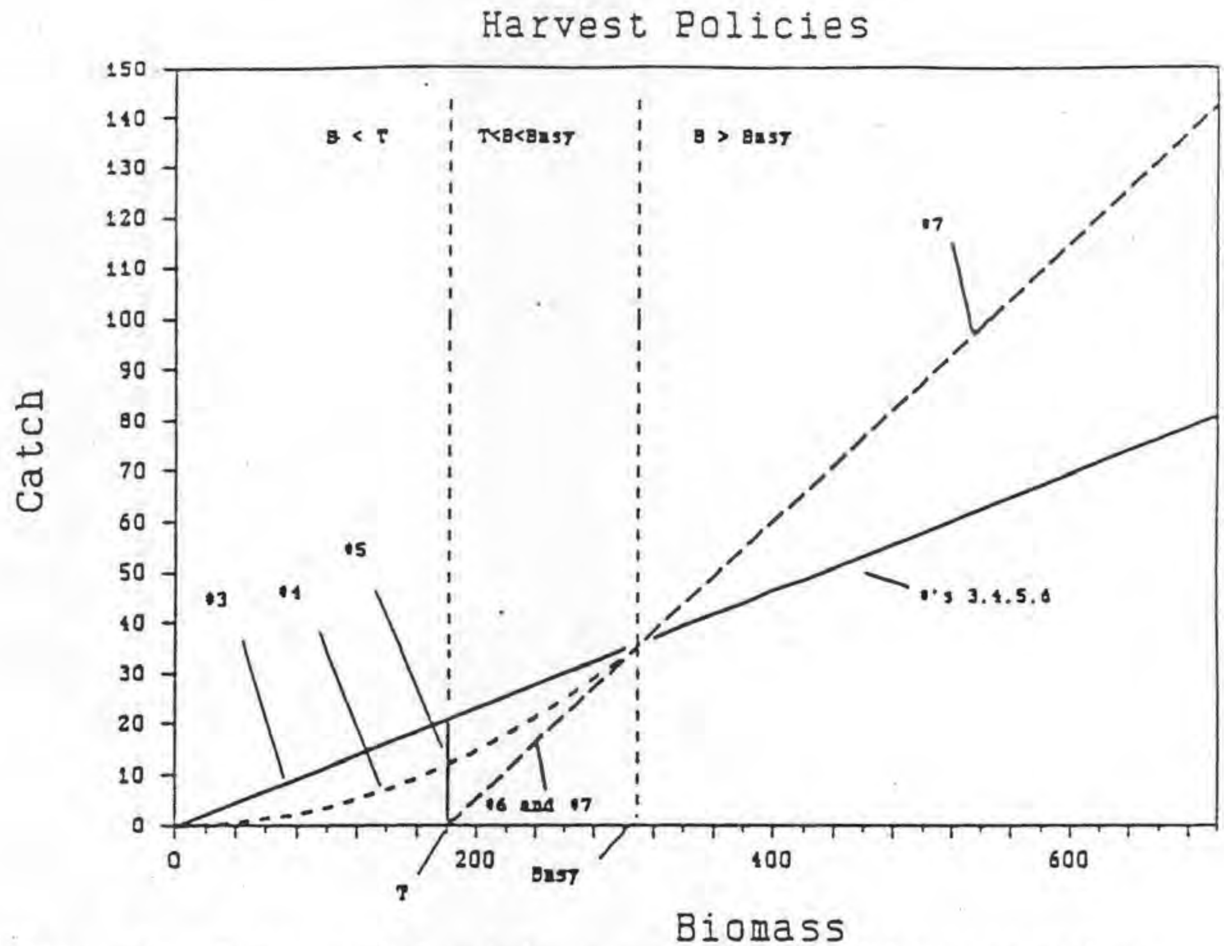

Figure 1. Recommended catch as a function of biomass under five harvest policies: constant rate (eq. 3); variable rate (eq. 4); constant rate w/threshold (eq. 5); variable $rate_1$ w/threshold (eq. 6); and variable $rate_2$ w/threshold (eq. 7).

4.0 ESTABLISH PROCEDURES FOR INTERIM TAC SPECIFICATIONS IN THE GULF OF ALASKA AND BERING SEA/ALEUTIAN ISLANDS

4.1 Description of the Problem and Need for the Action

Annual specifications of groundfish total allowable catches (TACs) and apportionments among user groups are based on the January 1 - December 31 calendar year. User groups may include U.S. fishermen catching/delivering to U.S. processors (domestic annual processing = DAP), U.S. fishermen delivering to foreign processors (joint venture processing = JVP), and foreign fishermen catching/delivering to foreign processors (TALFF). Procedures for establishing annual specifications of TACs are found in section 4.2.1.1 of the GOA FMP and section 11.3 of the BSAI FMP. Procedures in the GOA FMP differ from those in the BSAI FMP. The GOA FMP stipulates that annual TACs take effect for a fishing year on a date published in the FEDERAL REGISTER. The BSAI FMP is silent about an effective date for establishing annual TACs. FMP requirements notwithstanding, regulations implementing the GOA FMP stipulate that final TACs be published in the FEDERAL REGISTER on or about January 1 of each year. Regulations implementing the BSAI FMP stipulate that final TACs be published as soon as practicable after December 15 of each year.

The fishing year is the same as the January 1 - December 31 calendar year. Each specification expires when the fishing year terminates. During the fishing year, inseason management measures are implemented on the basis of current annual specifications for a current calendar year. Without annual specifications having been filed with the Office of the Federal Register, authority does not exist to allow enforcement of regulations, e.g. fishing area closures or directed fishing prohibitions.

Existing procedures require the Secretary to consider the record on which the Council has based its recommendations for establishing TACs, draft a final notice of initial specifications based on that record, obtain legal and policy review, and file the notice all during the period after the end of the December Council meeting, which is about 10 days.

Insufficient time is available during the period between the end of the December Council meeting and January 1 of a new fishing year for the NMFS, Alaska Region, to prepare, and the Secretary of Commerce to review and implement final TACs by publishing them in the Federal Register. For example, TACs were published in the FEDERAL REGISTER on the following dates in recent years:

GOA - January 4, 1985	GOA - January 14, 1988
BSAI - March 21, 1985	BSAI - January 14, 1988
GOA - January 9, 1986	GOA - February 13, 1989
BSAI - January 9, 1986	BSAI - January 25, 1989
GOA - January 9, 1987	GOA - January 31, 1990
BSAI - January 9, 1987	BSAI - January 16, 1990

These examples show that TACs are not made effective on January 1. The number of days that lapse from January 1 until the specifications are filed show the number of days during which no authority exists to manage the fishery. Strict interpretation of the FMPs suggests that fishing should not be allowed until TACs are published. The Secretary has heretofore not closed the groundfish fisheries during the hiatus in management authority in consideration of the overall public interest with respect to fishing opportunities that might be foregone during the hiatus, which is largely the fault of the bureaucracy. Should closures or inseason actions be necessary during the hiatus, however, authority would not be available to carry them out. Should action be necessary, the Secretary would have little recourse except to announce officially that the GOA and BSAI are closed until the specifications are made effective.

4.2 The Alternatives

4.2.1 Alternative 1: Do nothing - maintain the status quo

Under this alternative, no changes would be made to procedures used for establishing TAC specifications for groundfish species categories and apportionments thereof. Under these procedures, the Council provides recommendations to the Secretary following its September meeting about TAC specifications and apportionments among DAP, JVP, TALFF, and reserves. As soon as practicable after October 1, the Secretary publishes the proposed TAC specifications in the FEDERAL REGISTER and requests comments for 30 days. The Council considers all available information about proposed TAC specifications at its December meeting and makes final recommendations to the Secretary. The Secretary considers comments received and Council recommendations. The Secretary then makes a final decision about initial TAC specifications and publishes them in FEDERAL REGISTER. Initial TAC specifications become effective as soon as practicable after January 1 of a new fishing year. The hiatus, during which no enforcement action would be authorized, would continue each year.

4.2.2 Alternative 2: Extend proposed TAC specifications into a new fishing year as interim specifications, until changed.

Under this alternative, the proposed TAC specifications that the Council recommends to the Secretary following its September Council meeting would be extended into the new fishing year as interim specifications until changed. The interim specifications would be based on the information available at the September meeting, and would remain in effect until final TACs are approved and implemented by the Secretary on the basis of Council recommendations from its December meeting. Meanwhile, comments on the TAC specifications would be requested in the same manner as they would be under the status quo.

To implement this alternative, existing regulations might be revised to read as follows:

> Notices of proposed and interim harvest specifications. After consultation with the Council, and as soon as practicable after October 1 of each year, the Secretary will file a notice in the FEDERAL REGISTER proposing specifications of annual TAC, DAP, JVP, TALFF, reserves, and applicable PSC amounts for each target species, "other species" category, and species determined to be fully utilized by the DAP fisheries. These proposed amounts will be implemented as interim specifications on January 1 of the subsequent fishing year and will remain in effect until changed. They will reflect as accurately as possible the projected changes in U.S. processing and harvesting capacity and the extent to which U.S. processing and harvesting will occur during the coming year. Public comment on these amounts will be

accepted by the Secretary for 30 days after the notice is filed for public inspection with the Office of the Federal Register.

Notices of final harvest limits. The Secretary will consider comments received on the proposed specifications during the comment period and, after consultation with the Council, will specify the final annual TAC for each target species and the "other species" category and apportionments thereof among DAP, JVP, TALFF, and reserves. These final specifications will be published as a notice in the FEDERAL REGISTER on or about January 1 of each year and will replace the interim specifications.

4.2.3 Alternative 3: (Preferred) Extend one-fourth of the proposed TAC specifications into a new fishing year on an interim basis.

This alternative is similar to Alternative 2, except that only one-fourth of the proposed TAC specifications would be extended into the new fishing year. The purpose of allocating only a fraction of the TAC specifications is to avoid establishing an interim specification for a particular species that might be much larger than that which the Secretary might eventually implement as the final specification.

Differences in apportionments between DAP and JVP on the basis of proposed and final TACs could be significant. For example, during the 1989/1990 period in which TAC specifications for the BSAI were proposed and finalized under the status quo process, the proposed and final TACs for "rocksole" were 102,148 mt and 60,000, respectively. Proposed and final JVP apportionments were 36,965 mt and 0 mt, respectively. The final JVP was augmented by 16,539 mt from the operational reserve as bycatch to support the other JVP flatfish directed fisheries.

In 1990, the rocksole allocation to JVP was intended as bycatch only. But if all the proposed JVP had been available on an interim basis for purposes of allowing a directed JVP fishery, and if final specifications were not filed for several weeks, the JVP fishery could reasonably have harvested all of the interim JVP specification of 36,965 mt, exceeding the final JVP specification for rock sole by 20,426 mt.

If just one-fourth of the interim JVP specification of 36,965 mt for rock sole had been specified on January 1, 1990, only 9,241 mt would have been available. Rock sole was intended only as bycatch in the JVP yellowfin sole fishery for 1990. A bycatch amount of 9,241 mt would have been sufficient to support the yellowfin sole JVP fishery until final specifications had become effective.

Under this alternative, interim specifications of prohibited species catch (PSC) limits should also be allocated in the same proportion as the groundfish interim specifications to support bycatch needs in the directed groundfish fisheries. PSC limits of Pacific halibut are allocated in the Gulf of Alaska. An amount of Pacific halibut equal to one-fourth of the PSC by gear type would be allocated, therefore, on an interim basis to support GOA bycatch needs. PSC limits of Pacific halibut, red king crab, and Bairdi Tanner crab have also been allocated in the Bering Sea and Aleutian Islands Area (BSAI) under Amendment 12a to the BSAI FMP, which expires at the end of the 1990 fishing year.

If PSC limits in the BSAI are again authorized as a result of Council action for the beginning of the 1991 fishing year, then one-fourth of the available PSCs would also be allocated on an interim basis to support bycatch needs.

4.3 Biological and Physical Impacts

Under each alternative, the final TAC specifications would not be affected. Final TACs recommended by the Council would be implemented, replacing interim TACs. Total harvests during the fishing year could be different, however.

Under Alternative 2, for example, overharvesting a groundfish species could potentially occur if early fishing toward an interim TAC resulted in a harvest amount that was higher than the intended final TAC. To the extent that overharvesting a species caused overfishing is a cost under this alternative. Any overfishing would induce changes in predatory/prey relationships, which are difficult to anticipate. Changes could be short term or long term, depending on the severity of overfishing.

Under Alternative 3, potential overharvesting a groundfish species is reduced, because only 25 percent of the TAC would be available. The risk of overfishing would largely be removed, which would be a benefit under this alternative.

4.4 Socioeconomic Impacts

No changes in enforcement costs would be incurred under either alternative. No additional administrative costs would be incurred under either alternative, because only two notices would be published in the FEDERAL REGISTER: (1) the notice resulting from Council recommendations made at its September meeting, which would serve as proposed and interim TAC specifications; and (2) the notice resulting from Council recommendations made at its December meeting, which would be the basis for final TACs.

As discussed under the "Biological and Physical Impacts" section, Alternatives 2 and 3 vary with respect to potential overfishing. Alternative 3 is superior economically to Alternative 2, to the extent that the risk of overfishing is reduced, which promotes economic stability in the industry.

As a practical matter, no costs are expected to be imposed on the industry as a result of either alternative, because only a few days are expected to lapse during the period that interim specifications are in effect, before the final TACs are implemented.

5.0 MODIFY THE AUTHORIZATION LANGUAGE FOR DEMERSAL SHELF ROCKFISH MANAGEMENT IN THE GULF OF ALASKA

5.1 Description of the Problem and Need for the Action

Demersal shelf rockfish are harvested primarily in the waters of Southeastern Alaska by a longline fleet targeting on the ten species of rockfish which make up this management assemblage. Although some harvest of this assemblage also occurs in the East and West Yakutat Regulatory Districts, demersal shelf rockfish are currently recognized as an FMP species group only in the Southeast Outside District (Figure 1). In addition to the directed harvest, demersal shelf rockfish are taken in relatively small quantities incidental to the halibut longline fishery, salmon troll fisheries, and offshore trawl fisheries for other rockfish species.

The Magnuson Fishery Conservation and Management Act (MFCMA) requires that conservation and management measures prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery. The demersal shelf rockfish stock is considered to be very limited and vulnerable to localized depletion at low harvest levels (O'Connell and Bracken, 1988). The current annual TAC for the Southeast Outside District of less than 500 mt is difficult to regulate and, because the population level of these fish is so difficult to assess, there is little assurance that the current harvest levels are sustainable. Management by annual broad-area quotas alone is not considered to be restrictive enough to prevent localized depletion or to assure that the optimum yield can be sustained.

To reduce the risk of exceeding the annual TAC set for demersal shelf rockfish, the North Pacific Fishery Management Council (Council) adopted Amendment 14 to the Gulf of Alaska Groundfish Fishery Management Plan (FMP) in September 1985. That amendment gives limited authority to the State of Alaska to manage demersal shelf rockfish in Federal waters. The purpose of this authorization was to allow for management by smaller quotas and management areas than could be practically administered by the Council and regulated by the National Marine Fisheries Service (NMFS). However, the current language of the authorization provision restricts State authority to regulating the demersal shelf rockfish fishery "consistent with specific provisions of the FMP", to "establishing smaller areas and quotas", and applies only to vessels which are "registered/licensed under the laws of the State of Alaska".

In 1988 the Alaska Department of Fish and Game (ADF&G) requested and received funding from the Federal Interjurisdictional Fisheries Fund to develop a management strategy for demersal shelf rockfish in the Eastern Gulf of Alaska. The emphasis of that effort was to develop regulations which would provide for conservation of the resource while at the same time maximizing the value of the fishery. With that general objective in mind, much of the regulatory review was directed at developing management measures which would lengthen the seasons to assure a consistent supply of high quality fresh fish to the markets over an extended portion of the year. Extending the harvest over a longer time period was also recognized as a way to reduce the risk of exceeding the small annual TAC limits.

The Federal funding was used by the ADF&G staff to thoroughly analyze existing data on biology of demersal shelf rockfish and the history of the demersal shelf rockfish fishery and to support a

Rockfish Work Group made up of fishermen and processors from all major Southeast Alaska rockfish ports. The Work Group met twice during 1988 in workshops lead by ADF&G staff to consider management options for the demersal shelf rockfish fishery. The preferred management alternatives selected through that process were presented to the Alaska Board of Fisheries (Board), adopted in February 1989, and became State law in June 1989. As a result of that action, the State regulations for management of demersal shelf rockfish in Southeast Alaska are no longer consistent with the specific provisions of the FMP nor are they limited to establishing smaller quotas or areas. The specific State regulations and differences between them and the current Federal regulations are presented in section 5.5.1 of this chapter.

The directed longline fishery for demersal shelf rockfish occurs in both State (internal waters of S.E. Alaska and coastal waters out to 3 miles) and Federal waters (from 3 to 200 miles). Over half of the demersal shelf rockfish harvest from the Southeast Outside District occurs in Federal waters of the area. Fishermen move freely between State and Federal waters and at times even set directly across that boundary. In order for the State to carry out the management responsibility conferred to it by Amendment 14 of the Gulf of Alaska Groundfish FMP, it is necessary for State and Federal regulations for this fishery to be consistent. The State simply cannot manage the resource using two separate sets of regulations. A modification of the FMP language is needed to allow for full implementation of the newly-adopted State regulations into the EEZ.

5.2 The Alternatives

5.2.1 Alternative 1: Do nothing - maintain the status quo.

Under this alternative, the State would retain limited authority for demersal shelf rockfish management under the existing provision in the FMP, but could not legally enforce State regulations other than annual quota management beyond three miles.

Adoption of this alternative would result in continued discrepancies between State and Federal regulations and uncertainty over management authority for demersal shelf rockfish. This is confusing to the managing agencies and to the fishermen involved in the harvest of this resource. Because of the small demersal shelf rockfish quotas available, there is a valid concern that simple quota management does not offer the protection to the stock required in the MFCMA. This alternative also ignores the much higher value of this species group when landed in small amounts over an extended season.

5.2.2 Alternative 2: (Preferred) Modify the authorization language of the FMP to allow full implementation of State regulations in those Federal waters of the Eastern Gulf of Alaska where demersal shelf rockfish are recognized by the Council as an FMP species group.

Specific Proposal: Modify Section 3-1 on page 3-5 of the FMP pertaining to State regulation of demersal shelf rockfish assemblages as follows: The underlined sections are proposed new language and sections **[bracketed and in bold type]** would be deleted from the existing language.

"The TAC for demersal shelf rockfish in the Eastern Regulatory Area is specified by the Council each year. The State of Alaska will manage State registered vessels fishing for demersal shelf rockfish in the Eastern Regulatory Area with Council oversight. Under this oversight the State **[of Alaska]**'s management regime for demersal shelf rockfish in the Eastern Regulatory Area will be [is] directed at managing these rockfish stocks within the TAC specified by the Council. **[smaller management units than are provided for by the FMP.]** Such state regulations are in addition to and stricter than Federal regulations. They are not in conflict with the FMP as long as they: (1) are consistent with specific provisions of the goals and objectives of the FMP, and (2) **[limited to establishing smaller areas and quotas, which would]**, result in a total harvest of demersal shelf rockfish in the Eastern Regulatory Area **[each FMP regulatory area]** at a level[s] no greater than provided by **[for in]** the FMP. Such state regulations will **[may]** apply only to those vessels registered **[/licensed]** under the laws of the State of Alaska.

Regulatory changes proposed by the Alaska Board of Fisheries, which are related to the management of demersal shelf rockfish will be reviewed by NOAA and the Council prior their adoption to assure that any such proposed changes are consistent with the goals and objectives of the FMP.

Under Council oversight, the following categories of regulations are authorized by the FMP to be applied by the State to vessels in the demersal shelf rockfish fishery:

> The directed fishing standard for demersal shelf rockfish, inseason adjustments, seasons, seasonal apportionments of quotas, gear specifications, trip limits, directed fishing quotas, and management areas.

The following categories of regulations will be maintained as Federal regulations, unless specifically exempted, that must be complied with by Federally permitted vessels in this fishery:

> Notices establishing preliminary and final TACs, definitions (except the directed fishing standard for demersal shelf rockfish, relation to other laws, permits, recordkeeping and reporting, general prohibitions, penalties, harvest limits, prohibited species catch limits, measures to manage designated prohibited species, and observer requirements."

This alternative allows the State the greater flexibility needed to manage the demersal shelf rockfish assemblage while maintaining Federal oversight for managing the assemblage. Regulatory measures used by the State in the Territorial waters could be implemented to manage the demersal shelf rockfish fishery in the EEZ, as long as the measures are consistent with the provisions of the MFCMA and the FMP. This modification would result in consistent management of demersal shelf rockfish in both State and Federal waters, minimize the risks of localized depletion and reduce the possibility of exceeding the annual TAC, and assure that the greatest value of the product was realized. Virtually all vessels engaged in the demersal shelf rockfish fishery have obtained the appropriate State licenses. Therefore, the sentence referring to vessels registered/licensed under state laws is being deleted as it is considered to be unnecessary.

5.3 Historical Data and Description of the Fishery

5.3.1 Historical Data

Demersal shelf rockfish have been caught incidental to commercial fisheries for halibut, sablefish, and salmon since the early 1900s. Very small bycatch levels of demersal shelf rockfish were also reported by observers in the foreign trawl fisheries targeting on slope rockfish in the Eastern Gulf prior to 1982 (Table 5.4).

In 1979 a small shore-based fishery directed at nearshore rockfish commenced in the Sitka area of Southeast Alaska. Since that time landings of demersal shelf rockfish have increased dramatically throughout the region. The directed harvest increased from approximately 350,000 pounds (160 mt) of all rockfish species in 1982 to a peak of nearly 2.7 million pounds (1,225 mt) of demersal shelf rockfish alone during 1987. Through more restrictive regulations, the total harvest of demersal shelf rockfish was reduced to 1.5 million pounds (680 mt) in 1989. Approximately 860,000 pounds (390 mt) of the 1989 landings were reported from the Southeast Outside District.

The demersal shelf rockfish assemblage was first recommended as a separate management assemblage by ADF&G biologists in 1984 and adopted by both the Board and the Council later that year. The ten-species group was based on the predominant species landed by the longline fleet targeting on rockfish in the Southeast Area as determined by ADF&G port samples from shore based-landings between 1981 and 1984.

The history of domestic catches (mt) of demersal shelf rockfish are shown in table 5.1.

5.3.2 Description of the Fishery

The directed fishery for demersal shelf rockfish is conducted primarily by smaller shore-based longline vessels landing the fish heavily iced after short trips. The fish are flown out of state fresh and in the round to exclusive markets throughout the western half of the U.S. These markets pay a premium price for the product compared to other rockfish markets (see section 5.5.2).

These vessels deliver their product to a number of shore-based plants, with most of the landings occurring in Sitka, Ketchikan, Craig, and Petersburg. Fish are also delivered to Juneau, Wrangell, Hoonah, Pelican and other ports in the region. This fishery is conducted primarily during the "off-season" and provides income to fishermen and processors during the fall, winter, and spring when other small-vessel fishing opportunities are diminished.

Data from the Alaska Commercial Fisheries Entry Commission (CFEC) indicate that as many as 300 individual longline vessels have participated in the target fishery in a single year. A total of 720 individual longline vessels made directed landings of demersal shelf rockfish to Southeast Alaska ports from 1979 through 1988 and 624 individual longline vessels reported directed landings between 1984 and 1988 (CFEC, 1989a). A large percentage of the participants make only one or two trips per season and very few fishermen derive their entire fishing income from demersal shelf rockfish.

Both Alaskan and non-Alaskan fishermen participate in this fishery. CFEC data show that the number of non-Alaskan fishermen participating in this fishery ranged from 9% to 13% of the total number of participants between 1984 and 1987. The number of non-Alaskan fishermen increased in proportion to the increase in total fishermen during that time period (CFEC, 1989b).

Beginning this year a separate CFEC permit is required to participate in the directed fishery for demersal shelf rockfish. As of April 2, 219 permits have been issued. Of that total, 14 (6.4%) were issued to non-Alaskan fishermen (Personal communication with Kurt Schelle, CFEC, Box KB, Juneau, AK 99811). The total number of permits, both to Alaskans and non-Alaskans, is expected to increase as the year progresses.

In 1989, the only year for which comprehensive harvest data are currently available for all gear types and species groups, longline gear accounted for 97.2% of all demersal shelf rockfish landed in the Southeast Outside District. Small amounts were also reported by trawl gear (1.6%) and other hook and line gear (1.2%). Pounds and percentages of the ten species of demersal shelf rockfish landed in the Southeast Outside District during 1989 are listed by gear type in Table 5.2. That table also shows the reported harvest of the other rockfish management assemblages by gear type. During 1989 demersal shelf rockfish comprised nearly 74% of all rockfish landed by longline gear in the Southeast Outside District and only 0.4% of all rockfish landed by trawl gear. This suggests that demersal shelf rockfish are not inherently vulnerable to trawl gear and that separation by gear type is a viable management option. This data is consistent with the foreign observer data (Table 5.4) which also shows very low relative catches of demersal shelf rockfish during target fisheries for other rockfish species.

Table 5.3 shows the species composition of rockfish landed by longline vessels to shore-based processors in Southeast Alaska during 1988 and 1989. This table indicated that nearly 90% of all rockfish landed by longline vessels targeting on rockfish during those two years was from the demersal shelf rockfish assemblage followed by pelagic rockfish (9.4%) and three species of slope rockfish (2.1%).

An examination of observer data from trawl vessels fishing for rockfish in the Southeast Outside District during 1980 and 1981 also suggests a distinct separation of assemblage harvest by gear type (Table 5.4). Only 6.7% of all rockfish reported by both small trawlers and large factory trawlers operating during that time were species now included in the demersal shelf rockfish assemblage. Nearly 92% of the small amount of demersal shelf rockfish which was landed by trawl vessels was from three species, redstripe rockfish (*Sebastes proriger*), bocaccio (*S. paucispinus*), and silvergrey (*S. brevispinis*) rockfish (Table 5.2). These three species constitute only a minute fraction of the 1989 longline landings from the Southeast Outside District and are being considered for exclusion from the demersal shelf rockfish assemblage (see section 5.5.1).

5.4 Biological and Physical Impacts

5.4.1 Biology

Ten species of *Sebastes* rockfish are currently included in the demersal shelf rockfish management category. They represent the rockfish species which are most commonly taken by set line gear on the continental shelf in the Eastern Gulf of Alaska. The name "demersal shelf" refers to the fact that they are primarily bottom-dwelling species of the continental shelf. The species are shown in alphabetical order by common name in Table 5.5.

Methods used by the Canadian Department of Fisheries and Oceans for aging similar species such as rougheye rockfish indicate extreme ages for yelloweye and quillback rockfish, the predominant commercial species landed. Individual yelloweye rockfish have been aged in excess of 100 years and samples from commercial landings in some Southeast Alaska fisheries indicate an average age of over 50 years for that species (O'Connell and Funk, 1987). Preliminary aging data suggests that yelloweye rockfish do not attain sexual maturity until they are 12 to 15 years of age or older and do not recruit fully to the fishery until even older.

All rockfish in the genus *Sebastes* are ovoviviparous, extruding live larva after a reproductive cycle which begins with internal fertilization and extends over several months. Not all species have concurrent cycles and so some portion of the reproductive cycle, either copulation, fertilization, maturation, or parturition, occurs for some rockfish species over much of the year (O'Connell, 1987). For these reasons closures to protect spawning stocks are not considered to be an effective management tool.

These fish inhabit depths from 5 fathoms (9 meters) to over 100 fathoms (183 meters) with the greatest abundance between 20 and 80 fathoms (37 to 146 meters). Most demersal shelf species are closely associated with the bottom, at least as adults. They are generally found on or near rocky substrate, normally in areas with high bottom relief such as pinnacles and reefs. Surveys conducted by ADF&G and logbook data from the commercial fishery have shown that a longline set 50 meters or less from the desired location will often result in a substantial change in number of fish caught and in species composition of the catch. The suggested high degree of habitat specificity and assumed lack of movement of these species may render them particularly vulnerable to localized depletion. The concern for localized depletion associated with limited movements of demersal shelf rockfish has been noted for similar species of *Sebastes* in other areas (Mathews and Barker 1983, Love 1980).

Risk of localized stock depletion is increased by the low survival of individuals taken as bycatch in other fisheries and returned to the ocean. All *Sebastes* have a physoclistic (closed) gasbladder. Because of this, *Sebastes* and particularly the bottom-dwelling demersal shelf rockfish are susceptible to extensive soft tissue damage or death from decompression when they are brought to the surface. For that reason, size restrictions, species selection, and PSC discard requirements are not effective management tools for minimizing total fishing mortality for demersal shelf rockfish.

Available data indicates that the instantaneous rate of natural mortality is less than 0.04 for yelloweye rockfish (O'Connell and Bracken, 1988). For long-lived species such as rockfish, managers normally set the harvest level at an amount which does not greatly exceed the natural mortality rate to minimize the risk of significant population declines. The rate at which the population decreases depends to a large extent on the level of additional mortality induced by fishing. The demersal shelf rockfish resource has shown signs of dramatic reduction in some areas with only a relatively small amount of directed longline harvest (Bracken, 1989). With these biological characteristics, they are considered to be highly susceptible to localized depletion and possible long-term stock reduction if not managed very conservatively.

There are currently no estimates of MSY, ABC, or biomass for the demersal shelf rockfish assemblage in Alaskan waters. The habitat-specific nature of the species involved makes estimation of those biological parameters very difficult. ADF&G biologists have drafted the demersal shelf rockfish chapters for the annual Gulf of Alaska status of stock and Plan Team reports since 1984. For the past several years the TAC set by the Council for demersal shelf rockfish in the Southeast Outside District has been based directly upon recommendations made by the ADF&G staff.

Lacking the biological parameters normally used for setting TAC, the question is often asked how the TAC recommended by the ADF&G staff are derived. Annual harvest objectives for the directed hook and line fishery for demersal shelf rockfish in each of the five Southeast Alaska management areas are set annually based upon fisheries performance and fleet distribution data collected through a port sampling/skipper interview program. The annual directed harvest objective is then modified to include the anticipated demersal shelf rockfish bycatch levels estimated from the previous years reported bycatch to establish an annual total harvest. The total annual harvest objectives for the three outside management areas which make up the Southeast Outside District (Figure 2) are combined to obtain the TAC recommendation which is made to the Council each year.

The State made the original recommendation to the Council to establish demersal shelf rockfish as a separate management assemblage and have made the annual recommendations for harvest of this assemblage in the Southeast Outside District since demersal shelf rockfish were first recognized as an FMP species group. The current restrictive language in the FMP regarding the State's management authority for demersal shelf rockfish makes it difficult to manage the resource within the small annual TAC limits. This increases the risk that the annual TAC level will be exceeded and that stock depletion may occur.

5.4.2 Alternative 1: Do Nothing - status quo

Under this alternative the State could not implement regulations other than annual quota management to vessels operating in the EEZ. With the small quotas and the vulnerability of the predominant species to stock reduction at low levels of harvest, this constraint is considered to pose an undue risk to the demersal shelf rockfish assemblage. Under existing regulations, a small number of vessels could conceivably take a major portion of the quota in a single trip. Any delay in reporting could result in exceeding the annual TAC by a substantial amount, particularly if that harvest occurred late in the year. Also, under current Federal regulations, the entire quota could be taken from a small portion of the regulatory district potentially reducing the productivity of demersal shelf rockfish in that portion of the Southeast Outside District for an extended period of time.

Managing a fishery in such a way that the risks to the resource are not adequately considered in the management strategy and resulting regulations is contrary to the goals and objectives of the Council as outlined in the FMP. The current Federal management system precludes management of the demersal shelf rockfish fishery with the level of in-season intensity required to adequately protect this resource and maintain the annual harvest within safe biological limits.

5.4.3 Alternative 2: (Preferred) Modify the authorization language of the FMP to allow full implementation of State regulations in those Federal waters of the Eastern Gulf of Alaska where demersal shelf rockfish are recognized as an FMP species group.

Under this alternative the more restrictive State regulations would also apply to all vessels taking demersal shelf rockfish while operating in the EEZ portion of the Southeast Outside District. Current state regulations for the directed fishery which would be extended to the EEZ include: an annual fishing season separated into three segments, separate annual quotas for each of the three management areas which make up the Southeast Outside District, directed fishing restricted to hook-and-line gear, the directed harvest of demersal shelf rockfish limited to no more than 7,500 pounds during any five day period, and bycatch of demersal shelf rockfish in all other fisheries and when the season is closed limited to no more than 10% by weight of all fish on board. The bycatch limit does not apply to the halibut fishery and fishermen engaged in that fishery are encouraged to land all demersal shelf rockfish harvested to minimize waste.

The primary impetus behind the adoption of many of the State demersal shelf rockfish regulations was either economic or allocative. The specific regulations and the intent behind them are discussed in much greater detail in section 5.5.1 under Socioeconomic Impacts. Regardless, since a primary consideration of the State management objective was to spread out the harvest over as long a time span as possible, the State regulations make management within a set quota much more feasible and offer a much greater degree of protection to the resource than the current annual quota management strategy provided for in the FMP. This is particularly true given the small TAC limit and the many vessels currently operating in this fishery.

5.5 Socioeconomic Impacts

The Principal management goal outlined in the FMP states that "Groundfish resources of the Gulf of Alaska will be managed to maximize positive economic benefits to the United States, consistent with marine resource stewardship responsibilities for the continuing welfare of the Gulf of Alaska living marine resources." This is consistent with the State's principal objective for management of demersal shelf rockfish which states: "The Southeast Alaska demersal shelf rockfish fishery will be managed to provide positive economic and other benefits to the region while supporting a sustainable annual harvest of this resource. The benefits include, but are not limited to, profits to the fishing industry; benefits to consumers; income; employment; and recreational, personal, and subsistence uses." (Bracken, 1989).

5.5.1 State Regulations

To fully understand the socioeconomic impacts of extending the State's regulations for managing demersal shelf rockfish into the EEZ, it is important to know specifically what those regulations are and how and why they were adopted.

State regulatory changes for Southeast Alaska finfish are considered by the Alaska Board of Fisheries every other year. To be considered, proposals for specific changes must be submitted prior to a pre-announced deadline. The printed proposals are readily available to the public. They are reviewed thoroughly by the ADF&G staff, the Fish and Wildlife Protection (enforcement) staff, the local fish and game advisory committees, and the regional fish and game councils prior to the Board meetings. The Board then takes comments from the public and the various reviewers prior to making a decision whether to adopt, reject, or modify the proposal and establish regulations consistent with State management standards. All proposals submitted prior to the deadline are considered and weighted equally by the Board. Both Alaskan and non-Alaskan fishermen participate in this process.

In formulating the current State regulations regarding demersal shelf rockfish, an additional step was taken. A grant from the Federal Interjurisdictional Fisheries Fund was used to form an industry Work Group to discuss management alternatives and adopt preferred options for regulatory consideration. A fisherman and a processor from each of the major Southeast Alaska rockfish ports was invited to participate in two workshops held during the summer and fall of 1988. The primary concerns expressed by the participants at those workshops were that the fishery must be managed within safe biological limits and to ensure that demersal shelf rockfish are available for harvest over most of the calendar year. If a closure was necessary for conservation reasons, they recommended that it should be during May and June when the markets for their product was soft and the predominant species were in the parturition stage. Four of the current regulations, the gear restriction, the trip limit, the split season, and the mandatory logbook were recommended by the industry. The first three were intended to spread out the fishing effort and to maximize the value of this fishery to the fishermen involved.

The regulations currently in effect for State management of demersal shelf rockfish are:

1. Five separate management areas are established for demersal shelf rockfish management in Southeast Alaska (Figure 2). These areas were adopted based upon staff recommendations and input from the public. They represent the general geographic distribution of the fleets from the major ports in the region. Quotas and other groundfish regulations are established independently for each management area.

2. Separate guideline harvest ranges for the directed demersal shelf rockfish fishery are set for each of the five management areas. The ranges were recommended by the department staff and endorsed by the Rockfish Work Group at their 1988 workshops. The approved ranges are approximately 50% to 67% of the preliminary harvest limits used by ADF&G to manage the directed fishery during the 1986-87 and 1987-88 seasons (Bracken 1988). The harvest ranges and current annual harvest objectives for each area are listed in Table 5.6. An annual harvest objective is set within the guideline harvest range for each area based upon the best available information prior to the October 1 opening date of the directed demersal shelf rockfish season each year. The NSEO, CSEO, and SSEO areas make up the Southeast Outside District. The directed fishery harvest goal for the Southeast Outside District is 370 mt for the 1989-90 season leaving approximately 100 mt of the 470 mt TAC for bycatch in other fisheries.

3. Under State regulations the annual fishing year for the directed fishery runs from October 1 through September 30 and opens with a new annual quota at noon on October 1 each year. The fishing year is split into three segments. No more than 43% of the annual harvest objective for each fishing year can be taken during October and November. An additional 42% may be taken from December 1 through May 15 with the remainder of the harvest (15%) reserved for a summer season beginning on July 1. This regulation was proposed by the Work Group as a means of spreading out the harvest over a broader portion of the year to maximize the value of the resource. The May 15 - July 1 closure coincides with the peak parturition period for yelloweye rockfish and attendant presence of larval fish in rockfish sold in the round. The presence of larval fish reduces the marketability of rockfish sold in the round and thus tends to depress the market for demersal shelf rockfish. In addition, the availability of rockfish from other sources also tends to depress the market. This is not considered to be inconsistent with the FMP fishing year since the directed fishery will be managed to remain within the annual TAC set by the Council.

4. **Directed fishing** for demersal shelf rockfish is limited to hook and line gear. This restriction has been in effect in State waters since 1984 and was adopted at the recommendation of the shore-based fishing industry. The regulation was adopted by the Board of Fisheries because the demersal shelf rockfish resource was being fully utilized by hook-and-line vessels, the harvest can be better controlled with that gear type, and the greatest value from the resource comes from fresh fish deliveries of longline-caught fish (see section 5.5.2).

5. When the directed demersal shelf rockfish fishery is closed, either after the annual harvest objective has been reached, by gear restriction, or in areas with permanent closures to directed fishing for demersal shelf rockfish (Sitka and Ketchikan vicinity), any CFEC permit holder may retain demersal shelf rockfish only up to 10% by weight of all species on board. However, demersal shelf rockfish may be retained without restriction while fishing for halibut during a regular commercial halibut opening. These regulations were proposed by the ADF&G staff at the request of the industry and Work Group participants. They were adopted to meet the objective of minimizing waste of demersal shelf rockfish in fisheries for other species by allowing full utilization of all demersal shelf rockfish harvested while at the same time recognizing the greater value of a directed hook and line fishery. The directed fishing quotas are set low enough to accommodate the anticipated annual bycatch without exceeding the TAC level set by the Council, thus reducing the risk that demersal shelf rockfish would have to be declared a prohibited species. Anticipated annual bycatch levels are determined from actual bycatch landed in the previous year. Because the state does not have management authority over the other rockfish assemblages beyond the tree-mile territorial limit, both the gear restriction and the 10% bycatch limit would apply only to demersal shelf rockfish in the EEZ.

6. A Work Group proposal to limit the amount of demersal shelf rockfish landed by any fisherman during a weekly fishing period is in effect. The regulation states that "during the directed demersal shelf rockfish fishery no vessel or individual CFEC permit holder may land more than 7,500 pounds (3.4 mt round weight) of demersal

shelf rockfish during any five-day period". This action was recommended by the Work Group for two reasons, one economic and the other biological in nature. The weekly trip limit serves to spread out the harvest over a longer time period, maintains the predominantly small-vessel nature of the fishery, and minimizes market gluts which tend to reduce the value of the product. This regulation also spreads out the effort, makes quota accounting much easier, and thus reduces the risk of stock depletion.

7. A regulation requiring all participants in the directed demersal shelf rockfish fishery to maintain logbooks was also adopted. This regulation was requested by the Work Group as a way to provide better information with which to manage this fishery. The language of the regulation is very similar to the logbook requirements currently in effect for the halibut fishery in Alaska and are slightly more detailed than the current NMFS logbook requirements. The regulation specifies what information must be retained, but does not dictate a specific format.

Proposals which will be presented to the Board for consideration at the winter 1991 meeting include a minor modification of the State logbook requirements, a recommendation to consolidate the CSEO and the NSEO management areas into one management area (Figure 2), the transfer of silvergrey and redstripe rockfish and bocaccio from the demersal shelf rockfish assemblage to the slope assemblage, and the shift of redbanded rockfish (*Sebastes babcocki*) from the slope assemblage into the demersal shelf rockfish assemblage. The changes to the assemblages, if implemented, will also need to be made to the FMP species groupings. That recommendation will be made to the Council next fall as part of the demersal shelf rockfish stock status report.

The proposal to modify the logbook requirement will include a more precise definition of location and the exclusion of the current requirement to report the number of fish caught. Consolidation of two of the outside district management areas will eliminate the small northern outside area making in-season catch accounting and overall management less complicated (Figure 5.2). The recommendations for changes to the species groupings are based on the catch summaries presented earlier in this report. No other modifications to the current regulations are being considered by the ADF&G staff at this time. The deadline for submission for proposals to be considered in 1991 was April 10, 1990 so no additional proposals can be submitted for consideration next year. After the 1991 meetings the Board is not scheduled to consider changes to the demersal shelf rockfish regulations again until early 1993. However, proposals for changes in demersal shelf rockfish regulations may be submitted by petition for Board consideration prior to 1993.

5.5.2 Economic Considerations

Preliminary data (ADF&G Fish Ticket Data Base) indicate that most of the fish landed in the directed longline fishery are shipped fresh in the round while the bycatch in fisheries for other species are usually frozen and often are filleted prior to shipping. The fishticket records indicates that species landed in the directed fishery destined for out of state fresh fish markets are worth approximately twice as much to the fishermen as the hook and line caught fish which are filleted and frozen and nearly three times the value of trawl-caught species.

The more desirable species caught in the directed fishery and marketed fresh are currently worth about $0.70 per pound ex-vessel bled and in the round while other hook-and-line bycatch fish are worth only $0.30 to $0.35 dressed. Trawl caught demersal shelf rockfish landed at shore-based processors are worth only $0.15 to $0.25 depending on species (ADF&G Fish Ticket Data Base). No records are currently available for the value of trawl-caught demersal shelf rockfish processed at sea.

The current target harvest level for the directed fishery in the Southeast Outside District is 370 mt. At $0.70 per pound, that resource taken by hook and line gear in a directed fishery has an ex-vessel value of over $570,000. If the same product was taken entirely as bycatch in other hook-and-line fisheries the value would drop to approximately $285,000. If the fish were landed entirely in a shore-based trawl fishery the ex-vessel value would decrease to approximately $160,000. It should be noted that the predominant species recorded as bycatch in the trawl fisheries are silvergrey, bocaccio, and redstripe (Tables 5.2 and 5.4) which are lower value fish on the market at this time (ADF&G Fish Ticket Data Base).

The much higher value of the fresh hook and line caught product is the primary reason that the Rockfish Work Group developed a series of regulations which spread the effort over an extended period of the year to assure continuation of those markets. Most of the demersal shelf rockfish harvested in the directed longline fishery is flown to exclusive restaurants and fresh fish markets out of state. Those markets are not extensive and have come to rely on small amounts of high quality product shipped fresh over much of the year. There is a general concern among fishermen and processors that if the season becomes progressively shorter as has been observed in the other Eastern Gulf longline fisheries, that product quality would be diminished and those exclusive markets would be lost. Therefore, those regulations not only help to protect the resource from depletion, but also assure that the highest value is realized from the resource, consistent with provisions of the MFCMA.

Alternative 1: Status Quo

Under this alternative all users would have an equal opportunity for harvesting demersal shelf rockfish in the EEZ. A greater amount of the demersal shelf rockfish could conceivably be taken as lower value product in the future, diminishing the value of this resource to the fishing industry. The risk of stock depletion and the resulting reduction of long-term value are much higher with this alternative than with alternative 2. That is because the State regulations are structured to spread out the effort over a longer seasonal interval promoting a more orderly and controllable fishery, while maximizing the value to the fishermen.

Alternative 2: (Preferred) Modify the authorization language of the FMP to allow full implementation of State regulations in those Federal waters of the Eastern Gulf of Alaska where demersal shelf rockfish are recognized as an FMP species group.

Under this alternative State regulations which are in effect for management of the demersal shelf rockfish fishery in the territorial waters of the State, would be extended into the EEZ in regulatory areas of the Eastern Gulf where demersal shelf rockfish are designated as an FMP species group by the Council. This would make the regulations in effect for demersal shelf rockfish management consistent in both State and Federal waters of the Eastern Gulf.

State regulations designate the longline fleet as the principal user of the demersal shelf rockfish resource, establish a directed fishery quota to maximize the value of the resource while allowing for adequate bycatch in fisheries for other species, and spread the directed fishery out over a longer season to minimize the risk of overfishing and to protect the exclusive markets which require that small quantities of demersal shelf rockfish are available over an extended portion of the year.

The economic impacts of implementing the current state regulations into the EEZ vary considerably. However, it should be noted that at the current time virtually all of the shore-based longline vessels operating in the Southeast Outside District are complying with the state regulations. Thus, although this alternative is not the status quo in terms of the FMP language, it has tended to be the operational status quo. Therefore the overall impact on the directed fishery, as it is currently being conducted, is more hypothetical than real. The following section presents the consequences of implementation. The regulations are discussed in the same order as they appear in section 5.5.1.

Regulations 1, 2, and 3 (Management areas, annual harvest objectives, and split seasons)

Managing by smaller management units requires that the Southeast Outside District TAC be divided into three separate annual harvest objectives which are monitored independently by the State. The seasonal provision requires that the annual harvest objective for each area be further divided into seasonal components. Once the seasonal harvest objective for one of the areas is reached, the fishery is closed in that area for the remainder of the seasonal segment. While this form of management offers much greater protection to the resource, it may force a vessel to move from preferred fishing grounds sooner than would be required under alternative 1. This dislocation may preclude further fishing if new markets cannot be found. This might happen because, in the directed fishery as it is currently being conducted, the fish are delivered to a shore-based plant no later than four days after harvest. Therefore it may not be economically feasible for a fisherman to run to another management area to fish if he has to return to his home port to deliver within four days.

The short-term versus long-term economic effects of this form of management are difficult to evaluate. If a major portion of the annual TAC for all of the Southeast Outside District were taken from one management area, the demersal shelf rockfish stocks within that area could be reduced to the point that a viable fishery could not be conducted in the future. This may offset the seasonal dislocation and short-term disadvantage that may occur as the result of seasonal closures. According to CFEC data (CFEC,1989b), most fishermen who fish for demersal shelf rockfish derive a minor portion of their income from that fishery. The seasons which are currently established by the state correspond with the time of year that this fishery has occurred in the past. According to the testimony of processors involved in the Rockfish Work Group, the value of demersal shelf rockfish is much lower during the summer months than during other periods of the year. There is also a greater risk of fish spoilage during shipment of fresh fish in the summer months. The small amount of the annual quota reserved for the summer season was instituted at the request of some fishermen who market their product locally during the peak tourist season. Therefore, the seasonal allocations and distribution among management areas are considered to be consistent with the historic use patterns of this fishery, do not unduly impact the users of this resource, and allow for harvest to occur during the time of year that the product is most valuable.

Regulations 4 and 5 (Directed fishery gear allocation and bycatch allowances)

The directed fishery for demersal shelf rockfish has been conducted by fishermen using longline gear almost exclusively since this assemblage was first recognized as a separate management group. In fact, the development of the shore-based target fishery prompted ADF&G staff biologists to recommend a separate management group to allow for differential management of this resource. An examination of the historic bycatch data from the foreign trawl fishery (Table 5.4) and from the 1989 domestic trawl fishery (Table 5.2) show that bycatch of demersal shelf rockfish in that area has been minimal. Much of the trawl fishery in the Southeast Outside District targets on other species of rockfish. The very small bycatch of demersal shelf rockfish in the trawl fishery (less than 0.4% by weight in 1989) demonstrates that the state regulation allowing for up to 10% by weight of demersal shelf rockfish in fisheries for other species would not constrain the existing trawl fisheries in the area. Because most demersal shelf rockfish are associated with high relief rocky substrate and because the TAC is so low, it is doubtful that trawl vessels would risk their gear in an attempt to target on this species group. This suggests that management by gear type is feasible and that current bycatch limits will not act as a constraint on existing fisheries for other species. If adopted, the ADF&G recommendation to remove silvergrey, bocaccio, and redstripe rockfish from the demersal shelf assemblage discussed in section 5.5.1 should further reduce the overlap of species harvested by the different gear types.

Regulation 6 (trip limits)

If extended into the EEZ this regulation would mean that no vessel or vessel operator could land more than 7,500 pounds of demersal shelf rockfish in the directed fishery for that species group in any five-day period. A review of the fishticket data shows that less than 18% of the vessels involved in the directed fishery landed more than 20,000 pounds during all of calendar year 1988 (CFEC, 1989a). Some of these vessels made three or more trips during that year landing less than the current trip limit per delivery. Fish ticket records for 1987 and 1988 (prior to implementation of the 7,500 pound trip limit) indicated that only about 3% of the 3714 landings were in excess of 7,500 pounds. The mean weight of these landings was approximately 1500 and 2000 pounds in 1987 and 1988, respectively. Median weights were 540 and 315 pounds. Despite a historical peak in landings of 1,225 mt, almost three times the current TAC, average landing weights in 1987 were only about 20% of the current 7500 pound trip limit. Thus, according to available data, the 7,500 pound trip limit is not considered to be a major constraint to the operation of most of the existing fleet and is supported by most of the participants currently engaged in this fishery.

Many vessels engage in this fishery as a "shake down" trip prior to a fishery for sablefish or halibut and do not fish demersal shelf rockfish at other times of the year. The trip limit also helps to spread out the harvest over a longer season. Spreading out the season should be beneficial to those fishermen who wish to have greater flexibility planning their fishing strategy and should help prevent the market gluts which tend to reduce the value of the fresh fish product.

Regulation 7 (mandatory logbooks)

The State's regulation requiring mandatory logbooks was adopted just prior to the Federal logbook requirement. The State regulations do not dictate the format used, only the type of information which must be reported. The primary difference between the State and Federal reporting requirements is in the State's greater emphasis on set-by-set reporting of the directed catch by species for management purposes. With very little extra cost the fishermen should be able to record the necessary set-by-set data required in the State regulations on the Federal logbook form or on a supplemental logbook format.

Based on the fishticket, port sampling, and observer data reviewed for this report, current users of this resource would be not be impacted by the implementation of the State regulations in the EEZ. Virtually all fishermen engaged in the target fishery are complying with the State regulations at this time and the regulations do not constrain the current level of bycatch in fisheries for other species. While the implementation of State regulations would preclude development of new target fisheries for demersal shelf rockfish, fishermen should not be prohibited from harvesting this resource at current levels. In essence, adoption of alternative 2 formalizes the State's role in demersal shelf rockfish management and clears up legal ambiguities more than it modifies the status quo.

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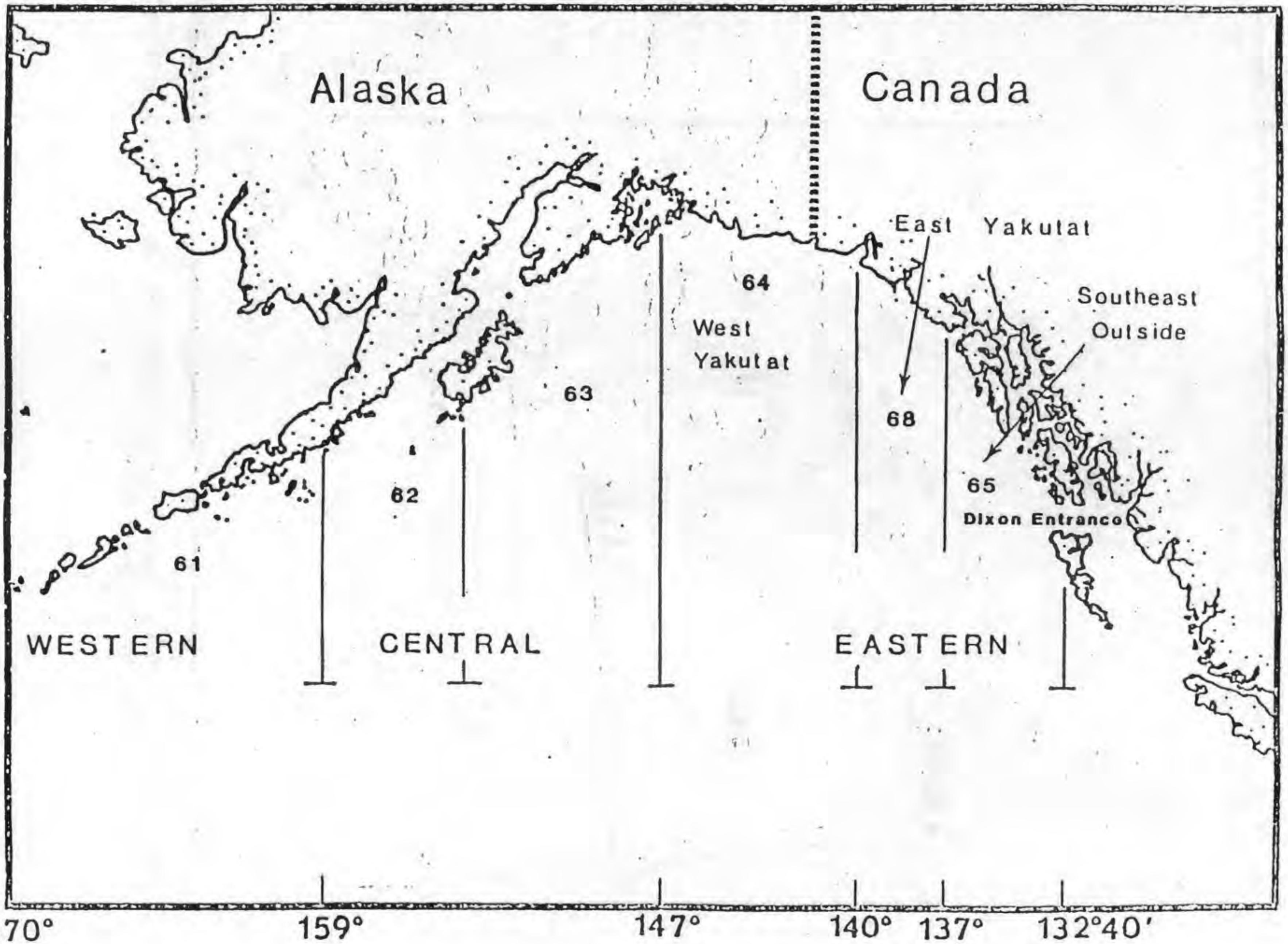

Figure 1. Regulatory and reporting areas of the Gulf of Alaska.

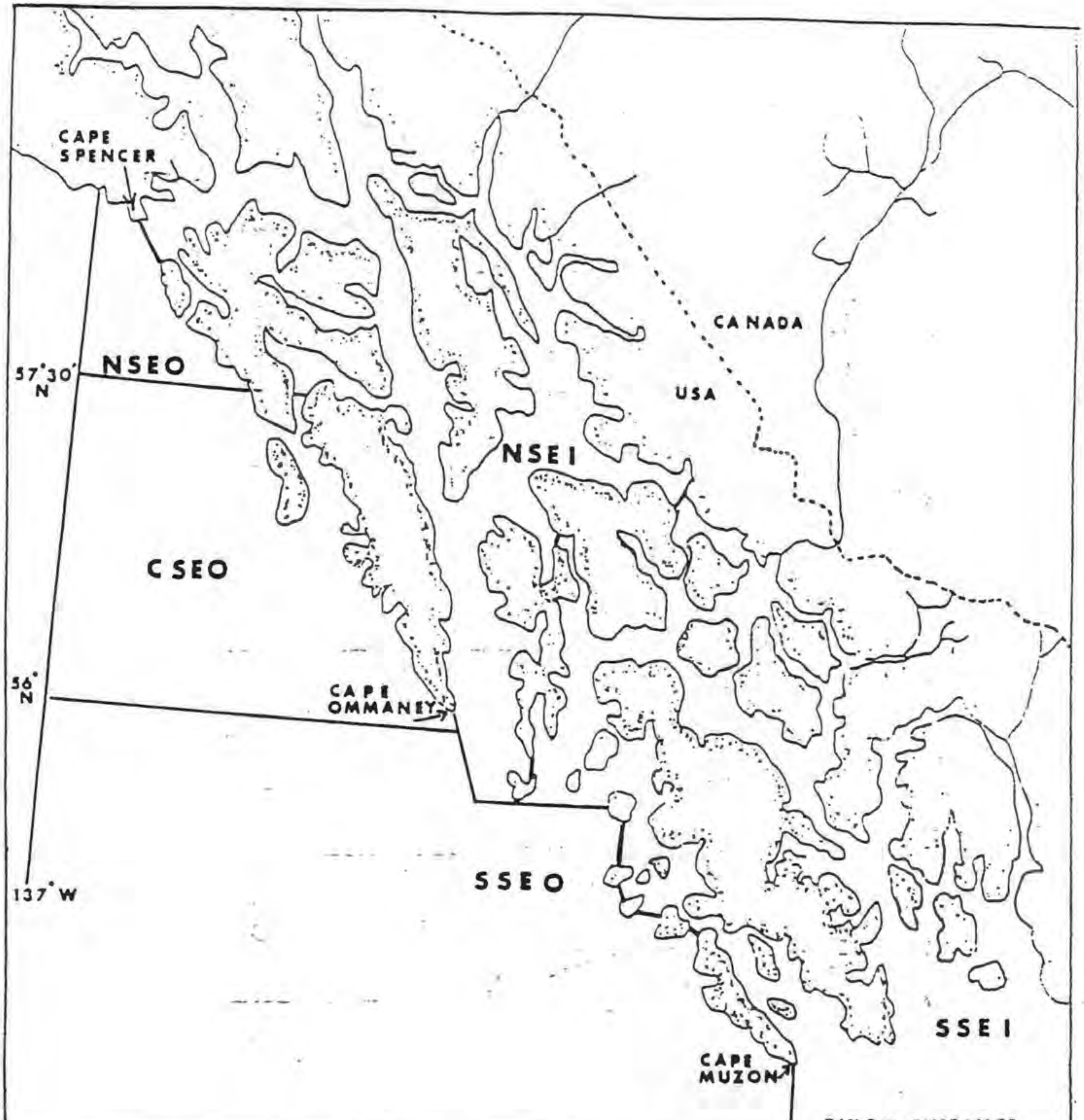

Figure 2. The Southeast Alaska coastline showing Alaska Department of Fish and Game groundfish management areas.

Table 5.1. Reported landings of demersal shelf rockfish from domestic fisheries in Southeastern Alaska in metric tons, 1982-1989.

Gulf of Alaska (East of 137°W longitude)			
Year	Directed Landings	Incidental Landings	Total Landings
1982	160	79	239
1983	291	103	394
1984	736	62	798
1985	665	38	703
1986	900	110	1,010
1987	1,034	174	1,208
1988	806	102	908
1989	452	226	678

Source: ADF&G fish ticket database.

Table 5.2. Rockfish catch data from the Southeast Outside District, Southeastern Alaska, 1989 from the ADF&G fishticket database.

SPECIES CODE	SPECIES NAME	MANAGEMENT GROUP*	LONGLINE POUNDS	LONGLINE PERCENT	TRAWL POUNDS	TRAWL PERCENT	OTHER HOOK & LINE POUNDS	OTHER HOOK & LINE PERCENT	ALL GEARS POUNDS	ALL GEARS PERCENT
137	BOCACCIO	DSR	935	59.0%	650	41.0%		0.0%	1,585	[illegible]
146	CANARY	DSR	3,936	98.6%		0.0%	56	1.4%	3,992	[illegible]
149	CHINA	DSR	3,179	100.0%		0.0%		0.0%	3,179	[illegible]
138	COPPER	DSR	422	98.1%		0.0%	8	1.7%	430	[illegible]
147	QUILLBACK	DSR	105,414	98.8%		0.0%	1,309	1.2%	106,723	[illegible]
153	REDSTRIPE	DSR	13	100.0%		0.0%		0.0%	13	[illegible]
150	ROSETHORN	DSR	5,736	99.3%		0.0%	39	0.7%	5,775	0.1%
157	SILVERGREY	DSR	2,023	13.1%	13,231	85.7%	178	1.2%	15,432	0.3%
148	TIGER	DSR	4,428	99.7%		0.0%	14	0.3%	4,442	[illegible]
168	UNSP. DEMERS	DSR	85,555	99.7%		0.0%	283	0.3%	85,838	[illegible]
140	UNSP.RED ROC	DSR	550	100.0%		0.0%		0.0%	550	[illegible]
145	YELLOWEYE	DSR	621,676	98.6%		0.0%	8,582	1.4%	630,258	13.4%
	TOTAL DEMERSAL		833,867	97.2%	13,881	1.6%	10,469	1.2%	858,217	18.2%
142	BLACK ROCK	PR	15,417	90.0%		0.0%	1,704	10.0%	17,121	0.4%
154	DUSKY	PR	3,232	4.0%	79,409	95.9%	97	0.1%	82,738	[illegible]
169	UNSP. PELAGI	PR	200	40.0%	187	37.4%	113	22.6%	500	[illegible]
156	WIDOW	PR	37	100.0%		0.0%		0.0%	37	[illegible]
155	YELLOWTAIL	PR	522	66.6%	234	29.8%	28	3.6%	784	[illegible]
	TOTAL PELAGIC		19,458	19.2%	79,830	78.9%	1,942	1.9%	101,230	2.2%
159	DARKBLOTCH	SR	1	100.0%		0.0%		0.0%	1	.0%
136	NORTHERN	SR	17	100.0%		0.0%		0.0%	17	.0%
141	POP	SR	1,704	0.1%	1,914,915	99.9%		0.0%	1,916,619	40.8%
153	REDBANDED	SR	9,388	96.7%	320	3.3%		0.0%	9,708	0.2%
151	ROUGHEYE	SR	127,140	31.6%	275,207	68.4%	48	.0%	402,395	8.5%
152	SHORTRAKER	SR	2,225	1.0%	227,703	99.0%		0.0%	229,928	4.9%
144	UNSP. SLOPE	SR	48,387	6.0%	756,405	94.0%		0.0%	804,792	17.1%
	TOTAL SLOPE		188,862	5.6%	3,174,550	94.4%	48	.0%	3,363,460	71.5%
143	IDIOTS (THORNYHEADS)	TR	92,017	2.0%	287,211	6.1%	200	.0%	379,428	8.1%
	TOTAL ALL ROCKFISH		1,134,204	24.1%	3,555,472	75.6%	12,659	0.3%	4,702,335	100.0%

* DSR = Demersal Shelf Rockfish
PR = Pelagic Rockfish
SR = Slope Rockfish
TR = Thornyhead Rockfish

Table [illegible]. Species composition of rockfish sampled in Southeast Alaska from hook and line catches in the Southeast Outside District, 1988 and 1989.

SPECIES CODE	SPECIES NAME	MANAGEMENT GROUP#	1988 NUMBER	1988 PERCENT	1989 NUMBER	1989 PERCENT	TOTAL NUMBER	TOTAL PERCENT
137	BOCACCIO	DSR	29	0.2%	5	0.2%	34	0.2%
146	CANARY	DSR	585	4.1%	1	.0%	586	3.5%
149	CHINA	DSR	267	1.9%	49	1.9%	316	1.9%
138	COPPER	DSR	23	0.2%	1	.0%	24	0.1%
147	QUILLBACK	DSR	3,137	22.1%	484	18.5%	3,621	21.5%
158	REDSTRIPE	DSR	39	0.3%	0	0.0%	39	0.2%
150	ROSETHORN	DSR	346	2.4%	65	2.5%	411	2.4%
157	SILVERGREY	DSR	214	1.5%	22	0.8%	236	1.4%
148	TIGER	DSR	256	1.8%	16	0.6%	272	1.6%
145	YELLOWEYE	DSR	7,574	53.4%	1,766	67.6%	9,340	55.6%
	TOTAL DEMERSAL		12,470	87.9%	2,409	92.3%	14,879	88.5%
142	BLACK ROCK	PR	811	5.7%	65	2.5%	876	5.2%
154	DUSKY	PR	425	3.0%	58	2.2%	483	2.9%
155	YELLOWTAIL	PR	205	1.4%	6	0.2%	211	1.3%
167	BLUE	PR	0	0.0%	3	0.1%	3	.0%
	TOTAL PELAGIC		1,441	10.2%	132	5.1%	1,573	9.4%
153	REDBANDED	SR	205	1.4%	70	2.7%	275	1.6%
151	ROUGHEYE	SR	65	0.5%	0	0.0%	65	0.4%
152	SHORTRAKER	SR	12	0.1%	0	0.0%	12	0.1%
	TOTAL SLOPE		282	2.0%	70	2.7%	352	2.1%
	TOTAL ALL ROCKFISH		14,193		2,611		16,804	

# DSR = Demersal Shelf Rockfish
PR = Pelagic Rockfish
SR = Slope Rockfish
TR = Thornyhead Rockfish

Table 5.4. Observer reports of rockfish catches by small and large foreign trawl vessels operating in the Southeast Outside District, 1980 and 1981.

			GEAR					
SPECIES CODE	SPECIES NAME	MANAGEMENT GROUP*	SMALL TRAWLERS		LARGE TRAWLERS		ALL GEAR	
			METRIC TONS	PERCENT	METRIC TONS	PERCENT	METRIC TONS	PERCENT
137	BOCACCIO	DSR	0.0	0.0%	0.5	0.1%	0.5	0.1%
146	CANARY	DSR	0.0	0.0%	0.1	.0%	0.1	.0%
149	CHINA	DSR	0.0	0.0%	0.0	0.0%	0.0	0.0%
138	COPPER	DSR	0.0	0.0%	0.0	0.0%	0.0	0.0%
147	QUILLBACK	DSR	0.0	0.0%	0.0	0.0%	0.0	0.0%
158	REDSTRIPE	DSR	0.0	0.0%	13.9	3.0%	13.9	3.0%
150	ROSETHORN	DSR	0.2	.0%	0.4	0.1%	0.6	0.1%
157	SILVERGREY	DSR	.0	.0%	13.6	3.0%	13.6	3.0%
148	TIGER	DSR	0.0	0.0%	0.0	0.0%	0.0	0.0%
145	YELLOWEYE	DSR	.0	.0%	2.1	0.5%	2.1	0.5%
	TOTAL DEMERSAL		0.2	.0%	30.5	6.7%	30.6	6.7%
142	BLACK ROCK	PR	0.0	0.0%	0.1	.0%	0.1	.0%
166	BLUE	PR	0.0	0.0%	0.1	.0%	0.1	.0%
154	DUSKY	PR	0.0	0.0%	1.6	0.4%	1.6	0.4%
156	WIDOW	PR	.0	.0%	6.1	1.3%	6.1	1.3%
155	YELLOWTAIL	PR	0.0	0.0%	0.2	.0%	0.2	.0%
	TOTAL PELAGIC		.0	.0%	8.0	1.8%	8.1	1.8%
159	DARKBLOTCH	SR	.0	.0%	0.6	0.1%	0.6	0.1%
136	NORTHERN	SR	0.0	0.0%	0.0	0.0%	0.0	0.0%
141	POP	SR	51.2	11.2%	149.0	32.7%	200.2	43.9%
153	REDBANDED	SR	0.6	0.1%	1.0	0.2%	1.6	0.4%
151	ROUGHEYE	SR	30.6	6.7%	36.5	8.0%	67.1	14.7%
152	SHORTRAKER	SR	26.4	5.8%	9.7	2.1%	36.1	7.9%
167	HARLEQUIN	SR	.0	.0%	44.6	9.8%	44.7	9.8%
165	SHARPCHIN	SR	0.6	0.1%	36.9	8.1%	37.5	8.2%
175	YELLOWMOUTH	SR	0.0	0.0%	13.8	3.0%	13.8	3.0%
	VERMILION	SR	0.0	0.0%	0.2	.0%	0.2	.0%
	SPLITNOSE	SR	0.0	0.0%	.0	.0%	.0	.0%
	AURORA	SR	.0	.0%	.0	.0%	0.1	.0%
	TOTAL SLOPE		109.5	24.0%	292.4	64.1%	401.9	88.1%
143	IDIOTS (THORNYHEADS)	TR	7.2	1.6%	8.3	1.8%	15.6	3.4%
	TOTAL ALL ROCKFISH		116.9	25.6%	339.2	74.4%	456.1	100.0%

* DSR = Demersal Shelf Rockfish
PR = Pelagic Rockfish
SR = Slope Rockfish
TR = Thornyhead Rockfish

Table 5.5. Rockfish which are included in the demersal shelf rockfish assemblage in the Gulf of Alaska.

Common Name	Scientific Name
Bocaccio	*Sebastes paucispinus*
Canary rockfish	*S. pinniger*
China rockfish	*S. nebulosus*
Copper rockfish	*S. caurinus*
Quillback rockfish	*S. maliger*
Redstripe rockfish	*S. proriger*
Rosethorn rockfish	*S. helvomaculatus*
Silvergray rockfish	*S. brevispinis*
Tiger rockfish	*S. nigrocinctus*
Yelloweye rockfish	*S.ruberrimus*

Table 5.6. Demersal shelf rockfish harvest guideline ranges in mt by Southeast Alaska rockfish management area and season segment for the 1989-90 fishing season.[1]

Management Area	October 1- November 30	December 1- May 15	July 1- September 30	Total
CSEO	65 - 86	63 - 84	23 - 30	150 - 200
NSEI	15 - 26	15 - 25	5 - 9	35 - 60
NSEO	11 - 22	11 - 21	4 - 8	25 - 50
SSEI	43 - 65	42 - 63	15 - 23	100 - 150
SSEO	54 - 73	53 - 72	19 - 26	125 - 170
TOTAL	188 -271	184 -265	66 - 95	435 - 630

[1] Target harvest levels for the 1989-90 season are underlined.

6.0 CHANGE FISHING GEAR RESTRICTIONS IN THE GULF OF ALASKA AND BERING SEA/ALEUTIAN ISLANDS

6.1 Description of the Problem and Need for the Action

The groundfish fisheries off Alaska are prosecuted with a variety of gear types. These gear types differ both in their usage to harvest groundfish and in unintended consequences of their use in areas such as bycatch, deadloss and conflicts with other gear. Present language of both FMPs concerning gear types is very limited. It offers little or no flexibility for the development of measures to mitigate problems in the groundfish fisheries associated with the use of particular gear types.

Section 4.3.1.3 Gear restrictions in the GOA FMP currently contains (1) restrictions on legal gear for harvesting sablefish and (2) time/area closures and reference to gear restrictions to protect king crab in the vicinity of Kodiak Island. It also includes anachronistic text that requires biodegradable panels on sablefish pots, which are not a legal gear type for sablefish in the Gulf of Alaska.

Section 14.4.4 Gear restrictions, in the BSAI FMP simply states "None".

The ability to define legal gear types for use in the groundfish fisheries off Alaska by regulatory amendment would give management the means to respond to problems appearing in rapidly evolving fisheries in a timely fashion. The GOA and BSAI FMPs could be amended to provide general guidance and Council policy with respect to gear restrictions under the current section headings that relate to gear. Possible text for both FMPs might be the following:

> "Gear types authorized by the FMP are trawls, hook-and-line, pots, jigs, and other gear as defined in regulations. Further restrictions on gear that are necessary for conservation and management of the fishery resources and which are consistent with the goals and objectives of the FMP are found at 50 CFR Part 672.24 [50 CFR Part 675.24].

Specific gear restrictions, however, would be found in the regulations implementing the FMPs. Except for changes in regulations necessary to implement the FMP amendments in this current amendment cycle, future changes to regulations with respect to gear restrictions would be accomplished with regulatory amendments. Existing pot and trawl gear restrictions in the GOA would be retained in the GOA regulations and FMP.

Three changes to regulations pertaining to gear restrictions are proposed as follows: (1) biodegradable panels on groundfish pots would be required; (2) halibut exclusion devices on groundfish pots would be required; and (3) pelagic trawls would be redefined.

Future changes to gear regulations would be accomplished by regulatory amendments with necessary environmental and socioeconomic analyses on a case-by-case basis.

A description of and need for each of the three changes to regulations pertaining to gear restrictions follows.

6.1.1 Biodegradable panels on groundfish pots

The NMFS permit database shows that 33 groundfish vessels are permitted in 1990 to use pot gear in the GOA and BSAI groundfish fisheries. Each vessel fishes about 70 pots. Pots that are lost at sea continue to "ghost" fish, i.e., fish continue to enter pots. Once in a pot, fish seldom escape. They die and decompose. Dead and live fish in pots will attract other fish, and scavengers such as crab, which will then enter the pot. This cycle continues indefinitely unless some way develops to allow trapped fish and crab to escape. Such fishing mortality is unaccounted and introduces additional uncertainty into estimates of abundance of fish stocks. It also is a potential waste of economically valuable resources that otherwise might have been harvested. The potential for ghost fishing is illustrated by Alaska Department of Fish and Game (ADF&G) findings with respect to crab pots. For example, crab pots left unchecked in Cook Inlet for 75 days during 1988 yielded 15,000 dead Tanner crabs.

To prevent groundfish waste, biodegradable panels are proposed to be required on all pots when fishing for groundfish in the GOA and BSAI. Biodegradable panels would be constructed according to ADF&G regulations for crab pots. ADF&G is currently recommending that crab pots be furnished with a panel of at least 18 inches in length that is parallel to, and within 6 inches, of the bottom of the pot. Each panel would be laced with #30 cotton twine. ADF&G studies indicate that biodegradable panels on king crab pots degrade within 50 to 100 days.

6.1.2 Halibut exclusion devises on groundfish pots

Halibut are caught as bycatch in groundfish pots, at least in the Gulf of Alaska. As more fishermen fish for Pacific cod in the Gulf, bycatch problems could increase. At its June 20-23, 1989, meeting, the Council requested NMFS to prepare a regulatory amendment that would prohibit the use of pots in the groundfish fisheries that do not reduce the catch of Pacific halibut (halibut) below levels being experienced with pots of contemporary design. The purpose underlying the Council's recommendation is to reduce halibut bycatches by requiring each groundfish pot be modified or constructed in such a way that halibut could not easily enter it. Reduced halibut bycatch would foster the Council's objective to develop management measures that encourage the use of gear that reduces the discard of fish, including prohibited species such as halibut, which are caught as bycatch in groundfish fisheries.

Discussions with management personnel in the ADF&G suggest that merely partitioning the pot opening into smaller openings may accomplish this objective. Narrow openings impede entry by halibut but do not impede entry by groundfish species targeted with pot gear, such as Pacific cod. Partitioning the pot opening might be accomplished by tying strong cords vertically across the vertical plane of a pot opening in such a way that either side of the partitioned opening would be no more than about 12 inches. Or, it might be accomplished by constructing a pot opening that has a width of no more than 12 inches, with no restrictions on the height of the opening.

Data to define the extent of the halibut bycatch problem in groundfish pot fisheries are scarce. However, data are available from crab indexing surveys using pot gear near Kodiak Island, which were conducted in summer months during 1972 - 1980 by the ADF&G. These data indicate the potential problem of halibut bycatch in groundfish fisheries using pots. Total numbers of pots checked annually during these years ranged from 895 to 2,390. During these years, a total of 16,079 pots were checked, and 4,158 halibut were caught for an average catch rate of 0.26 halibut/pot.

In contrast, the ADF&G monitored four commercial pot vessels in the Kodiak area during 1987-1988. These vessels used crab pots to fish for Pacific cod. Each pot was modified in various ways to reduce the catch of halibut. Some modifications were accomplished simply by partitioning the pot opening along the vertical plane by tying heavy twine at eight-inch intervals, thereby forming openings narrower than the single wide entrance. During these years, ADF&G monitored 667 pot lifts. Forty-five halibut were caught for an average catch rate of 0.07 halibut/pot. Although the catch rate by modified pots is small, the results cannot be compared to those from the king crab index surveys, because the time series and fishing locales are different. Nonetheless, information from ADF&G personnel who are familiar with fisheries in the Kodiak area suggests that narrow pot openings significantly reduced halibut bycatch.

Use of pots is not currently common in the groundfish fisheries. Pot catches of groundfish in 1989 totaled about 100 metric tons of groundfish, most of which was Pacific cod. About 70 pots are used on each vessel. If all vessels were fishing at the same time, 2,310 pots would be employed, and if each pot were lifted once, 112 halibut would be caught, assuming each pot was modified to reduce halibut bycatch and 0.07 halibut/pot was a typical bycatch rate. For comparison, 600 halibut would be caught if unmodified pots were used and the bycatch rate was 0.26 halibut/pot as observed during the king crab index surveys.

NMFS published an Advance Notice of Proposed Rulemaking on December 27, 1989 (54 FR 53135) and invited comments from the fishing industry until February 26, 1990 with respect to ways halibut bycatch in pots might be reduced. Information received to-date as a result is hereby summarized:

- Fishermen want to use halibut exclusion devices in pots to keep large halibut out, because pots quit fishing if large halibut get in.

- Small halibut that are caught in pots do not cause pots to cease fishing and often escape through the opening.

- A standard pot opening with a rigid opening is 9" high by 36" wide.

- Fishermen recommend the 36" width be split on the vertical plane to create two 18" wide openings.

- A 18" wide opening is necessary even though the widest Pacific cod rarely exceed 12 inches in width, because additional room is required to accommodate movement of the Pacific cod as it strives to enter the pot.

- Halibut bycatch in groundfish pots is a problem in the Gulf of Alaska but not in the Bering Sea.

- A Bering Sea study indicated that 367 pot lifts of pots equipped with Tanner crab boards caught zero halibut.

At this time, the NMFS Alaska Region is recommending a smaller opening than the 18-inch minimum opening recommended by the industry. An opening of 9 inches should allow entry of most Pacific cod, although the largest Pacific cod might not gain entry. A smaller opening would prevent entry by a larger number of smaller halibut.

6.1.3 New definition of pelagic trawl gear

A new definition of pelagic trawl is proposed (see Option C, below), which would result in a definition that reflects the way a pelagic trawl is fished, and which includes a modification that promotes the escape of halibut and crab that might be caught. Pelagic trawls are used to fish for pollock during certain times of the year in the BSAI and in the GOA when pollock move in schools off the bottom. Other groundfish, e.g. flatfish, Pacific cod, and demersal species of rockfish, are found on or in close proximity to the bottom, and cannot be fished effectively with pelagic trawls. Bottom trawls are used for these species. Pacific cod occur within 1 fathom of the bottom, but will dive toward the bottom when crowded by a moving trawl and escape under the footrope of a pelagic trawl. Pollock in the BSAI behave like Pacific cod during the period from October through the end of the fishing year. They tend to dive under the foot rope of a pelagic trawl, and, therefore can only be fished effectively with a bottom trawl during this period. Pollock in the GOA behave differently late in the year and are found off-bottom where pelagic trawls continue to be effective.

The current definition of a pelagic trawl reads as follows:

> Pelagic trawl means a trawl on which neither the net nor the trawl doors (or other trawl-spreading device) operates in contact with the seabed, and which does not have attached to it protective devices, such as rollers or bobbins, that would make it suitable for fishing in contact with the seabed.

Prohibitions on parts of the pelagic trawl contacting the bottom that are part of the current definition are not enforceable and therefore should not be part of the pelagic trawl gear definition. Rather, pelagic trawl gear should be defined to reflect the way it is fished. Pelagic trawl gear is not fished on the bottom, but may contact the bottom at times. The above restrictions about parts of the trawl not contacting the seabed were intended to minimize the bycatches of halibut and crab. Ideally, however, trawl gear definitions should allow for maximum groundfish catches while catching minimal prohibited species catches (PSCs) of halibut and crab.

6.2 The Alternatives

6.2.1 Alternative 1: Do nothing - maintain the status quo.

Adoption of this alternative would maintain current gear definitions in the two FMPs and would not provide for biodegradable panels and halibut exclusion devices in pots.

6.2.2 Alternative 2: (Preferred) Specify legal fishing gear in the GOA and the BSAI FMPs and provide specific gear restrictions in the regulations.

Adoption of this alternative would clarify what gear is legal in the GOA and BSAI and would provide for specific gear restrictions in the implementing regulations. Future changes to gear restrictions could be made by regulatory amendment. Three options are recommended. Any one or all three options may be adopted by the Secretary.

Option A: Biodegradable panels on groundfish pots.

Require biodegradable panels on all pots used to fish groundfish in the GOA and BSAI. This option would be coordinated with regulations of the Alaska Department of Fish and Game. The Department has submitted a proposal to the Alaska Board of Fisheries that would require pots used in the shellfish fisheries and also in the groundfish fisheries have biodegradable panels. Using proposed Alaska Codes 5 AAC 39.145 and 5 AAC 02.010 as models, a federal regulation might read:

> "Each pot used in the groundfish fisheries must have a biodegradable panel at least 18 inches in length that is parallel to, and within 6 inches of, the bottom of the pot, and which is sewn up with untreated cotton thread of no larger size than #30.

Option B: Halibut exclusion devices on groundfish pots.

Require halibut exclusion devices on all pots used to fish groundfish in the GOA and BSAI. A regulation might read:

> "All pots used in the groundfish fisheries must have tunnel openings that are no wider than 9 inches and no higher than 9 inches."

Option C: New definition of pelagic trawl gear.

Adoption of this option would provide for a redefinition of pelagic trawl gear. An appropriate pelagic trawl definition might read:

> Pelagic trawl means a trawl which has stretch mesh size openings of at least 1 meter, or parallel lines with spaces of at least one meter, starting at the fishing line and extending aft for a distance of at least 10 meshes and going around the entire circumference of the trawl, and which is tied to the fishing line with no less than 0.3 meter (12 inches) between knots around the circumference of the net, and which does not have plastic discs, bobbins, rollers, or other chafe-protection gear attached to the foot rope.

This proposed definition excludes reference about whether the net or trawl doors come in contact with the seabed. Whether these parts come in contact with the seabed is not enforceable. The purpose of the large mesh sizes in back of the fishing line is to provide escape panels for halibut and crab in case the pelagic trawl contacts or comes near the seabed, resulting in a bycatch of halibut and crab. Requiring 12-inch spacing around the net circumference instead of just the belly panel would prevent a loophole where a fisherman could fish a net up-side down. When bycatch PSC limits of halibut or crab are reached, closure notices would stipulate that further trawling with trawls other than pelagic trawls would be prohibited.

Historical joint venture data provide evidence that halibut and crab bycatches are minimal when using pelagic trawl gear configured as described in the above definition.

This pelagic trawl as defined would have the advantage of reducing drag for the towing vessel while reducing bycatch of halibut and crab.

6.3 Socioeconomic impacts of the alternatives.

Option A: Biodegradable panels on groundfish pots.

Status quo alternative. Biodegradable panels would not be required for groundfish pots. Lost pots would continue to fish. Mortality of fish and crab is a cost under this alternative and may result in economic losses to fishermen. Thirty-three vessels are permitted to fish with pots in 1990. The average number of pots per vessel is about 70, although some vessels may use as many as 90 pots.

Based on ADF&G experiences in the crab fishery, 5 percent of the pots may be lost in groundfish operations, thus a loss of 132 pots, or four pots per vessel, might be expected during 1990. The actual amount of fish that might be caught by lost pots through ghost fishing is not known, because fish are often consumed by sand fleas or other scavengers when trapped in pots.

Some examples of costs are available. The Alaska Department of Fish and Game conducted test studies of crab abundance in the Bering Sea during late 1987 and early 1988, which resulted in the recovery of king crabs from twenty-one lost crab pots. These crabs were sold by the ADF&G for $70,000. The 15,000 Tanner crabs found in the pots in Cook Inlet, noted in the problem statement, were worth $82,400, based on a weight of 2.3 pounds per crab and a value of $2.40 per pound.

Proposed regulatory measure. Biodegradable panels would be required for each groundfish pot. The panel would deteriorate over a time period, creating an opening in a lost pot and enabling animals to escape. Costs to fishermen would be minimal.

Fishermen would be required is to open up the web on a pot for a length of at least 18 inches and then re-sew it with #30 untreated cotton thread. #30 cotton thread deteriorates in about 50-100 days.

Assuming 70 pots per vessel and thirty-three vessels, fishermen would have to replace the biodegradable panel on 2,310 pots about every two months. Panel replacement might take about ten minutes. Replacing panels on all pots would require about 385 hours every two months, or about 1,155 hours annually, assuming the pot gear is fished for six months per year. Assuming $15 per hour for labor, costs for all thirty-three vessels would be $17,325 annually, or $525 per boat.

No administrative costs would be incurred under the status quo or proposed options. Enforcement officers would monitor pots on board a vessel to determine whether they were constructed in compliance with the definition of a legal groundfish pot. Pots actually fishing could not be checked.

Option B: Halibut exclusion devices on groundfish pots.

Status quo alternative. Under this alternative, no limitations on pot gear for purposes of impeding entry by halibut would be required. No additional costs resulting from materials or labor needed to modify groundfish pots with exclusion devices would be imposed on fishermen. Halibut that gain entry into groundfish pots would be removed from the directed halibut fishery. Information provided above indicated that the halibut bycatch rate in unmodified pots is 0.26 halibut per pot per set. Thirty-three vessels using 70 pots per vessel could deploy 2,310 pots simultaneously. Using the halibut bycatch rate of 0.26 halibut per pot, 600 halibut could be caught in an aggregate set. If a pots are used for six months annually, and are checked every three days on average, 36,000 halibut per year could be lost as bycatch.

Proposed regulatory measure - All pots used in the groundfish fishery would be modified such that the width of each opening was no wider than 9 inches and no higher than 9 inches. Because openings on pots with rigid openings are already no higher than 9 inches, no further modification of the heights would be required. Widths on rigid pot openings, however, likely must be modified. Commercially constructed openings usually are 36 inches wide. Some have halibut exclusion devices that divide the widths into two equal openings.

Under this proposal, each opening would be partitioned vertically such that the widest opening would no more than 9 inches, which would result in four openings with widths 9 inches wide, for example. The vertical partition could be constructed with rigid material such as metal or non-rigid material such as heavy monofilament thread. In the latter case, costs would be mostly those attributed to labor.

Using an average of 70 pots per vessel, thirty-three vessel operators must construct exclusion devices on 2,310 pots. Constructing the exclusion devices by installing vertical partitions in openings might require 30 minutes per pot. Modifying the openings on 2,310 pots would then take 1,155 hours. Assuming $15 per hour for labor, total costs for all thirty-three vessel operators would be $ 17,325. Each of thirty-three vessel operators, therefore, would incur $525 in labor costs to install and maintain halibut exclusion devices.

No administrative costs would be incurred under the status quo or proposed options. Enforcement costs under this option should not change significantly relative to the status quo. Boarding officers would monitor pots on board a vessel to determine whether they were constructed in compliance with the definition of a legal groundfish pot. Pots actually fishing could not be checked.

Benefits to halibut fishermen would accrue as a result of adoption of this alternative. As noted in the problem statement, the bycatch rate, per set, of unmodified pots was 0.26 halibut per pot. The bycatch rate of pots modified to have openings no wider than eight inches was 0.07 halibut per pot per set. The difference - 0.19 halibut per pot per set - represents 439 halibut in a simultaneous set by all 33 vessels of a total of 2,310 pots. If pots are fished six months per year, and each set lasts three days, each pot is set 60 times per year. Therefore, approximately 439x60=26,340 halibut would not be taken as bycatch per year in the groundfish pot fishery, if halibut exclusion devices were required on all groundfish pots.

A plausible range of values for these 26,340 halibut can be presented. If halibut that are caught as bycatch in pots are 1.03 kilogram in size, they are estimated to be 4 year-old fish. A metric ton of halibut of this size would contribute 10,316 pounds in a directed halibut fishery if they had not been caught as bycatch, assuming they recruit into the fishery at 8 years of age and allowing for growth and natural mortality. At a 5 percent annual discount rate over four years, the loss of 10,316 pounds of halibut as bycatch would have a present wholesale value of $11,800. If the average size of bycaught halibut was 10.7 kilograms, they are estimated to be eight year-old fish, the age of recruitment into the directed fishery. A metric ton of halibut of age 8 as bycatch represents a metric ton, or 2205 pounds, of halibut unavailable to the directed fishery. The present wholesale value of these fish would be $3065 ($1.40 per pound). Using these examples for perspective, 26,340 halibut at age 4 would have weighed 27.13 mt, and would have a present wholesale value of about $320,000 (5% discount per year, allowing for growth and natural mortality). At age 8, 26,340 halibut would weigh about 281.8 mt and have a present wholesale value of about $863,000. The range of $320,000 to $863,000 represents possible annual benefits to the directed halibut fishery if the bycatch rate per pot per set drops from 0.26 halibut per pot to 0.07 halibut per pot due to the installation of halibut exclusion devices.

Option C: New definition of pelagic trawl gear.

Status quo alternative. Under this alternative, no changes in the definition of pelagic trawl would be implemented. Any bycatches of halibut and crab that are caught when fishing near the ocean bottom might not escape unless fishermen were using pelagic trawls configured in a manner described for the proposed definition. No industry, enforcement, or administrative costs would change under this alternative.

Bycatches of crab and halibut are small in fisheries that use pelagic trawls. Evidence for this is found in bycatch rates experienced by joint venture fishermen during 1986-1988 (see NOAA Technical Memorandum NMFS F/NWC-155). Industry representatives suggest that a reason for low bycatches is the large mesh openings already used in pelagic trawls. Large mesh openings are necessary to reduce drag. They also provide escape routes for crab and halibut. If all pelagic trawls are already constructed using large mesh openings, then the status quo alternative is essentially the same as the proposed regulatory measure (described below), except that the proposed measure includes specific dimensions for the web openings. Crab and halibut will be caught in the same amounts in either case. The same savings with respect to reduced bycatches of halibut and crab will accrue in either case.

Proposed regulatory measure. Under this proposed option, all pelagic trawls, which are used by fishermen while fishing, or which are on board any vessel used for trawl fishing, must be constructed to meet the requirements of the definition. All operators of trawl vessels that use pelagic trawls must modify their trawls or purchase new trawls. The costs of modifying a trawl to meet the new definition, including labor costs, are estimated to be about $1,000 per trawl. This is the cost of adding a panel with 1 meter meshes around the net for a distance of 10 meters from the fishing line. Vessel operators who do not already own such a modified pelagic trawl must obtain one to comply with the definition. It does not include the basic cost of purchasing a new trawl, which would be incurred regardless.

Every trawl vessel operator would have to comply with the definition if they are using pelagic trawls. As many as 205 trawl vessels could be involved, if each operator had to modify at least one trawl to conform to the definition. This is the number of trawl vessels that made groundfish landings in 1989. A total cost of $205,000 could be incurred at a cost of $1,000 per modification. Industry sources have stated that many of the large catcher/processor vessels already use pelagic trawls that are modified as described. In 1989, 55 catcher/processors using trawl gear that are 125 feet long or longer, LOA made landings. The actual number of vessels that might need net modifications might be reduced, therefore, by 55, from 205 to 150. A total cost of $150,000, therefore, might be incurred as a result of only a portion of the trawl fleet having to modify their trawls.

As discussed under the status quo, no differences in savings with respect to bycatches of halibut and crab will occur under either alternative if pelagic trawls that are now being used accomplish the intent of the definition.

No administrative costs would be incurred under the status quo or proposed options. Actual enforcement costs under this proposed option should not change significantly relative to the status quo. Under the status quo, however, the definition of a pelagic trawl includes a stipulation that none of the net parts, including the trawl doors, can operate in contact with the sea bed, which is not enforceable. This stipulation would be deleted under the proposed option. Boarding officers would monitor nets on board a vessel to determine whether nets being used were in compliance with the definition of a pelagic trawl. Nets that are on reels would be checked, which might require partial unwinding of the reel until the initial 10 meters of net webbing in back of the fishing line were visible, causing a small enforcement cost in terms of time. Nets that are on the deck could be checked easily.

6.4 Environmental impact of the alternatives

Option A: Biodegradable panels on groundfish pots.

If trapped fish and shellfish cannot escape lost pots, they will perish and be removed from the ecosystem as predators or prey. Other predator species or scavengers would consume the trapped animals. Species attracted to the pots may be fed upon by other predators. If escape is possible, however fish and shellfish would remain in the ecosystem in their normal roles as predator or prey. While actual effects on the ecosystem are not measurable they are likely insignificant compared to natural variability.

Option B: Halibut exclusion devices on groundfish pots.

Under this alternative, substantially fewer halibut would enter groundfish pots, and therefore perish. Because the International Pacific Halibut Commission deducts estimated bycatch from its annual quotas for directed fishing. No direct impacts to the halibut resource are expected from the adoption of this alternative.

Option C: New definition of pelagic trawl gear.

Bycatches of halibut and crab in pelagic trawl fisheries will continue to be small under either the current or proposed definition of a pelagic trawl. To the extent that the changes in the configuration of the pelagic trawl as described for the proposed definition would result in even fewer numbers of halibut and crab being caught is an ameliorating, albeit largely unmeasurable environment effect. The normal roles of halibut and crab as predator or prey species would continue. As predators they will continue to consume other organisms. As prey, they will continue to be consumed. Actual effects on the ecosystem are considered to be insignificant compared to natural perturbations in the environment.

7.0 EXPAND HALIBUT BYCATCH MANAGEMENT MEASURES FOR THE GULF OF ALASKA

7.1 Description of the Problem and Need for Action

The incidental catch and mortality of halibut in the groundfish fisheries of the GOA is a major bycatch management issue. Halibut are distributed throughout the Gulf, and are taken as bycatch by all gear groups. Halibut bycatch mortality limits established by the Council constrain the full prosecution of GOA groundfish fisheries, and thus have economic consequences to all sectors of the fleet.

In 1989 the Council adopted Amendment 18 to the GOA FMP which suspended the PSC framework for 1990 and established halibut prohibited species (PSC) mortality caps of 2,000 mt for trawl gear and 750 mt for fixed gear for the 1990 fishery. In 1991 and beyond, the Council will return to a halibut PSC management system prescribed in the PSC framework.

The halibut PSC framework provides a process through which the NMFS Regional Director (RD), in consultation with the Council, can manage halibut bycatch. Specifically, the framework allows the RD to annually determine:

(1) The level of PSC limit for DAP and JVP fisheries,

(2) The level of PSC limit for specific gear,

(3) The level of PSC limit by Regulatory Area/District,

(4) The level of each PSC limit by fishery,

(5) Whether PSC limits will be allocated to individual operations,

(6) The methods of allocation to be used, and

(7) The types of gear or modes of operation to be prohibited once a PSC limit is taken.

The regulations that implemented the PSC framework have resulted in significantly less flexibility. Specifically, commencing with the 1991 fishing year, regulations will allow annual determinations of (1), (2), and (3). Specifically not provided for in regulations (or judged to be unclear for implementation in regulations) are items (4), (5), and (6). Item (7), regarding the types of gear prohibited once the PSC limit is reached, is included in the regulations, but the ability to change the prohibited gear types is not included.

The omission of item (4) from the regulations means that the halibut PSC framework cannot be used to establish separate PSC limits for distinct DAP fisheries, such as pollock bottom trawl, deep water flatfish bottom trawl, pollock midwater trawl, Pacific cod pot, or other specific fisheries. The problem this creates is that one fishery can close another or, in the extreme case, prevent another fishery from occurring.

Items (5) and (6) pertain to allocation of PSC limits to individual operations and to methods of allocation that might be used. Omission of these items from the regulations diminishes the ability to reduce halibut bycatch at the lowest possible cost and, perhaps, in the most equitable manner, depending on measures that might be developed to implement them. One such measure is the use of vessel incentives, which are now only partly developed in current regulations. Vessel incentives are intended to encourage vessel operators to actively avoid or reduce halibut bycatches, and by doing so, to gain additional fishing opportunities.

Under current regulations, if the halibut PSC is reached the RD may allow some or all vessels to continue fishing after issuing findings about certain considerations, including:

(1) The extent to which these vessels had avoided incidental halibut catches up to the time of a closure;

(2) The confidence of the RD in the accuracy of the estimates of incidental halibut catches up to the time of the closure; and

(3) Whether observer coverage of these vessels would be sufficient to assure adherence to prescribed conditions and to alert the RD to increases in a vessel's halibut bycatch rate.

These regulations explicitly infer that only certain vessels would have access to additional fishing opportunities. Vessels that had avoided halibut bycatches to the satisfaction of the RD would be rewarded with additional fishing opportunities. Vessels that could not demonstrate halibut bycatch avoidance would not have such opportunities. In 1989, these regulations encouraged at least one processor to employ observers for purposes of satisfying the first and second consideration in hopes of being allowed to continue bottom trawling once the PSC limit was reached.

Using the current regulations, NMFS closed the GOA to further bottom trawling on September 2, 1989 when the PSC limit for halibut had been reached.

When the PSC limit was reached, however, the regulations proved inadequate to implement an incentive program as envisioned by the industry. Although the regulations provided NMFS with authority to allow certain participants to continue bottom trawling, they failed to provide guidance as to how NMFS should discriminate among participants. As a result, NMFS implemented an after-the-fact vessel incentive program, in which all vessels could participate with bottom trawl gear if they carried an observer regardless of their previous fishing practices. As part of the program, NMFS stipulated acceptable halibut bycatch rates. When observer information indicated a vessel had exceeded these rates, the vessel was prohibited from further fishing.

NMFS declined to exclude vessels that had relatively high bycatch rates during the 1989 fishery prior to the general closure. NMFS had not established standards and criteria to guide vessel operators as to what bycatch rates would be considered unacceptable. Without standards and criteria, NMFS was not able to exclude vessels from an after-the-fact vessel incentive program in a way that would have been fair and equitable. Without standards and criteria, some participants would have been able to present good arguments that they had avoided halibut while fishing for groundfish, based on bycatch rates they had experienced, regardless of the level of observer coverage.

To make a vessel incentive system fair and equitable, regulations need to be amended in such a way that standards and criteria on which to base necessary findings would be available and known in advance by the fishing industry. Development of Items (5) and (6) should include vessel incentives with methods described such that participants would know what fishing standards they would be held accountable for and what mechanisms would be used to allow additional fishing opportunities.

The PSC framework does not clearly provide for seasonal allocation of PSC limits, although it could be argued that such a management measure is inferred in item (6). Seasonal PSC limits could optimize groundfish catch in some fisheries since PSC would be available during periods of time when certain fisheries were most active.

Although item (7) is not completely included in the regulations, the 1991 regulatory provisions will permit apportionment of the PSC limits to trawl and to fixed gear groups. When a PSC limit for trawl gear is reached, bottom trawl fisheries will close. When a PSC limit for fixed gear is reached, both longline and pot gear fisheries will close. In the first case, there will be an equity problem, in that one fishery may close another without being closed itself (e.g. the pollock midwater trawl fishery may continue while all bottom trawl fisheries are closed). This situation is exacerbated by developments in trawl technology that result in "midwater trawl" gear that can be fished near-bottom, possibly with higher halibut bycatch rates than previously assumed. (A proposal to clarify definitions of trawl gear types is being examined in Chapter 6 of this EA/RIR.)

In the second case (fixed gear fisheries for 1991 and beyond), a single PSC limit will apply to all fixed gear types. This also may result in an equity problem since longline gear bycatch could greatly limit or even preclude pot fisheries. Industry has expressed interest in expanding a pot fishery for Pacific cod; however, without a separate PSC limit for pot gear, or perhaps an exclusion of pot fisheries from the PSC framework, this fishery may not fully develop.

An additional problem in bycatch management is caused by the current olympic system of managing the groundfish fishery, where any properly-licensed vessel can compete for a limited amount of available groundfish. This open access to the groundfish fishery causes a race for fish, as each individual operator attempts to harvest as much groundfish as possible before the TAC is reached. PSC limits do not stop the race, but may actually accelerate the race as the PSC limit is approached. This occurs as operators attempt to maximize their groundfish harvest before the PSC limit is attained without regard to the bycatch rates encountered. Without incentives for individual vessels to reduce bycatch rates or maintain low rates during this period, this trend will likely continue.

Although bycatch management has been improved with the implementation of Amendment 18, the Council still recognizes that further refined measures are desirable. Some of the problems associated with the existing halibut bycatch management régime are:

(1) It is not equitable. One fishery can close another, and individual fishermen who reduce bycatch or bycatch rates do not benefit relative to those who do not.

(2) It is not effective. It does not prevent the desired level of bycatch from being exceeded.

(3) It is not efficient. It results in unnecessary costs, including those associated with both discard waste and an arbitrary distribution of the effort among the fisheries to reduce bycatch rates.

(4) It has not equitably distributed the cost to the groundfish fisheries of reducing bycatch rates.

Some halibut bycatch management measures may not be practicably analyzed at present. There are very limited data on actual bycatch rates in all DAP fisheries to fully explore an analysis of allocating PSC limits to separate target fisheries. Definitions of pot and trawl gear, including analysis of requiring halibut exclusion devices and biodegradable panels on groundfish pots, are being addressed in Chapter 6 of this EA/RIR and will not be evaluated here.

7.2 The Alternatives

The alternatives proposed in this chapter include: (1) taking no action, thus returning to the existing halibut bycatch framework in 1991; (2) adding halibut bycatch measures currently specified in the framework and FMP but which are not included in the regulations; and (3) adding an incentive program to the halibut bycatch management program designed to reduce the number of vessels that exhibit excessive halibut bycatch rates.

7.2.1 Alternative 1: Do nothing - maintain the status quo.

Under this alternative, the halibut bycatch management program for 1991 for the GOA will allow the RD to determine annually:

(1) The level of PSC limit for DAP and JVP fisheries,

(2) The level of PSC limit for the trawl gear group and the fixed gear group, and

(3) The level of PSC limit by Regulatory Area or District.

The Council has requested that changes in the definitions of trawl and pot gear be evaluated. If no changes are approved, the status quo will include a prohibition of pot gear in the sablefish fishery and no requirements of pot gear to minimize halibut bycatch. Status quo also may include continued unclear definitions of midwater and bottom trawl gear. However, a greatly expanded domestic observer program initiated in 1990 will allow the Council and RD to account for halibut mortality in all fisheries more accurately and provide greater flexibility to close fisheries based on actual observed mortality versus assumed mortality based on assumed bycatch and mortality rates.

7.2.2 Alternative 2: (Preferred) More fully implement and clarify the existing halibut PSC framework.

This alternative provides two options the Council considered in improving halibut bycatch management specified in the PSC framework. These measures are:

Option A: Apportion the halibut PSC limits by season, and/or

Option B: Set levels of fixed gear halibut PSC limits by (a) longline and (b) pot gear groups, or omit entirely pot gear fisheries from the framework.

Options A and B are not mutually exclusive and a halibut bycatch control program could be constructed by combining either or both measures in this alternative with an incentive measure from Alternative 3.

Setting halibut PSC limits by season was requested by the Council for the 1990 fishing year. Using emergency rule authority, the Council asked the Secretary to apportion the 2,000 mt trawl and 750 mt fixed gear PSC limits as follows:

Trawl gear:	30% (600 mt) first quarter
	30% (600 mt) second quarter
	40% (800 mt) third and fourth quarters combined.
Fixed gear:	20% (150 mt) first quarter
	60% (450 mt) second quarter
	20% (150 mt) third and fourth quarters combined

The Council's intent was to spread the bycatch limits over the year to the greatest extent possible to minimize economic hardships resulting from fisheries closing earlier than expected. Unused PSC from any quarter would roll over into the next.

A further apportionment of the fixed gear PSC limit into separate pot and longline PSC amounts would treat each gear group more equitably. However, the very low bycatch rates experienced with pots, coupled with a revised definition of pot gear to require halibut excluders (see Chapter 6 of this EA/RIR), may justify eliminating pot gear from the PSC framework. When implementing the above emergency rule, the Secretary in fact exempted pot fisheries for the 90-day duration of the rule (February 15-May 15, 1990). If this suboption were adopted, pot fisheries could be prosecuted during the entire year and would not be affected by PSC limit closures in hook-and-line or trawl fisheries.

The Council adopted both options under this alternative, and preferred the suboption which would establish a separate halibut PSC limit for pot gear. It felt that (1) it was inequitable to exempt a gear type known to take PSC species from PSC caps when other gear groups were subject to caps, and (2) a PSC cap for this gear group provides a measure of protection for the resource in the event of unanticipated changes in the fishery.

7.2.3 Alternative 3: (Preferred) Implement a program to identify and penalize vessels that exhibit excessive bycatch rates of halibut.

The halibut PSC framework contained in Amendment 14 to the GOA Groundfish FMP was developed with the premise that PSC limits would provide a fleet-wide incentive to reduce halibut bycatch rates and thereby allow the fishery to more fully prosecute the available groundfish TAC. However, there is no evidence to suggest that the fleet will take measures to reduce bycatch rates in the absence of an incentive program. Without incentives, vessels may not continue reduced bycatch rates because the cost, in lower groundfish catch rates, is not borne by other groundfish fishermen. Thus, the practical effect of PSC limits in the current regulatory environment seems to be that the "race for fish" in an "olympic" fishery reduces the emphasis on halibut bycatch rates and may even increase bycatch rates. As a result, the halibut PSC limit is reached at an earlier date each successive year.

This effect is most pronounced in the BSAI trawl fisheries, which is discussed in Chapter 2 of this EA/RIR. The effect is less so in the Gulf of Alaska, but the concern by industry is sufficient that they petitioned the Council to apportion the 1990 halibut PSC limits by quarter so that fall and winter fishing would not be closed due to an early attainment of the PSC limits (seasonal PSC apportionments are addressed in Alternative 2 of this chapter).

Alternative 3 provides for a program to identify and penalize vessels that exhibit excessive bycatch rates of halibut. The program would be applied to trawl vessels that use other than pelagic trawl gear and to vessels that use hook-and-line gear in the directed fishery for Pacific cod.

Each vessel participating in the program would be placed in one target fishery category each week based on its total GOA groundfish catch (not retained catch) during that fishing week. The rules for identifying the fishery for each vessel and fishing week are as follows (N.B. the percentage figure following the fishery refers to the minimum proportion of the specified species in the overall groundfish catch):

(1) bottom trawl pollock: 50%

(2) Pacific cod: 50%

(3) rockfish: 35%

(4) deep water flatfish: 35%

(5) shallow water flatfish: 35%

(6) arrowtooth flounder: 35%

(7) all other trawl fisheries using other than pelagic trawl gear: 35%

(8) Pacific cod (hook-and-line gear): 35%

A vessel will be assigned to the first fishery for which it meets the minimum catch requirement; therefore, both the minimum catch composition rule and the order of the rules are important in identifying the fishery for a vessel each week.

This program would be based on bycatch rates observed on vessels such that:

(a) Weekly monitoring of each vessel's observed bycatch rates would be conducted to determine the vessel's average bycatch rates for each evaluation period. The evaluation period would be one week building up to the preceding four week period.

(b) All vessels with at least 2 days observer coverage during a fishing week will be included in the program for that week.

(c) Observed bycatch rates would be based on total catch rather than retained catch.

(d) If a vessel's average rate for any of the three bycatch species exceeds 2 times the fishery average for the evaluation period, that vessel will be suspended from further directed fishing for groundfish in all Federally managed waters off Alaska and adjacent State of Alaska waters. The Council considered, but did not adopt, an option that no vessel would be penalized if it meets the historic industry average based on an update (1986-1989) of the rates in the NOAA Technical Memorandum NMFS F/NWC-155.

(e) Suspension periods would be five days for the first offense, two weeks for the second offense, and six weeks for the third offense. Multiple offenses would be counted "within PSC species" only. The period for accruing multiple offenses would be the most recent twelve month period.

(f) Unless otherwise required to do so by the domestic observer program, vessels returning to the fishery after suspension for a second offense would be required to carry an observer for the following two weeks. Vessels returning after a third offense would be required to carry an observer for the following four weeks.

(g) This program assumes that various fisheries can be adequately defined based on the definitions listed above. Revisions to these definitions will be based on the best information available.

(h) The number of target fishery cells to which the program will be applied will be determined by the Regional Director, in consultation with Council, based on optimal utilization of resources available to him.

The Council had considered other incentive programs to reduce halibut bycatch rates in the Gulf of Alaska. These programs, however, were ultimately judged too complex to implement at this time given the limited amount of observer information collected to date during the newly implemented observer program and limitations on technical and administrative abilities to carry out the program the way the Council intended. The alternative incentive programs included a PSC reserve option and a PSC bycatch credit option. Modifications of both programs may be considered by the Council under future regulatory amendments once the observer database is sufficiently expanded and/or technical and administrative constraints can be addressed.

7.3 Biological and Physical Impacts

7.3.1 Terms of Reference

To understand the proposed alternatives for bycatch management it is necessary to define and describe several terms:

Bycatch is an incidental byproduct of operations targeting other resources. An example is halibut taken in groundfish trawl fisheries. In contrast to target fishing, an important variable determining amount of bycatch is the density of that part of the population susceptible to the gear. However, size of the susceptible bycatch biomass is not the only variable. Magnitude of the target fishery, both in amount and rate of fishing, is important along with harvesting areas and times and fishing strategy and technique.

Bycatch rates in groundfish fisheries are generally expressed as numbers of crabs or metric tons of halibut (or other fish species) per metric ton of groundfish.

Fishing and bycatch exploitation rates are expressed in a number of different ways that sometimes add confusion to the bycatch issue. For example, a 40% annual exploitation rate on crab normally means that, on the average, 40% of the available male crab over a certain minimum size are taken each year by the directed pot fishery. The situation is similar for the halibut longline fishery since quotas and rates of harvest are generally computed for the exploitable or legal-sized biomass. However, the population effects of bycatch are normally evaluated as the impact on the entire population that is vulnerable to the groundfish gear.

Incidental mortality is the sum of (1) bycatch retained, (2) non-retained bycatch that dies as a result of capture and handling, and (3) individuals that are killed by the gear but are not observed as bycatch taken aboard. There can be a great deal of variability in mortality depending upon gear and mode of operation as well as size and condition of the individuals present. At the high end of the range is the common assumption of 100% halibut mortality in trawl fisheries with codend transfers or long towing and sorting times. An example of an intermediate value is the halibut mortality rate of 50% for short trawl tows with rapid sorting. "Low-end" halibut mortality rates would be 13% from longline gear or 12% from groundfish pots. These rates are currently used by the IPHC and the Gulf of Alaska Plan Team in assessing halibut bycatch.

Adult equivalents is a term that expresses the bycatch of different age/size groups in standardized units. This allows for a direct comparison of the catch of bycatch species, generally juvenile in size and age, to the harvest of adults taken by the directed fisheries for those species. The IPHC staff has developed a method of accounting for halibut bycatch mortality that determines the short-term yield loss to the directed halibut fishery. In this case, bycatch mortality is multiplied by an adult equivalent factor to determine the amount of lost yield. The adult equivalent factor represents lost growth of sublegal halibut combined with halibut fishery quota reduction and is estimated at 1.6.

7.3.2 Biological Background

The estimated coastwide exploitable biomass of Pacific halibut peaked in 1986 at approximately 259 million pounds and has declined to approximately 232 million pounds in 1988. The overall biomass, however, has remained near historical levels and the minor decline of the exploitable biomass of Pacific halibut was caused by a drop in abundance of young fish. It is not certain if the decline in young fish is a short-term or long-term trend. Stock assessments for the Gulf of Alaska area indicate that biomass more than doubled from 1974 to 1986. In spite of recent declines, current estimated abundance for that area is above the biomass that produces MSY.

Foreign, joint venture, and domestic trawl and longline halibut bycatch mortality in the Gulf of Alaska has resulted in an estimate of 1,500 mt to 2,300 mt of mortality annually since 1987. Coastwide, halibut bycatch mortality from all sources steadily decreased during 1980-85 (Table 7.1). Adult equivalents of the 1989 bycatch mortality accounted for approximately 22% of total estimated halibut removals that year (Table 7.2). Bycatch mortality in all GOA groundfish fisheries in 1989 accounted for approximately 32% of the coastwide bycatch mortality, or 4% of total removals.

Less than 10% of the bycatch of halibut, by number, in joint venture trawl fisheries is of animals of size (80 cm) and age that occur in the directed longline fishery. On average, there is a difference of five years between age of trawl bycatch and directed longline harvest. Groundfish longline bycatch of halibut tends to be of larger animals but available data are not sufficient to generalize length frequency or age differences (R. Trumble, IPHC, pers. comm.).

Bycatch of Pacific halibut needs to be examined in a coastwide perspective since there is a major migration of fish between management areas. There is a general eastward migration from the Bering Sea to the Gulf of Alaska and a southward shift from Alaskan waters to areas off British Columbia, Washington and Oregon (Figure 7.1). The proportion of Gulf of Alaska bycatch yield loss that occurs in any area depends on the migration rate from the Gulf; however, these rates are currently unknown. Yield loss to the coastwide halibut fishery is estimated with a general factor of 1.6 derived by IPHC to account for growth and natural mortality between the age of bycatch and the age fish are taken in the directed fishery.

7.3.3 Alternative 1: Do nothing - maintain the status quo.

Adopting this alternative would return halibut bycatch management in the GOA to the PSC framework utilized by the Council since 1985. The framework is a means for the Council of determining a halibut PSC limit for trawl and fixed gear fisheries.

Since 1985, the Council has adopted an annual limit for halibut bycatch mortality of 2,000 mt. This amount was based on a then-recent five-year average of bycatch mortality in the Gulf of Alaska (1,800 mt) and also allowed for some growth in DAP fisheries and their resulting bycatch needs. In 1989, the Secretary implemented Amendment 18 to the Gulf of Alaska Groundfish FMP which specified fixed bycatch mortality caps for the 1990 fishery; these PSC limits are in effect only for 1990, and are 2,000 mt for trawl gear and 750 mt for fixed gear. The Secretary exempted pot gear from the fixed gear PSC limits for 180 days by extended emergency rulemaking effective February 15 through August 13, 1990. For 1991 and beyond, halibut bycatch PSC limits will be annually determined by the Council.

The biological and physical impacts of this alternative would consist of expected changes in groundfish catches or halibut bycatch mortality as a consequence of a change in the PSC limits and the gear groups covered by such limits relative to the 1990 regime. Since the halibut PSC limits for 1991 and the applicable fisheries will be determined by the Council at its December, 1990 meeting, the true impact cannot be determined. However, assuming the Council adopts PSC limits and applicable gear groups for 1991 identical to those used in 1990, potential impacts can be estimated.

Under the status quo, no incentives other than PSC caps and the existing DAP apportionment of PSC limits to trawl and fixed gear fisheries will be in place to manage halibut bycatch in the GOA for 1991 and beyond. Thus, 2,750 mt halibut mortality will continue to occur annually from the various longline and trawl groundfish fisheries. Fishing seasons may gradually become shorter as vessels increasingly race for available groundfish quotas. The trawl fishery in the Gulf closed September 2 during the 1989 season because the 2,000 mt PSC limit was reached; this closure date will likely occur earlier and earlier under status quo management. The likelihood of overharvest of both target groundfish species and halibut may increase as fishing effort increases. The Council and RD could apportion trawl and fixed gear PSCs by regulatory area, but this is not expected to reduce overall bycatch amounts.

7.3.4 Alternative 2: (Preferred) More fully implement and clarify the existing halibut PSC framework.

7.3.4.1 Option A: Apportion the Halibut PSC Limits by Season.

The impact of apportioning the halibut PSC limit by season would be reflected in the amount of groundfish unharvested due to the attainment of a PSC limit early in the year. Since the amount of halibut taken as bycatch is limited, there would be no change in the biological impact of a seasonal apportionment of the halibut PSC limit from the current impact, assuming no change in the actual PSC limit.

As previously stated, Amendment 18 to the FMP established separate halibut PSC limits for trawl gear and fixed gear fisheries of 2,000 mt and 750 mt, respectively, for 1990. The halibut bycatch management actions implemented under Amendment 18 include: (1) a mandatory domestic observer program that will generate more accurate estimates of halibut bycatch; (2) separate halibut PSC limits for trawl and fixed gear that will hold each gear type individually accountable for its halibut bycatch mortality; (3) the establishment of 1990 PSC limits in the FMP that cannot be exceeded; and (4) the curtailing of the flexibility of inseason management of groundfish during 1990 compared to 1989, because PSC limits are separated now into two gear type categories, rather than being one PSC limit for all gear types.

During the December 1989 Council meeting, representatives for fishermen using fixed and trawl gear expressed concern that the halibut PSC limits established for fixed and trawl gear would be taken prematurely in the 1990 fishing year, causing an early closure of the Gulf of Alaska to either or both gear types. They petitioned the Council to allocate the 1990 halibut PSC limits on a quarterly basis to provide sufficient amounts of PSC to fall and winter fisheries and avoid the premature closure of the Gulf of Alaska to groundfish fishing during the last half of the fishing year.

As a result, the Council recommended that the Secretary implement an emergency rule that would allocate the halibut PSC limits established for trawl and fixed gear on a quarterly basis and in amounts proportional to the needs of specific fisheries throughout the year. The Secretary agreed that Amendment 18 may increase the probability of early closures of the groundfish fisheries (see Emergency Interim Rule, February 15, 1990) and therefore approved the request. See Section 7.2.2 for a list of the quarterly 1990 halibut PSC limits established for trawl and fixed gear in the Gulf of Alaska by emergency rule.

When a seasonal allocation of halibut PSC is reached by any gear group, the Gulf of Alaska will be closed to further fishing with that gear until the beginning of the following quarter. Unused PSC from any quarter will be added to the next quarter's PSC allocation. Observer data will be used to monitor bycatch amounts unless such data is considered inadequate. Lacking sufficient observer information, the assumed bycatch and mortality rates discussed in Section 7.3.1 will be used to estimate halibut bycatch mortality.

Without seasonal PSC limits, groundfish fisheries operating during the early part of the year will probably reach the allowable PSC amounts, preventing fall and winter fisheries. The continuing expansion of the groundfish fishery and the attendant increase in vessel effort results in each participant in the fishery attempting to harvest as much groundfish as is individually possible before PSC limits or groundfish quotas are reached. This further contributes to higher than normal bycatch rates and premature attainment of PSC limits.

Seasonal PSC limits will likely constrain the bycatch of Pacific halibut to established levels during the first half of the year. Sufficient portions of halibut PSC limits will then be left over to provide for subsequent groundfish fisheries later in the year. Providing for a year-round groundfish fishery will allow a greater opportunity to harvest the optimum yield established for the Gulf of Alaska groundfish resource and will extend the time during which observer information may be collected from groundfish operations. Observer information collected during 1990 will provide the basis for management of the groundfish fisheries in 1990 and beyond.

Seasonal PSC limits will likely maintain halibut bycatch mortality at reasonable levels each season (e.g. quarter) if observer information indicates that bycatch rates are higher than anticipated. In 1989, the Gulf of Alaska was closed to bottom trawl gear on September 2, when the estimated bycatch mortality of halibut in all groundfish operations reached 2,000 mt. During 1990, data collected by observers on actual bycatch and mortality rates are expected to lead to premature closures of the Gulf of Alaska, given the lack of incentives to reduce halibut bycatch rates, together with increasing incentives to harvest as much groundfish in as short a period of time as possible.

7.3.4.2 Option B: Set Separate Halibut PSC Limits for Each Fixed Gear Group (e.g. longline and pot) or Omit Pot Gear Fisheries from the PSC Framework.

A regulatory amendment to more fully implement the current FMP would provide the Council and RD with the authority to annually establish separate halibut PSC limits for each fixed gear group. Such authority would eliminate the current situation in which bycatch in the longline fisheries counts against the overall fixed gear PSC limit which triggers a closure of all fixed gear fisheries. This situation is inequitable since pot gear fisheries may be closed when the fixed gear PSC limit is reached, yet the pot gear bycatch rate, currently assumed to be 0.7%, is much lower than longline gear rates (longline bycatch rate is assumed at 8% and 10% for sablefish and Pacific cod, respectively). Furthermore, in Chapter 6 of this EA/RIR, the Council is considering requiring halibut exclusion devices on all pot gear, effectively eliminating high halibut bycatch rates in groundfish pots. The expected growth of the longline fisheries increases the severity of the problem. The Council also could amend the FMP and exclude pot gear from the PSC framework. Either option would enhance the Council's ability to minimize the problems stated above.

The Council has repeatedly signaled the industry that it encourages pot fishing, where practicable, because of the low bycatch rates measured in past groundfish pot fisheries. Pot gear is very selective, and if tunnel openings are configured properly, pot gear effectively catches negligible amounts of halibut. (See Chapter 6 for more background on this issue.) Thus, the Council could exempt pot gear fisheries from the PSC framework. In doing so, then, only longline gear would be restricted by any halibut PSC limits for fixed gear in the Gulf of Alaska.

Exempting pot gear from the PSC framework may encourage development of pot gear fisheries, since these fishermen would not be constrained by PSC limits, only by the amount of TAC available for the target species (principally Pacific cod). This could lead to increased investment in new pots and an increased number of pots deployed on the grounds. This could result in an increased potential for gear conflicts (pot vs. longline, pot vs. trawl) and grounds preemption problems. If pot fishing were to increase to a point where these conflicts required regulatory action, additional burdens would be placed on the Council process to take remedial action.

7.3.5 Alternative 3: (Preferred) Implement a program to identify and penalize vessels that exhibit excessive bycatch rates of halibut.

Observer information on prohibited species bycatch during 1990 indicates that a relatively small number of vessels can take a large share of prohibited species bycatch allowances established for the trawl fisheries in the BSAI and for the trawl and longline fisheries in the GOA. In response to this finding and the desire to maximize groundfish harvests for a given PSC limit, the Council adopted the "penalty box" incentive program for prohibited species bycatch management in the BSAI and GOA.

This program is intended as an interim measure to sanction vessels with excessive bycatch rates during the period that a more comprehensive vessel incentive program to reduce halibut bycatch rates is analyzed and developed. As such, the "penalty box" program is not intended to provide a comprehensive response to the issue of halibut bycatch in Gulf of Alaska groundfish fisheries. This program is, however, directed at vessels which demonstrate excessive bycatch rates when judged against a system of acceptable performance standards. It is intended to increase the opportunity to harvest groundfish TACs before established PSC limits are reached by encouraging vessels to maintain average bycatch rates within acceptable performance standards and discourage fishing practices that result in excessive bycatch rates.

7.3.6 Summary of Biological and Physical Impacts

The biological and physical impacts of Alternative 1 (status quo) will be partially dependent on the extent to which the current olympic system of fishery management changes in the coming years. As fishing effort increases, greater pressure on the available halibut bycatch limits will occur. If the halibut biomass levels continue declining as projected for the next several years, increasing pressure will be likely to maintain or even reduce halibut PSC limits. Fishing seasons will continue to shorten, and fishery managers will find it more and more difficult to close seasons so that quotas or PSC limits are not exceeded. The extent to which industry can voluntarily reduce bycatch rates under the status quo will greatly affect how much groundfish quota can be harvested and how long fishing seasons extend.

The true extent of halibut bycatch mortality is currently unknown. Therefore, it is not possible to determine if the implementation of Alternative 2 would provide for a decrease or an increase in the bycatch mortality of halibut, although the change is not expected to be large. There may also be increased or decreased perturbation of the physical environment due to the activity of fishing gear. The extent to which these perturbations occur is speculative at best and impossible to measure against the normal variability of factors affecting marine life in the epibenthos and water column.

Implementation of Alternative 2 could affect the amount of groundfish taken in fisheries which catch halibut incidentally. Some fisheries may be prevented from attaining their full TAC due to the PSC caps. This would reduce the fishing mortality on these stocks. There would be more groundfish available, which could affect predator-prey relationships. Improvements in the environment may occur due to decreased fishing activity. The extent to which changes could occur are unknown and probably negligible compared to the normal variability of the ecosystem.

Implementation of Alternative 3 will have no effect on the PSC limits, but should increase the amount of groundfish harvested. The amount of the increase is dependent upon the desire and ability of groundfish fishermen to avoid excessive halibut bycatch rates and perhaps reduce overall average bycatch rates within a target fishery category.

7.4 Socioeconomic Impacts

7.4.1 Fishery Costs and Benefits

7.4.1.1 Alternative 1: Do nothing - maintain the status quo

The status quo for 1990 may result in foregone groundfish catch if industry cannot maintain bycatch rates at or below preseason estimated rates. Using the 1990 TACs and published assumed bycatch and mortality rates (see 55 FR 3223, January 31, 1990, for a table listing these rates), the Council's GOA bycatch prediction model projects a trawl halibut mortality of 2,485 mt, or 485 mt above the

PSC limit. This excess mortality could result in approximately 36,000 mt of groundfish foregone (485 mt ÷ .0135) with a value of $18 million (assuming $500/mt value). If the bottom trawl rate increases from 2.7 to 3.0%, groundfish harvest foregone increases to 50,074 mt with a value of $25 million. However, reducing the bottom trawl rate from 2.7 to 2.5% could result in an increased groundfish harvest of 13,040 mt with a value of $6.5 million. Incentives or other measures to encourage reduced bycatch rates could have significant economic benefits; otherwise, the status quo situation will continue and foregone groundfish catches are likely.

7.4.1.2 Alternative 2: (Preferred) More fully implement and clarify the existing halibut PSC framework.

Option A: Apportion the Halibut PSC limits by Season.

The closure of the Gulf of Alaska to bottom trawl fisheries on September 2, 1989, notwithstanding the subsequent re-opening for the deep water flatfish fishery, resulted in a loss of opportunity to harvest nearly 56,000 mt of groundfish. This amount of groundfish might have had an exvessel value of $32.1 million at an average value of $0.26 per pound if it had all been harvested. Losses of this nature will be mitigated under the emergency rule to the extent that this action provides for greater opportunity to harvest the groundfish optimum yield. The potential for a premature closure of the longline fishery for sablefish in 1990 due to excessive halibut bycatch in the increasingly lucrative longline fishery for Pacific cod is of special concern to fishermen and processors involved in the sablefish fishery. In 1989, this fishery harvested 20,500 mt of sablefish. At $0.87 per pound, this harvest had an estimated exvessel value of $39.3 million. Representatives for sablefish fishermen supported the quarterly allocation of halibut PSC under this emergency rule as a management action that will provide a reasonable opportunity to harvest the total allowable catch for sablefish.

Option B: Set Separate Halibut PSC Limits For Each Fixed Gear Group (e.g. longline and pot) or Omit Pot Gear Fisheries from the PSC Framework.

The establishment of separate fixed gear PSC limits for pot and for longline gear would eliminate two problems. During the fishing year, the estimated bycatch in the longline fisheries could not result in the closure of pot fisheries, and bycatch in the longline fisheries would be limited. This would tend to benefit the pot fisheries and/or the halibut fishery, at the expense of the longline groundfish fisheries. In the absence of an accurate estimate of the value of an increase in a PSC limit for each groundfish fishery, it is difficult to determine whether a reallocation of bycatch from one fishery to another will result in positive or negative net benefits. If groundfish fishing techniques are changed or if groundfish catch is limited, and bycatch mortality is less due to the PSC limits, there will be costs imposed on the groundfish fishery and benefits provided to the halibut fishery.

Forty five vessels have landed groundfish caught with pot gear to date in 1990. In 1989, turbot, rock sole, other flatfish, ling cod, and Pacific cod were taken with pots. However, the harvest by pots was less than 1% of the 1989 total groundfish harvest (Table 7.4).

In 1989, 31,787 mt were taken by longline gear, or 98% of the fixed gear harvest. Using a bycatch rate of 8% for longline gear and 0.4% for pot gear, and an assumed halibut mortality rate of 13%

and 12% for those gears, respectively, the 1989 groundfish fixed gear harvest "required" 326 mt and 2 mt of halibut bycatch, respectively. Actual observed rates from the 1990 fishery may change these results. However, allocating PSC limits between longline and pot gear would have little impact on the longline gear group unless either (1) longline bycatch rates are significantly higher than assumed (i.e. more than double) or (2) the amount of groundfish harvested by pots increases dramatically (e.g. tenfold or more).

7.4.1.3 Alternative 3: (Preferred) Implement a program to identify and penalize vessels that exhibit excessive bycatch rates of halibut.

The "penalty box" program is directed at vessels which demonstrate excessively high bycatch rates of halibut while fishing for groundfish. Under this alternative, separate target fisheries would be defined and average halibut bycatch rates observed on vessels participating in those fisheries would be judged for one week building up to the preceding four week period against the fleet average for up to four weeks.

Information was obtained from the 1990 NMFS observer database to represent possible behavior of fishermen under circumstances in which they operated under no particular incentive to reduce bycatch rates. Under the status quo alternative, results of the examination represent what might occur in 1991 if fishing opportunities and conditions were the same in 1991 as in 1990.

A performance standard was used, whereby a vessel's bycatch rate was judged to exceed an acceptable performance standard if its 1-4 week average rate was greater than two times the fleet average for the preceding 1-4 week period. Four target bottom trawl fisheries - Pacific cod, rockfish, flatfish, and pollock -- and the hook-and-line Pacific cod fishery were examined.

With respect to the Pacific cod directed fishery, 87 fishing periods occurred in which vessel rates were determined to be within the acceptable performance standard, i.e., two times or less than the fleet average (Table 7.5). Twenty-eight fishing periods occurred in which vessel rates exceeded the performance standard.

With respect to the rockfish directed fishery, 32 fishing periods occurred in which vessel rates were determined to be within the acceptable performance standard, and seven fishing periods occurred in which vessel rates exceeded the performance standard.

With respect to the directed flatfish target fishery, all fishing periods examined (5) were determined to be within the acceptable performance standard. No information was available for the pollock bottom trawl fishery. Through June 30, 1990 only about 3,000 mt of pollock have been harvested with bottom trawl gear and that was not observed. Insignificant amounts of halibut are caught in the pelagic trawl pollock fishery.

Should all fishermen fish within an acceptable performance in 1991 under Alternative 3, substantial additional amounts of Pacific cod and rockfish could be harvested. In 1990, amounts of halibut and groundfish that were caught by vessels that fished in excess of the acceptable performance standard while fishing with bottom trawl gear for Pacific cod and rockfish were summed from the NMFS observer database. By subtracting these amounts from the overall observed amounts of halibut and

Pacific cod and rockfish, estimates of "clean rates", i.e., those within the acceptable performance standard were obtained. These rates were 10.15 and 23.83 kilograms of halibut per metric ton of groundfish in the Pacific cod and rockfish target fisheries, respectively.

With respect to the Pacific cod bottom trawl fishery, if all fishermen had fished within the acceptable performance standard such that the bycatch did not exceed a rate of 10.15 kilograms, a savings of 72,129 kilograms of halibut could have occurred. This amount would have supported an additional Pacific cod harvest of 7,106 mt. Assuming a product recovery rate of 0.64 for headed and gutted product, western cut, and $1.00 per pound, this amount of Pacific cod could have an additional gross revenue of about $10.0 million.

With respect to the rockfish bottom trawl fishery, if all fishermen had fished within the acceptable performance standard such that the bycatch rate did not exceed a rate of 23.83 kilograms, a savings of 194,655 kilograms of halibut could have occurred. This amount would have supported an additional rockfish harvest of 8,168 mt. Assuming a product recovery rate of 0.60 for headed and gutted product, western cut, and $1.00 per pound, this amount of could have an additional gross revenue of about $10.8 million.

With respect to the Pacific cod hook-and-line fishery, if all fishermen had fished within the acceptable performance standard such that the bycatch rate did not exceed a rate of 71.59 kilograms, a savings of 31,805 kilograms of halibut could have occurred. This amount would have supported an additional Pacific cod hook-and-line harvest of 444 mt. Assuming a product recovery rate of 0.60 for headed and gutted product, western cut, and $1.00 per pound, this amount of could have an additional gross revenue of about $587,000.

Assuming fishing opportunities are the same in 1991 and fishermen change their fishing behavior under the penalty box program, additional amounts of about $10.6 million and $10.8 million in the Pacific cod and rockfish fisheries could result under this alternative. Because all vessels are expected to strive to fish a lower bycatch rates in order to avoid the "penalty box", overall bycatch rates ought to be reduced. To the extent that this happens, even fewer halibut ought to be taken as bycatch, which would allow more groundfish to be harvested.

7.4.2 Reporting Costs

Weekly monitoring of bycatch has proven inadequate for precise monitoring of PSC limits, particularly in short-term fisheries where fishery apportionments of PSC caps are sometimes exceeded. Timely inseason management of PSC limits, particularly in the vessel incentive programs addressed under Alternative 3, will require considerable improvement to current communication and information processing systems. A regulatory amendment should be developed to provide the RD with the authority to require groundfish processors to submit daily catch reports as PSC limits or groundfish quotas are approached. More frequent catch reports will provide inseason managers with updated information on which to monitor PSC amounts and enhance their ability to maintain bycatch within specified PSC limits. Prompt processing of daily observer messages and/or processor catch reports will require full implementation of a satellite communication system, e.g. COMSAT Standard C, for direct two-way communication of data and information between vessel operators and/or observers and Regional managers. Costs of this system are estimated at between $5,000 and $10,000 per unit, the burden of which would be borne by participating vessels and processors. The specific costs to the industry to submit daily reports when requested to do so by the RD will be analyzed under the regulatory amendment that is developed to implement this requirement and are not addressed further within the context of the bycatch alternatives considered above. Additional administrative costs may be incurred by NMFS staff if the number of observer reports are increased and additional time and/or personnel are needed to compile, edit, and enter daily observer reports. Computer-to-computer communication of reports would minimize some of these costs.

7.4.3 Administrative, Enforcement, and Information Costs and Benefits

The implementation of an additional gear regulation will result in increased administrative, enforcement, and information burdens. These include those associated with determining the specifics of the gear restrictions and both implementing and enforcing the regulations.

The use of gear-specific PSC limits would result in increased administrative and information burdens but would not affect enforcement. If pot gear is exempt from PSC management, some administrative cost savings may be realized, although such savings would likely be small. The information required to determine the appropriate PSC limit for each fixed gear group is difficult to collect and, therefore, tends to be costly. In the absence of credible information concerning the value of an increase in the PSC limit for each fishery, the issue of allocating limits among fisheries will continue to be contentious and as a result the process of allocating limits will place a large burden on the Council process, although this issue may be less contentious among the fixed gear group.

Quarterly or another seasonal PSC allocation measure will increase administrative costs, since bycatch mortality records will be required for each gear group and must be provided to fishermen on a frequent schedule. NMFS will be required to close each of several fisheries on a seasonal basis when each PSC limit is attained. More detailed and real-time PSC accounting will be necessary which will increase staff costs.

The "penalty box" program proposed under Alternative 3 would increase the administrative and information burdens because it would be necessary to keep track of observer data for each individual vessel.

Under Alternative 1, administrative, enforcement, and information costs would remain unchanged, because no changes in monitoring halibut PSC bycatch amounts inseason will occur. Under Alternative 2, administrative and enforcement costs are the same as those identified for Alternative 3 to the extent that Alternative 3 is implemented in conjunction with Alternative 2.

Under Alternative 2, a total of four separate Gulf-wide PSC halibut bycatch apportionments might be monitored on at least a weekly basis (daily for fast-paced fisheries or as fisheries approach their apportionment of a PSC limit). The apportionments are:

DAP trawl, JVP trawl, DAP fixed gear, and JVP fixed gear.

JVP fisheries, however, have not been conducted in the Gulf of Alaska since 1988. Including JVP fisheries in this analysis, however, is appropriate for planning purposes.

If PSCs are further apportioned among the three regulatory areas, a total of twelve PSC halibut bycatch apportionments might be monitored. No additional costs of Alternative 2 will occur, unless the "Penalty Box" program is implemented under Alternative 3. Discussion of costs are discussed, therefore, under Alternative 3.

Under Alternative 3, the analysis of costs is derived from the analysis of costs prepared for Chapter 2 of this EA/RIR, which also includes a "penalty box" program as an alternatives to extending Amendment 12a to the BSAI Groundfish FMP. NMFS estimates that personnel and administrative costs associated with inseason monitoring of prohibited species bycatch will approach $100,000 by 1991. This amount includes personnel costs associated with three statisticians working between 10 and 40 hours a week on PSC monitoring, and one part-time programmer (total personnel costs of about $75,000 per year).

Administrative and enforcement costs under Alternative 3 will increase due to additional personnel and computer hardware necessary for individual vessel monitoring and enforcement. Appendix 2.1 to Chapter 2 that addresses BSAI vessel bycatch incentives contains a summary of NMFS' experience with individual vessel/company monitoring, the administrative burden to implement these programs, and risks associated with vessel incentive programs.

Timely inseason management of individual vessels would require improvements to current communication and information processing systems. Federal costs associated with installing Standard C communication hardware would include $16,000 for stations at Juneau and Dutch Harbor, $15,000 for five PCs, and file server costs of $6,000, for a total hardware cost of $37,000. Personnel costs for systems development and implementation are estimated at another $50,000, for a total initial cost of $87,000. An alternative to incurring theses costs to accelerate receipt and processing of catch data is to close the fishery periodically to allow the data to catch up with the fishery.

The NMFS' experience with vessel incentive programs over recent years indicates that one staff person working a 40-hour week would be required to monitor up to 20 separate vessels or operations if daily monitoring were required. In those situations where weekly monitoring of bycatch were appropriate, a single person working about 20 hours a week could monitor about 40 vessels or operations if the receipt of weekly reports from vessels and observers were spread throughout the week. Assuming the number of observer reports would increase with daily or even weekly monitoring of individual operations, an additional part-time position would be required within the NMFS observer program to receive and verify additional observer reports.

The number of vessels that might fish in specified target fishery categories under the "penalty box" should not require additional personnel to that already projected for a similar program proposed for the Bering Sea/Aleutian Islands area in Chapter 2. In summary, NMFS estimates that a full-time programmer and up to four additional staff would be required for inseason monitoring of individual vessel bycatch rates or credits under the Gulf and Bering Sea "penalty box programs" (approximately $150,000 to $170,000 per year). Given that different fisheries are prosecuted at different times of the year, staff needs would likely be irregularly spaced throughout the year, which suggests that some of the additional positions could be filled by short-term assignments of personnel from other regions or agencies.

Similarly, additional enforcement costs should not exceed those already projected for the "penalty box" program analyzed under Chapter 2 to this EA/RIR. In summary, individual vessels may choose to challenge information used to estimate their bycatch rates and the fishery average rates and may request an adjudicative hearing. How often individual vessels or operations would challenge actions taken against individual vessels as the result of estimated bycatch rates is unknown. However, actions of this sort would be administratively time consuming and costly. Frequent hearings procedures would, at a minimum, require another staff position with the Region's Office of General Counsel (approximately $50,000 per year).

In summary, additional administrative costs for development, implementation, and maintenance of a reliable vessel incentive program under Alternative 3 could be as high as $434,000 during the 1990-1991 development and implementation period and about $355,000 annually thereafter.

Another cost that should be considered is that of the additional burden that may be placed on observers. With any vessel incentive program, there will be substantial pressure to have the observer observe or report less bycatch. The intensity of this pressure may be greater with individual vessel incentive programs than with fleet-wide caps.

7.4.4 Impacts on Consumers

Because neither halibut nor groundfish from the Gulf of Alaska is a major item in many household budgets and because there are relatively good substitutes for both, none of the measures being considered is expected to have a significant impact on individual consumers. However, consumers as a whole would be affected by changes in the quantity, quality, and prices of halibut and probably to a less extent groundfish.

Allocating fixed gear PSC limits to both longline and pot gear would only benefit consumers to the extent it reduced total bycatch mortality and, therefore, increased halibut fishery quotas. Additionally, reduced bycatch rates would mean a larger groundfish harvest, therefore, more groundfish available to the consumer.

The "penalty box" program is not expected to significantly affect consumers.

7.4.5 Redistribution of Benefits and Costs

PSC limits are expected to change the distribution of net benefits among the groundfish and halibut fisheries. Because a frameworked measure is being considered, the probable winners and losers depend on how this authority would be used. The intent is for groundfish fishermen to receive a larger groundfish harvest for the same or lower amount of halibut bycatch. In the absence of adequate information, the possibility exists of making a change that will decrease the total net benefits of the groundfish and halibut fisheries combined.

The establishment of either a "penalty box" program would tend to benefit vessels that change fishing practices to avoid excessive bycatch rates of halibut at the expense of those that do not.

Table 7.1 **Pacific halibut bycatch mortality (in metric tons, round weight) in Gulf of Alaska foreign, joint venture, and domestic groundfish fisheries and in all areas and fisheries, 1977-1989.**

Year	Gulf of Alaska	All Areas & Fisheries	Year	Gulf of Alaska	All Areas & Fisheries
1977	2,278	6,816	1984	1,390	5,859
1978	1,244	7,097	1985[1]	378	4,358
1979	2,460	8,931	1986[1]	185	4,998
1980	2,427	10,994	1987	1,476	6,516
1981	1,547	8,676	1988	1,879	8,599
1982	1,564	7,176	1989[2]	2,281	8,203
1983	1,745	6,278			

[1]Does not include estimate for U.S. fully domestic fisheries.
[2]Preliminary data for 1989.

Source: G. Williams, IPHC, personal communication.

Table 7.2 Coastwide removals of Pacific halibut, 1977-1989, in thousands of metric tons, round weight.

Year	Directed Catch	Bycatch (Adult Equiv.)	Recreational Catch	Waste	Total Removals
1977	13.2	10.9	0.2	0.0	24.3
1978	13.3	11.4	0.2	0.0	24.9
1979	13.6	14.3	0.3	0.0	28.2
1980	13.2	17.6	0.5	0.0	31.3
1981	15.5	13.9	0.7	0.0	30.1
1982	17.5	11.5	0.8	0.0	29.8
1983	23.2	10.0	1.0	0.0	34.2
1984	29.1	9.4	1.1	0.0	39.6
1985	33.8	6.9	1.6	0.9	43.2
1986	42.0	8.0	2.1	1.9	54.0
1987	41.9	10.4	2.5	2.5	57.3
1988	44.8	13.8	3.1	2.1	63.8
1989	40.2	13.1	3.5	2.0	58.8

Source: G. Williams, IPHC, personal communication.

Table 7.3. Number of vessels and landed catch (mt) for the 1989 fully domestic fisheries in the Gulf of Alaska region by vessel length group and gear type. Vessel length is length overall. Number of vessels is only for those vessels which supplied vessel length information on federal permit application.

Vessel Length Group	Longline		Trawl		Pot	
	No. of Vessels	MT Landed	No. of Vessels	MT Landed	No. of Vessels	MT Landed
< 60 ft.	487	13,935	18	5,166	9	235
60 - 124 ft.	128	12,276	63	58,925	4	130
125+ ft.	11	2,676	33	102,840	1	0
Total	626	28,887	114	166,931	14	365

***Total 1989 Harvest: 196,183 mt.**

Source: R. Berg, NMFS AK Region, from ADF&G Fish Tickets through March 19, 1990 (NMFS89.dbt).

Table 7.4. 1989 groundfish harvest in the Gulf of Alaska by gear type.

	Harvest (mt)	Percent
All Gear:		
Trawl	135,131	81
Net	1	<1
Longline	31,787	19
Other hook & line	116	<1
Pot	415	<1
Other gear	Tr	<1
Total All Gear	167,450	100
Fixed Gear Only:		
Longline	31,787	98
Other hook & line	116	<1
Pot	415	1
Total Fixed Gear	32,318	100

Source: PacFIN Rpt #124, 2/12/90

Table 7.5 Numbers of vessel periods that resulted in clean versus "dirty" rates in the Gulf of Alaska while bottom trawling for Pacific cod, flatfish, pollock and rockfish. Source: NMFS observer database through June 30, 1990.

Gulf of Alaska Fisheries - Bottom Trawl Gear
(based on current management definitions)

Evaluation Period	Cod C[1]	Cod D[2]	Flatfish C	Flatfish D	Pollock C	Pollock D	Rockfish C	Rockfish D
Jan 6-Jan 27	0	0	0	0	0	0	0	0
Feb 3-Feb 14	12	2	0	0	0	0	0	0
Mar 3-Mar 24	24	9	1	0	0	0	4	1
Mar 31-Apr 21	30	13	3	0	0	0	12	2
Apr 18-May 19	19	3	1	0	0	0	10	2
May 26-Jun 9[3]	2	1	0	0	0	0	6	2
Period Totals	87	28	5	0	0	0	32	7

Gulf of Alaska Fisheries - Hook-and-Line Gear
(based on current management definitions)

Evaluation Period	Cod C	Cod D	Evaluation Period	Sablefish C	Sablefish D
Jan 6-Jan 17	1	0	Apr 7-Apr 28	24	6
Feb 3-Feb 24	2	0	May 5-May 26	20	4
Mar 3-Mar 24	4	1	Jun 2	3	2
Mar 31-Apr 21	1	1			
Apr 28-May 19	5	1			
May 26-Jun 9	1	1			
Jun 23-Jul 14	1	0			
Period Totals	15	4		47	12

[1] Number of "clean" vessels with average halibut bycatch rates less than or equal to 2 times the fleet average.

[2] Number of "dirty" vessels with average halibut bycatch rates more than 2 times the fleet average.

[3] Observer database through June 9, 1990.

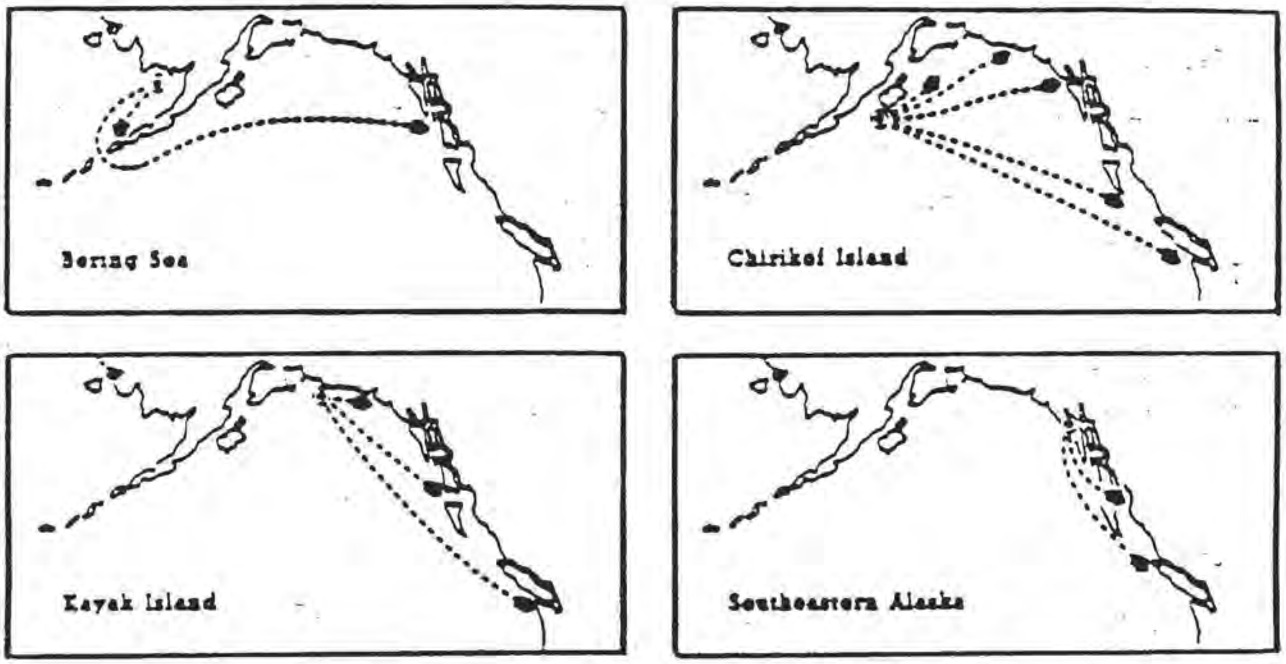

Figure 7.1 Migratory patterns of juvenile Pacific halibut from different tagging sites. Source: IPHC.

8.0 EFFECTS ON ENDANGERED SPECIES AND ON THE ALASKA COASTAL ZONE

None of the alternatives would constitute actions that "may affect" endangered species or their habitat within the meaning of the regulations implementing Section 7 of the Endangered Species Act of 1973. Thus, consultation procedures under Section 7 on the final actions and their alternatives will not be necessary.

Also, for the reasons discussed above, each 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 307(c)(1) of the Coastal Zone Management Act of 1972 and its implementing regulations.

9.0 OTHER EXECUTIVE ORDER 12291 REQUIREMENTS

Executive Order 12291 requires that the following three issues be considered:

(a) Will the amendment have an annual effect on the economy of $100 million or more?

(b) Will the amendment lead to an increase in the costs or prices for consumers, individual industries, Federal, State, or local government agencies or geographic regions?

(c) Will the amendment have significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of U.S. based enterprises to compete with foreign enterprises in domestic or export markets?

Regulations do impose costs and cause redistribution of costs and benefits. If the proposed regulations are implemented to the extent anticipated, these costs are not expected to significant relative to total operational costs.

The amendment will not have significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of U.S. based enterprises to compete with foreign enterprises in domestic or export markets.

The amendment should not lead to a substantial increase in the price paid by consumers, local governments, or geographic regions since no significant quantity changes are expected in the groundfish markets. Where more enforcement and management effort are required, costs to state and federal fishery management agencies will increase.

This amendment should not have an annual effect of $100 million, since although the total value of the domestic catch of all groundfish species is over $100 million, this amendment is not expected to substantially alter the amount or distribution of this catch.

10.0 IMPACT OF THE AMENDMENTS RELATIVE TO THE REGULATORY FLEXIBILITY ACT

The Regulatory Flexibility Act (RFA) requires that impacts of regulatory measures imposed on small entities (i.e., small businesses, small organizations, and small governmental jurisdictions with limited resources) be examined to determine whether a substantial number of such small entities will be significantly impacted by the measures. Fishing vessels are considered to be small businesses. A total of 1,348 vessels may fish for groundfish off Alaska in 1990, based on Federal groundfish permits issued by NMFS through March 29, 1990. While these numbers of vessels are considered substantial, regulatory measures will only affect a smaller proportion of the fleet.

11.0 FINDINGS OF NO SIGNIFICANT IMPACT

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

for [signature]

Assistant Administrator for Fisheries

December 10, 1990

Date

12.0 COORDINATION WITH OTHERS

The Gulf of Alaska Groundfish Plan Team and the Bering Sea/Aleutian Islands Groundfish Plan Team consulted extensively with representatives of the Alaska Department of Fish and Game (ADF&G), National Marine Fisheries Service (NMFS), members of the Scientific and Statistical Committee and Advisory Panel of the Council, and members of the academic and fishing community.

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14.0 TEXT TO AMEND THE GROUNDFISH FISHERY MANAGEMENT PLANS

14.1 BERING SEA/ALEUTIAN ISLANDS PROHIBITED SPECIES MANAGEMENT

In Chapter 2.0, Section 2.1 entitled "History and Summary of Amendments," add the following:

Amendment 16 implemented on ____________, 1990.

(1) Extended the effective date of Amendment 12a (originally scheduled to expire December 31, 1990) with the following three changes:

- Prohibited species catch (PSC) apportionments would be established for the DAP rock sole and deep water turbot/arrowtooth flounder fisheries;
- PSC limits could be seasonally apportioned; and
- An interim incentive program is established to encourage vessels to avoid excessive bycatch rates.

In Chapter 14 entitled "Management Regime" the following sections are affected:

Section 14.4.2 "Prohibited Species"

In Section 14.4.2, "Prohibited species," replace the text in Subsection E, PSC Limits and Time/Area Closures for DAH Fisheries with:

The PSC limits and area closures for DAH fisheries will be reviewed each year to determine whether changes in prohibited species stock abundance or other factors justify consideration of alternative PSC limits or time/area closures.

Section 14.4.2.1 "Bycatch Limitation Zones, subsection C:
Remains as amended under Amendment 12a.

Section 14.4.2.2 Prohibited Species Catch Limits

Remains as amended under Amendment 12a

Section 14.4.2.3 Apportionment of PSC limits to Target Fisheries

Replace with the following:

Section 14.4.2.3 Apportionment of PSC limits to Target Fisheries.

A. The PSC limits for prohibited species apply to DAH (DAP and JVP) trawl fisheries for groundfish that are categorized by target species or species groups. Fishery categories will be implemented by regulations that accomplish the goals and objectives of the FMP, the Magnuson Act, and other applicable law. Fishery categories will remain in effect unless amended by regulations implementing the FMP. When recommending a regulatory amendment to revise fishery categories, the Council will consider the best information available on whether recommended fishery categories would best optimize groundfish harvests under the PSC limits established under Section 14.4.2.2.

B. Apportionments of PSC limits to target fishery categories established under Part A of this section and seasonal allocations of those apportionments may be determined annually by the Secretary of Commerce, after consultation with the Council, using the following procedure:

(1) Prior to the September Council meeting. The Plan Team will prepare for the Council a preliminary Stock Assessment and Fishery Evaluation (SAFE) Report under Section 11.3 which provides the best available information on estimated prohibited species bycatch and mortality rates in the target groundfish fisheries, and estimates of seasonal and annual bycatch rates and amounts. Based on the SAFE report, the Plan Team will provide recommendations for apportionments of PSC limits to DAP and JVP target fisheries, seasonal allocations, thereof, and an economic analysis of the effects of the PSC limit apportionments or allocations.

(2) September Council meeting. While setting preliminary groundfish harvest levels under Section 11.3, the Council will also review the need to control the bycatch of prohibited species and will recommend appropriate apportionment of PSC limits to DAP and JVP target fisheries in a manner that will optimize total groundfish harvest under establish PSC limits, taking into consideration the anticipated amounts of incidental catch of prohibited species in each fishery category. The Council will also review the need for seasonal allocations of the PSC limit apportionments.

The Council will consider the best available information when recommending fishery apportionments of PSC limits and seasonal allocation of those apportionments, including that contained in the preliminary SAFE report prepared by the Plan Team. Types of information that the Council will consider relevant to seasonal allocation of fishery bycatch quotas include:

(a) Seasonal distribution of prohibited species;

(b) Seasonal distribution of target groundfish species relative to prohibited species distribution,

(c) Expected prohibited species bycatch needs on a seasonal basis relevant to changes in prohibited species biomass and expected catches of target groundfish species,

(d) Expected bycatch rates on a seasonal basis,

(e) Expected changes in directed groundfish fishing seasons,

(f) Expected start of fishing effort, and

(g) Economic effects of establishing seasonal halibut allocations on segments of the target groundfish industry.

(3) As soon as practicable after the Council's September meeting, the Secretary will publish the Council's recommendations as a notice in the FEDERAL REGISTER. Information on which the recommendations are based also will be published in the FEDERAL REGISTER or otherwise made available by the Council. Public comments will be invited by means specified in regulations implementing the FMP.

(4) Prior to the December Council meeting. The Plan Team will prepare for the Council a final SAFE report under Section 11.3 which provides the best available information on estimated halibut bycatch rates in the target groundfish fisheries. The Plan Team will provide final recommendations for apportionments of PSC limits among DAP and JVP target fisheries, seasonal allocations of fishery bycatch apportionments, and also an economic analysis of the effects of the PSC limit apportionments or seasonal allocations.

(5) December Council meeting. While setting final groundfish harvest levels, the Council reviews public comments, takes public testimony, and makes final decisions on apportionment of PSC limits among fisheries and seasonal allocations, using the same factors (a) through (g) set forth under Section 14.4.2.3, Part B (seasonal allocations of the PSC limits). The Council will recommend its decisions, including no change for the new fishing year, to the Secretary of Commerce for implementation.

(6) As soon as practicable after the Council's December meeting, the Secretary will publish the Council's final decisions as a notice in the FEDERAL REGISTER. Information on which the final recommendations are based will also be published in the FEDERAL REGISTER or otherwise made available by the Council.

Section 14.4.2.4 Incentive programs to reduce bycatch rates of prohibited species

This new section is added as follows:

> The Secretary of Commerce, after consultation with the Council, may implement by regulation measures that provide incentives to individual vessels to reduce bycatch rates of prohibited species for which PSC limits are established under section 14.4.2.2. The intended effect of such measures is to increase the opportunity to harvest groundfish TACs before established PSC limits are reached.

Section 14.4.3.4 Implementation of Time and Area Limitations.

Replace with the following:

> When a DAP or JVP target fishery specified in regulations attains a PSC limit apportionment or seasonal allocation specified in regulations, the bycatch zone(s) or management area(s) to which the PSC limit apportionment or seasonal allocation applies will be closed to that target fishery (or components thereof) for the remainder of the year or season, which ever is applicable.

Appendix III, entitled, "Descriptions of Closed Areas".
Retain as amended under Amendment 12a

14.2 OVERFISHING DEFINITION

14.2.1 Gulf of Alaska Groundfish FMP

In Section 2.2 entitled Operational Definitions of Terms, the paragraph defining overfishing is replaced with the following:

Overfishing is defined as a maximum allowable fishing mortality rate. For any stock or stock complex under management, the maximum allowable fishing mortality rate will be set at the level corresponding to maximum sustainable yield (F_{msy}) for all biomass levels in excess of the level corresponding to maximum sustainable yield (B_{msy}). For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the origin and increasing to a value of Fmsy at Bmsy, consistent with other applicable laws.

If data are insufficient to calculate F_{msy} or B_{msy}, the maximum allowable fishing mortality rate will be set equal to the following (in order of preference):

1) the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine value;

2) the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine value; or

3) the natural mortality rate (M).

If data are insufficient to estimate any of the above, the TAC shall not exceed the average catch taken since 1977.

14.2.2 Bering Sea/Aleutian Islands Groundfish FMP

In Section 4.3 entitled Operational Definitions of Terms, paragraph 1.e. is replaced with the following:

Overfishing is defined as a maximum allowable fishing mortality rate. For any stock or stock complex under management, the maximum allowable fishing mortality rate will be set at the level corresponding to maximum sustainable yield (F_{msy}) for all biomass levels in excess of the level corresponding to maximum sustainable yield (B_{msy}). For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the origin and increasing to a value of Fmsy at Bmsy, consistent with other applicable laws.

If data are insufficient to calculate F_{msy} or B_{msy}, the maximum allowable fishing mortality rate will be set equal to the following (in order of preference):

1) the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine value;

2) the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine value; or

3) the natural mortality rate (M).

If data are insufficient to estimate any of the above, the TAC shall not exceed the average catch taken since 1977.

14.3 ESTABLISH PROCEDURES FOR INTERIM TAC SPECIFICATIONS

14.3.1 Gulf of Alaska Groundfish FMP

In Section 4.2.1.1, paragraph (3) is changed by adding the following sentence:

> "The Secretary will implement one-fourth of the preliminary TACs and apportionments thereof on or about January 1 of each year on an interim basis. They will be replaced by final TACs as approved by the Secretary following the Council's December meeting.

14.3.2 Bering Sea/Aleutian Islands Groundfish FMP

In Section 11.3, paragraph (l) is modified by inserting the following sentence:

"The Secretary will implement one-fourth of the preliminary TACs and apportionments thereof on or about January 1 of each year on an interim basis. They will be replaced by final TACs as approved by the Secretary following the Council's December meeting.

14.4 MODIFY THE AUTHORIZATION LANGUAGE FOR DEMERSAL SHELF ROCKFISH MANAGEMENT IN THE GULF OF ALASKA

Section 3.1 would be changed to read as follows:

The TAC for demersal shelf rockfish in the Eastern Regulatory Area is specified by the Council each year. The State of Alaska will manage State registered vessels fishing for demersal shelf rockfish in the Eastern Regulatory Area with Council oversight. Under this oversight, the State's management regime for demersal shelf rockfish in the Eastern Regulatory Area will be directed at managing these rockfish stocks within the TAC specified by the Council. Such State regulations are in addition to and stricter than Federal regulations. They are not in conflict with the FMP as long as they are (1) consistent with specific provisions of the goals and objectives of the FMP, and (2) result in a total harvest of demersal shelf rockfish in the Eastern Regulatory Area at a level no greater than that provided by the FMP. Such State regulations will apply only to vessels registered under the laws of the State of Alaska.

Regulatory changes proposed by the Alaska Board of Fisheries, which are related to the management of demersal shelf rockfish will be reviewed by NOAA and the Council prior their adoption to assure that any such proposed changes are consistent with the goals and objectives of the FMP.

Under Council oversight, the following categories of regulations are authorized by the FMP to be applied by the State to vessels in the demersal shelf rockfish fishery:

The directed fishing standard for demersal shelf rockfish, inseason adjustments, seasons, seasonal apportionments of quotas, gear specifications, trip limits, directed fishing quotas, and management areas.

The following categories of regulations will be maintained as Federal regulations, unless specifically exempted, that must be complied with by Federally permitted vessels in this fishery:

Notices establishing preliminary and final TACs, definitions (except the directed fishing standard for demersal shelf rockfish, relation to other laws, permits, recordkeeping and reporting, general prohibitions, penalties, harvest limits, prohibited species catch limits, measures to manage designated prohibited species, and observer requirements.

14.5 CHANGE FISHING GEAR RESTRICTIONS

14.5.1 Gulf of Alaska Groundfish FMP

In Section 4.3.1.3 Gear restrictions, the first and last paragraphs are deleted and a new first paragraph is added to read as follows:

"Gear types authorized by the FMP are trawls, hook-and-line, pots, jigs, and other gear as defined in regulations. Further restrictions on gear that are necessary for conservation and management of fishery resources and which are consistent with the goals and objectives of the FMP are found at 50 CFR Part 672. In addition, the following gear or area limitations apply as follows:

subsequent paragraphs are unchanged

14.5.2 Bering Sea/Aleutian Islands Groundfish FMP

Section 14.4.4 Gear restrictions. Change text to read,

"Gear types authorized by the FMP are trawls, hook-and-line, pots, jigs, and other gear as defined in regulations. Further restrictions on gear that are necessary for conservation and management of fishery resources and which are consistent with the goals and objectives of the FMP are found at 50 CFR Part 675."

14.6 EXPAND HALIBUT BYCATCH MANAGEMENT MEASURES FOR THE GULF OF ALASKA

Section 4.2.3.1 is retitled and changed to read,

Section 4.2.3.1 Procedure for establishing prohibited species catch mortality limits for halibut, and seasonal allocations thereof.

PSC mortality limits and seasonal allocations of halibut will be determined annually, if necessary, by the Secretary of Commerce in consultation with the Council using the following procedures:

(1) Prior to the September Council meeting. The Plan Team will prepare for the Council a preliminary Stock Assessment and Evaluation Report under Section 4.2.1 which provides the best available information on estimated halibut bycatch and mortality rates in the target groundfish fisheries, estimates of halibut PSCs and apportionments thereof needed for DAP, JVP, and TALFF by target fisheries and gear types and also an economic analysis of the effects of the apportionments.

(2) September Council meeting. While setting preliminary groundfish harvest levels under Section 4.2.1, the Council will also review the need to control the bycatch of halibut and will, if necessary, recommend preliminary halibut PSC mortality limits (PSCs) and apportionments thereof among DAP, JVP, and TALFF. The Council will also review the need for seasonal allocations of the halibut PSCs.

The Council will make preliminary recommendations to the Secretary about some or all of the following:

The following text in paragraphs (1)-(5)is unchanged

(1) The regulatory areas and districts for which PSCs might be established;
(2) PSCs for particular target fisheries and gear types;
(3) Seasonal allocations by target fisheries, gear types, and/or regulatory areas and district;
(4) PSC allocations to individual operations;
(5) and types of gear or modes of fishing operations that might be prohibited once a PSC is reached.

The Council will consider the best available information in doing so, including that contained in the preliminary SAFE report prepared by the Plan Team. Types of information that the Council will consider relevant to recommending preliminary PSCs and which may be found in the SAFE report, include:

[no change except to reference "halibut" instead of "bycatch species]

(a) Estimated change in biomass and stock condition of halibut,
(b) Potential impact on halibut stocks,
(c) Potential impacts on the halibut fisheries,
(d) Estimated bycatch in years prior to that for which the halibut PSC is being established,
(e) Expected change in target groundfish catch,
(f) Estimated change in target groundfish biomass,
(g) Methods available to reduce halibut bycatch,
(h) The cost of reducing halibut bycatch, and
(i) Other biological and socioeconomic factors that affect the appropriateness of specific bycatch measures in terms of objectives.

Types of information that the Council will consider in recommending seasonal allocations of halibut include:

(a) Seasonal distribution of halibut,
(b) Seasonal distribution of target groundfish species relative to halibut distribution,
(c) Expected halibut bycatch needs on a seasonal basis relevant to changes in halibut biomass and expected catches of target groundfish species,
(d) Expected bycatch rates on a seasonal basis,

(e) Expected changes in directed groundfish fishing seasons, and
(f) Expected actual start of fishing effort,
(g) Economic effects of establishing seasonal halibut allocations on segments of the target groundfish industry.

The Council will release the recommended preliminary PSCs and seasonal allocations, if any, for a minimum 30-day public review.

(2) As soon as practicable after the Council's September meeting, the Secretary will publish the Council's recommendations as a notice in the FEDERAL REGISTER. Information on which the recommendations are based will also be published in the FEDERAL REGISTER or otherwise made available by the Council. Public comments will be invited by means specified in regulations implementing the FMP.

(3) Prior to the December Council meeting. The Plan Team will prepare for the Council a final Stock Assessment and Evaluation Report under Section 4.2.1 which provides the best available information on estimated halibut bycatch rates in the target groundfish fisheries, recommendations for halibut PSCs and apportionments thereof among DAP, JVP, and TALFF by target fisheries and gear types and also an economic analysis of the effects of the apportionments.

(4) December Council meeting. While setting final groundfish harvest levels, the Council reviews public comments, takes public testimony, and makes final decisions on annual halibut PSC limits and seasonal allocations, using the same factors (a) through (i) concerning PSC limits, and the same factors (a) through (e) concerning seasonal allocations of the PSC limits. The Council will recommend its decisions, including no change for the new fishing year, to the Secretary of Commerce for implementation.

(4) As soon as practicable after the Council's December meeting, the Secretary will publish the Council's final decisions as a notice in the FEDERAL REGISTER. Information on which the final recommendations are based will also be published in the FEDERAL REGISTER or otherwise made available by the Council.

14.7 ESTABLISHMENT OF A PENALTY BOX IN THE GULF OF ALASKA

Section 4.2.4 Inseason adjustment of time and area, is redesignated as Section 4.2.5, and a new Section 4.2.4 is added to read as follows:

Section 4.2.4 Incentive programs to reduce bycatch rates of halibut .

The Secretary of Commerce, after consultation with the Council, may implement by regulation measures that provide incentives to individual vessels to reduce halibut bycatch rates of halibut for which PSC limits are established under Section 4.2.3.1. The intended effect of such measures is to increase the opportunity to harvest groundfish TACs before established PSC limits are reached by encouraging individual vessels to maintain average bycatch rates within acceptable performance standards and discourage fishing practices that result in excessively high bycatch rates.