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

May 16, 1990

TABLE OF CONTENTS

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amendment (Amendment 12) was adopted initially by the Council at its July and December 1982 meetings but was later rescinded by the Council at its September 1984 meeting without having been submitted formally for Secretarial review.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, [redacted] 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

BASED ON TELEPHONE AREA CODES.

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.

Length (ft)	Catcher Trawl	Catcher Pot	Catcher LL	Catcher M*	Catcher/Processor Trawl	Catcher/Processor Pot	Catcher/Processor LL	Catcher/Processor M*	Mothership
<= 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 the 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 of NMFS, 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 this amendment package 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,

- allow seasonal apportionments of PSC caps, and

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

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

- temporarily close bycatch hot spots with in-season authority,

- allocate the pollock TACs among bottom trawl and mid-water trawl gear,

- ban bottom trawling at night.

The last item is to be included only if there is sufficient time and data to evaluate it.

The Council also instructed the 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 solutions 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. This third action was taken because the Council recognized that the first two actions may not provide more than stop gap solutions to the bycatch problem.

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 is not valid.

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. However, it is also in the best interest of each individual operation to ignore bycatch and harvest groundfish as rapidly as possible. This 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.

The basic problem is that 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.

To date the 1990 closures have been as follows:

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

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

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

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

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

It is estimated that the DAP bottom trawl pollock and cod fisheries will be closed by early June in Zones 1 and 2H and by mid-July in all of the BSAI. The unused TACs could be over 60,000 mt for Pacific cod and could approach 200,000 mt for all flatfish. Although much of the pollock TAC remaining as of mid-August will probably be taken with off-bottom gear, the closure of the bottom trawl fisheries is expected to decrease pollock catch in 1990. The cost to the groundfish fleet of the foregone catch could be in excess of $100 million dollars in lost gross earnings. 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.

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 occurs.

The appropriate (i.e., 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 is appropriate given 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 the perspective of the Nation as a whole, 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 marginal values of an additional unit of crab or halibut for both of these two 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) can also be thought 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 catch mortality of halibut and crab in the groundfish fisheries. This mortality will generally be referred to simply as bycatch. The control costs are the costs of actions that the groundfish fleet takes to reduce bycatch. The agency costs are those borne by agencies (e.g., the Council, NMFS, etc.) to select, implement, administer, and enforce the bycatch program.

There is a bycatch problem, that is 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 the optimal allocation of crab and halibut among the alternative uses. The reason for this is that, 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. As a result of ignoring the impact costs, he will tend to take too much bycatch from society's perspective. Therefore, the root of the problem is that the impact cost is an external cost and is not considered by the groundfish fisherman.

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. The problem with these approaches is that, to be used to effectively solve the bycatch problem, they require a substantial amount of information that is typically 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, respectively, 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 populations 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, there is the difficulty of measuring the nonmonetary benefits of increases in the future harvest of crab or halibut. For example, the previously mentioned effects on the maintenance of traditional fisheries and dependent communities and the maintenance of international treaty obligations are difficult to estimate and may be even more difficult to measure 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 the rigors of 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 reduce target catch than to further reduce bycatch and/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 actually reduce groundfish catch, 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 only the halibut PSC cap is constraining groundfish catch, if the bycatch rate is 1% (i.e., 1 mt of halibut per 100 mt of groundfish, if the discard mortality rate is 50%, and if the value of groundfish catch net of variable costs is $100 per mt, 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 would 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 reduced due to PSC caps. It also tends to indicate what the groundfish industry would be willing to pay, in the short run, to be able to take an additional metric ton of bycatch mortality. If the groundfish fishery changes its fishing practices to keep from exceeding PSC caps and does not decrease its catch as a result of the caps, 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.

Partly in recognition of the source of the bycatch problem, the Council will consider market-oriented solutions. However, due to 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 future amendment package that will address more effective and comprehensive intermediate to long-term solutions to the bycatch problem.

2.3 The Alternatives

2.3.1 Alternative 1: Do Nothing (the status quo).

Adoption of this alternative would eliminate direct bycatch control measures, since the existing domestic and joint venture bycatch cap provisions and closed areas under Amendment 12a expire on December 31, 1990.

Thus, under this alternative, regulatory bycatch control measures for the domestic and joint venture groundfish fisheries would be limited primarily 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), salmonids, and any other fishery resources managed outside the BSAI Groundfish FMP, but it would provide only a minimal incentive to control bycatch rates.

2.3.2 Alternative 2: Extend the Amendment 12a regulations 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 other groundfish gear, such as longline or mid-water trawl gear, does not count against the bottom trawl PSC caps and the use of this other gear is not prohibited if a bottom trawl 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 (that area south of 58° N and north of the Alaska peninsula from 160° to 162° W., and west to 163° from March 15 to June 15), and the associated exemption for domestic trawling for Pacific cod shoreward of the line approximating the 25 fathom depth contour, will 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. All other statistical areas 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 when the closure of one fishery due to one cap being attained results in unused caps for other species.

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

Adoption of this alternative would add to and modify the bycatch provisions of Amendment 12a and extend them for one year or for an indefinite period. 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 other groundfish gear, such as longline or mid-water trawl gear, would not count against the bottom trawl PSC caps and the use of other gear would not be prohibited if a bottom trawl 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, and 3 and the Crab and Halibut Protection Zone. The restrictions on the Pacific cod fishery that could occur in the last zone would also be the same.

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 seasonal. The apportionment of the halibut, king crab, and C. bairdi Tanner crab caps will be among the following five trawl fisheries:

1. JVP 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 the addition of the DAP rock sole fishery and the DAP turbot fishery, the deletion of the JVP other fishery, and the addition of the ability to make seasonal apportionments.

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 areas (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 due to one cap being attained results in unused caps for other species.

A major addition with Alternative 3 is that it provides for a program to identify and impose sanctions on bottom trawl vessels with excessively high 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:

1. rock sole 35%
2. deep water turbot 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 period could be from one week to a month.

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

(c) If a vessel's average rate for any of the three bycatch species exceeds [2-4] times the fishery average for the evaluation period, that vessel will be prohibited from further trawling, or perhaps only bottom trawling, for a period of one day to a week the first time the rate is exceeded. The penalty period will increase each time a rate is exceeded. An option being considered is that no vessel will 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.

(d) This program would assume that various fisheries can be adequately defined based on the definitions listed above.

(e) 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.

(f) All vessels with [100%] observer coverage during a fishing week will be included in the program for that week and month.

This program assumes that the beginning of the JVP flatfish fishery is delayed until some time between May 15 - June 15. The option of also delaying the DAP yellowfin/other flatfish (excluding rock sole) is also being considered. It is also assumed that the definition of the rock sole fishery will be changed by regulatory amendment to allow greater retention of yellowfin sole/other flatfish in the rock sole fishery.

Although the Council may change several of the specific elements of this alternative if it is determined to be the preferred alternative, there are several elements for which a choice is clearly needed because the alternative includes options. These elements include the following:

1. whether or not the provisions of this alternative will automatically expire at the end of 1991;

2. the length of the periods for which the bycatch rates of vessels will be compared to determine if a vessel should be penalized for an excessively high bycatch rate;

3. the definition of an "excessively high" bycatch rate;

4. the length of the penalty;

5. whether the penalty is foregone fishing time or just foregone bottom trawl fishing time; and

6. whether the penalty program will apply to all vessels with observer coverage or just those with 100% coverage.

7. whether vessels with a bycatch rate that is "excessively high", but below the 1986-89 average, would be penalized.

These issues will be more fully addressed in a separate issues paper to be prepared by the NMFS Alaska Region.

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 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 incidentally takes 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 l,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 somewhat 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. The IPHC has developed independent estimates of halibut bycatch in all domestic fisheries.

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 in the various target fisheries and in the management zones of Amendment 12a 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.

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 best approach available is to use the most recent bycatch data. This has been the approach taken here, with 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 bycatch rates used in the model are presented in Table 2.7

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 (Table 2.8).

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 predictions of the future 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 estimates of the area and seasonal distributions of TACs used in the model are in Table 2.9.

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 2.9, the addition of an economic component, and the use of a different aggregation of fisheries.

The model proportionately redistributes fishing effort and catch from the areas in which they would have occurred to the areas that are estimated to remain open. 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 2.10); (3) estimates of fixed costs, variable costs that are dependent on CPUE, and variable costs that are only dependent on catch (Table 2.11); and (4) estimates of the gross value per metric ton of groundfish catch (Table 2.12). 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 prices of the resulting processed products were 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 (Bill Clark), 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

The bycatch model was run eight times to provide estimates of the implications of the three alternatives. The results of the eight runs were used to estimate the effects of one case for Alternative 1 and two cases each for Alternatives 2 and 3.

The first run was used to estimate the implications of Alternative 1, the expiration of the 12a regulations. Three runs were used to estimate the implications of two cases for Alternative 2. The first of the three provides estimates of Alternative 2 if the joint venture flatfish fishery is not delayed until May 15; the other two provide estimates of the effects of delaying that fishery until April 1 or July 1. Because the model has quarterly time steps, the estimates of these two starting dates were used to estimate the effects of delaying the fishery until May 15. Four runs were used to estimate the effects of two cases for Alternative 3. The first two were used to estimate the effects of Alternative 3 if the incentive program does not change bycatch rates. The second two were used to estimate the effects of Alternative 3 if the incentive program results in specific changes in bycatch rates. The method used to estimate what those changes would be is discussed below. Each of the two cases considered under Alternative 3 required two runs because each case assumes that the joint venture flatfish fishery begins May 15 and because the model has quarterly time steps. As under Amendment 12a, apportionment of PSC caps among defined fisheries for runs under Alternatives 2 and 3 were based on the fisheries' proportionate "need" for bycatch. That is, if a specific (hypothetical) fishery was projected to take 50% of the total bycatch of a PSC species in the unconstrained scenario, that fishery would be apportioned 50% of the PSC cap. The results for Alternative 1 and two cases each for Alternatives 2 and 3 are summarized in Tables 2.13 through 2.16.

2.5.1.1 Alternative 1

The results suggest that, in the absence of the 12a regulations, bycatch would include about 667,000 red king crab, 3.5 million C. bairdi Tanner crab, and 5,300 mt of halibut and the total bycatch impact cost would be about $26.3 million (Table 2.13). With Alternative 1, it is projected that only the current red king crab and C. bairdi Tanner crab PSC caps in Zone 1 would be exceeded. They would be exceeded by about 460,000 crab and 1.6 million crab, respectively (Table 2.15).

2.5.1.2 Alternative 2

If the 12a regulations are in place and if the joint venture flatfish fishery begins early in the year, it is projected that: (1) the DAP flatfish fishery will attain its primary halibut and Zone 1 C. bairdi PSC apportionments well before the end of the first quarter and be closed in Zones 1 and 2H; and (2) the joint venture flatfish fishery will attain it Zone 1 red king crab apportionment very early in the first quarter and attain its Zone 1 C. bairdi apportionments just before the end of the first quarter and be closed in Zone 1. However, because of the quarterly time steps in the model, the model results are based on what would happen if the fishery were not closed until the end of the quarter. By that time, the DAP flatfish fishery is projected to exceed its primary halibut and Zone 1 C. bairdi PSC apportionments by 243 mt and about 73,000 crab, respectively, and the joint venture flatfish fishery is projected to exceed its red king crab and C. bairdi apportionments by about 466,000 crab and 2,700 crab, respectively (Table 2.16).

The total red king crab and C. bairdi Tanner crab PSC caps in Zone 1 are projected to be exceeded by about 459,000 crab and 1.6 million crab, respectively (Table 2.15), because quarterly time steps are used in the model. This demonstrates an important weakness of the bycatch projection model. A model with monthly time steps, would have projected a joint venture fishery closure in Zone 1 in January. As a result, the projected crab bycatches in Zone 1 would have been much closer to the caps, the joint venture fishery would have moved to another area as it did in 1991, and the projected bycatch in other areas would have increased. The actual levels of bycatch by area, fishery closures, and foregone groundfish catch that occurred in 1990 provide a much better estimate of the effects of case 1 of Alternative 2 than does the current bycatch model.

If the closures are not imposed until the end of the first quarter, as is assumed in the model, groundfish catch is not reduced as a result of the PSC caps. If the closures occur before the end of the first quarter, there will be a reduction in catch unless additional groundfish can be taken in the areas that remain open. The 1990 experience indicates that there could be substantial reductions in groundfish catch with this alternative.

The estimated effects of Alternative 2 are quite different for case 2 in which the joint venture flatfish fishery is delayed until May 15. In that case, projected bycatch is significantly less, none of the total PSC caps is attained, and none of the individual fishery apportionments is exceeded.

The bycatch of red king crab is reduced from over 666,000 crab to about 183,000 crab, C. bairdi bycatch is reduced from about 3.5 million crab to 2.1 million crab, but halibut bycatch remains at about 5,300 mt. The estimated total bycatch impact cost for all three species is reduced from $26.3 for Alternative 1 or case 1 of Alternative 2 to $20.1 million for case 2 of Alternative 2.

The apparent cost of this savings in bycatch is increased fishing costs for the joint venture fishery. The higher fishing costs result from lower CPUE later in the year. The CPUE and cost estimates used in the model indicate that delaying the fishery would turn a profitable fishery into an unprofitable one. This result is somewhat surprising because the joint venture fishermen have not indicated a hesitance to delay the fishery and because at one time the fishery occurred later in the year. This suggests that the increase in fishing costs is over estimated.

In addition to providing benefits in terms of reduced bycatch, the delayed start also provides benefits in terms of an increased probability that the TACs can be taken. Due to the great uncertainty concerning future bycatch rates, this could be an important benefit to the groundfish fishery.

2.5.1.3 Alternative 3

There are three major differences between Alternative 3 and case 2 of Alternative 2. 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. The second difference is that the PSC caps can be apportioned seasonally in addition to being apportioned by fishery. The third difference is the addition of sanctions against vessels with excessively high bycatch rates. The merits of each of these three differences is 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 caps for Zones 1 and 2H and the BSAI as a whole are taken. 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 wisely.

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 is used wisely.

The ability to seasonally apportion PSC caps can eliminate equity and efficiency problems. With respect to equity, seasonal apportionments 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 apportionments 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 apportionment 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 apportionments, 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 and preclude a later fishery can be reduced or eliminated.

The seasonal apportionments 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 apportionments can determine the magnitude of the fisheries during the first part of the year, it may be desirable to have the final apportionments 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 apportionments provide additional flexibility for managing bycatch equitably and efficiently. The way that this flexibility is used will determine the benefits of this flexibility. Due in part to the fact that the model used to analyze these alternatives has quarterly time steps, the model was not used to evaluate alternative seasonal apportionments. However, the model can be used in determining quarterly or semi-annual apportionments.

The third major difference with Alternative 3 is that it includes sanctions on vessels with excessively high 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 excessively high 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 excessively high bycatch rates. It may have little effect on fishermen who already have bycatch rates that are close to fishery averages.

The length of the periods for which bycatch rates would be measured against the fishery average has not been determined. It is expected to be between one week and a month. With a shorter period, a vessel that has excessively high 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.

There is also a question concerning whether each vessel will be judged against either a known rate from a previous period or a fishery average rate that will not be known until after the end of each evaluation period. With the former plan, the fishery average rates from the most recent period for which the average rates are known could be used. This plan has two advantages. First, each vessel would know what rates it would have to stay below before each evaluation period began and would know during the period if it was taking the necessary actions to control bycatch. Second, the need to quickly determine fishery averages would be reduced because vessels would not need to know the current fishery average to judge their own performance. This second advantage could reduce the management costs and increase the administrative feasibility of the program. It is not a disadvantage for vessels to know what rates they will be judged against, if the objective of the program is to impose sanction on vessels with excessive rates.

It could be a disadvantage if the objective is to provide each vessel with an incentive to reduce bycatch regardless of its bycatch rates.

Another issue is the amount of time that a vessel would be forced to forgo fishing if it had too high of a bycatch rate. 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 excessively high bycatch rates. The option of having the penalty increase if the vessel's bycatch rate is substantially greater than the acceptable level would discourage a vessel from ignoring bycatch once it was clear that its rate will be above the acceptable level.

It must also be determined what constitutes an excessively high rate. An analysis is being conducted with respect to six definitions. They are: (1) 2 times the mean rate; (2) 4 times the mean rate; (3) 6 times the mean rate; (4) one standard deviation above the mean; (5) 1.5 standard deviations above the mean; and (6) 2 standard deviations above the mean. The analysis will use 1989 and 1990 data to estimate the proportion of catch and bycatch accounted for by vessels with an excessive rate for any bycatch species. The average bycatch rates of the other vessels will also be estimated.

An option is to establish historical bycatch rates against which the bycatch rates of each vessel would also be judged. With this option, a vessel that had an excessive rate in terms of a current fishery average but did not have a bycatch rate greater than the historical average would not be penalized. This provides protection for a vessel that happens to be competing against a vessel or vessels that for a variety of reasons may have exceptionally low bycatch rates. It also provides each vessel with a known rate to stay under even if the current period fishery average rates are used to define excessive rates. The other advantages and disadvantages of this option are similar to those of having the excessive rates defined before the beginning of each evaluation period. The tentative historical rates from the NMFS Foreign Vessel Observer Program for 1986 through 1989 are as follows for red king crab, C. bairdi, and halibut:

1.	rock sole	0.46 crab/mt, 2.66 crab/mt, and 0.0037 mt of halibut/mt
2.	Pacific cod	0.029 crab/mt, 1.79 crab/mt, and 0.0094 mt of halibut/mt
3.	b. t. pollock	0.36 crab/mt, 0.95 crab/mt, and 0.0031 mt of halibut/mt
4.	Atka mackerel	0.0073 crab/mt, 0.024 crab/mt, and 0.0024 mt of halibut/mt
5.	yfs/o. flat.	0.47 crab/mt, 1.49 crab/mt, and 0.0028 mt of halibut/mt
6.	other	0.19 crab/mt, 5.18 crab/mt, and 0.012 mt of halibut/mt.

These rates are from the joint venture fisheries, therefore, they do not include information for a turbot, rockfish, or sablefish fishery. The other fishery is as defined in Section 2.3.3 and does not include the three fisheries for which the joint venture fisheries do not provide bycatch rates. Data from the 1989 and 1990 domestic observer program could be used to provide historical rates for these three fisheries.

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 second case for Alternative 2 is 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 both cases 1 and 2 of Alternative 3 are presented in Table 2.7b. Note that, for some of the fisheries some bycatch rates are higher for case 2 with the sanctions than for case 1 without the sanctions.

The projected effects are identical for case 2 of Alternative 2 and case 1 of Alternative 3. This is because neither a total PSC cap nor a fishery specific apportionment of a PSC cap is projected to be attained with either of these two cases. Therefore, the comparisons will be made between the two cases for Alternative 3.

Some of the effects of Alternative 3 differ between the two cases because the bycatch rates used for the two cases differ. As noted above, the bycatch rates for case 2 have been adjusted to reflect how they might change as the result of discouraging individual vessels from having excessively high bycatch rate. Because neither a total PSC cap nor an apportionment of a PSC cap is projected to be attained in either case, the only differences between the effects of these two cases are for the projections of bycatch and bycatch impact costs.

In comparison to case 1, case 2 results in the projected red king crab bycatch increasing by about 11,500 crab to 194,600 crab, C. bairdi bycatch decreasing by about 400,000 crab to 1.7 million crab , and halibut bycatch decreasing by about 1,300 mt to 4,000 mt (Table 2.13). The projected total bycatch impact cost decreases by $4.1 million to $16.0 million. Although the caps are not projected to constrain groundfish catch with either case 1 or 2, the projected reduction in halibut bycatch with case 2 may provide the groundfish industry a valuable margin for error considering that the bycatch projections can be subject to large errors for reasons noted above.

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. Substantial additional burdens will be placed on observers if their reports may be used to impose sanctions against a vessel. 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.

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 2.14) 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 with any of the three alternatives being considered, 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.

2.6 References

ADF&G (Alaska Department of Fish and Game). 1988. Westward Region shellfish report to the Alaska Board of Fisheries, April 1988. 384 p.

Berger, et. al. 1986. Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1985. NWAFC.

Berger, J. 1988. By-catch rates in the Bering Sea and Aleutian Islands joint venture groundfish fishery, 1986-1988. NOAA Technical Memorandum NMFS F/NWC-155. 137 pp.

Berger, J. and H. Weikart. 1989 Summary of U.S. observer sampling of foreign and joint venture fisheries in the northeast Pacific ocean and eastern Bering sea. 1988 NOAA Technical Memorandum NMFS F/NWC-172.

Berger, J., R.F. Kappenmann, L-l Low, and R.J. Marasco. 1989 Procedures for bycatch estimation of prohibited species in the 1989 Bering sea domestic trawl fisheries. NOAA Technical Memorandum NMFS F/NWC-173.

Clark, W. 1989 Regional and seasonal differences in halibut bycatch rates in joint venture bottom trawl fisheries in the Bering sea. IPHC, 1990 Stock Assessment Document III.

IPHC (International Pacific Halibut Commission). 1989. Population assessment of Pacific halibut stocks Appendix 1 to the NPFMC Bering Sea/Aleutian Islands Stock Assessment and Fishery Evaluation (SAFE) Document. September, 1989.

IPHC. 1988. Stock Assessment Document I: Trends in the fishery, 1987. Seattle, WA.

NMFS (National Marine Fisheries Service). 1988. Fisheries of the United States, 1987. Curr. Fish. Stat. No. 8700, Wash. D.C. 115 p.

NPFMC. 1986 EA/RIR/IRFA for Amendment 10 to the BSAI FMP.

NPFMC. 1989 EA/RIR/IRFA for Amendment 12a to the BSAI FMP.

PacFIN. 1988. PacFIN data base, NPFMC monthly value and landings reports. July 1988 and earlier issues.

Reeves, J. and J. Terry. 1986. A biological and economic analysis of the bycatch of prohibited species in the Bering Sea Area I Joint Venture flounder fishery. NMFS document, NWAFC, Seattle, WA. 57 p.

Schmidt, D. 1988. ADF&G, Kodiak, AK. Personal communication.

Smoker, J. 1990 NMFS/AK Region, Juneau, AK. Personal communication.

Stevens, B. and R.A. MacIntosh. Report to Industry on the 1989 Eastern Bering Sea Crab Survey. NMFS Report 89-18, 47 p.

Wiese, C. and P. Burden. 1988 The Intelligent Investor's Guide to Alaska's Groundfish Fishery. Pacific Fishing, Sept. 1988, pp. 46-57.

Williams, G. 1990 IPHC, Seattle, WA. Personal communication.

Williams, G.H., C.C. Schmitt, and S.H. Hoag. 1988. Incidental catch and mortality of Pacific halibut through 1986. IPHC, draft Tech. Rpt. No. 23. Seattle, WA.

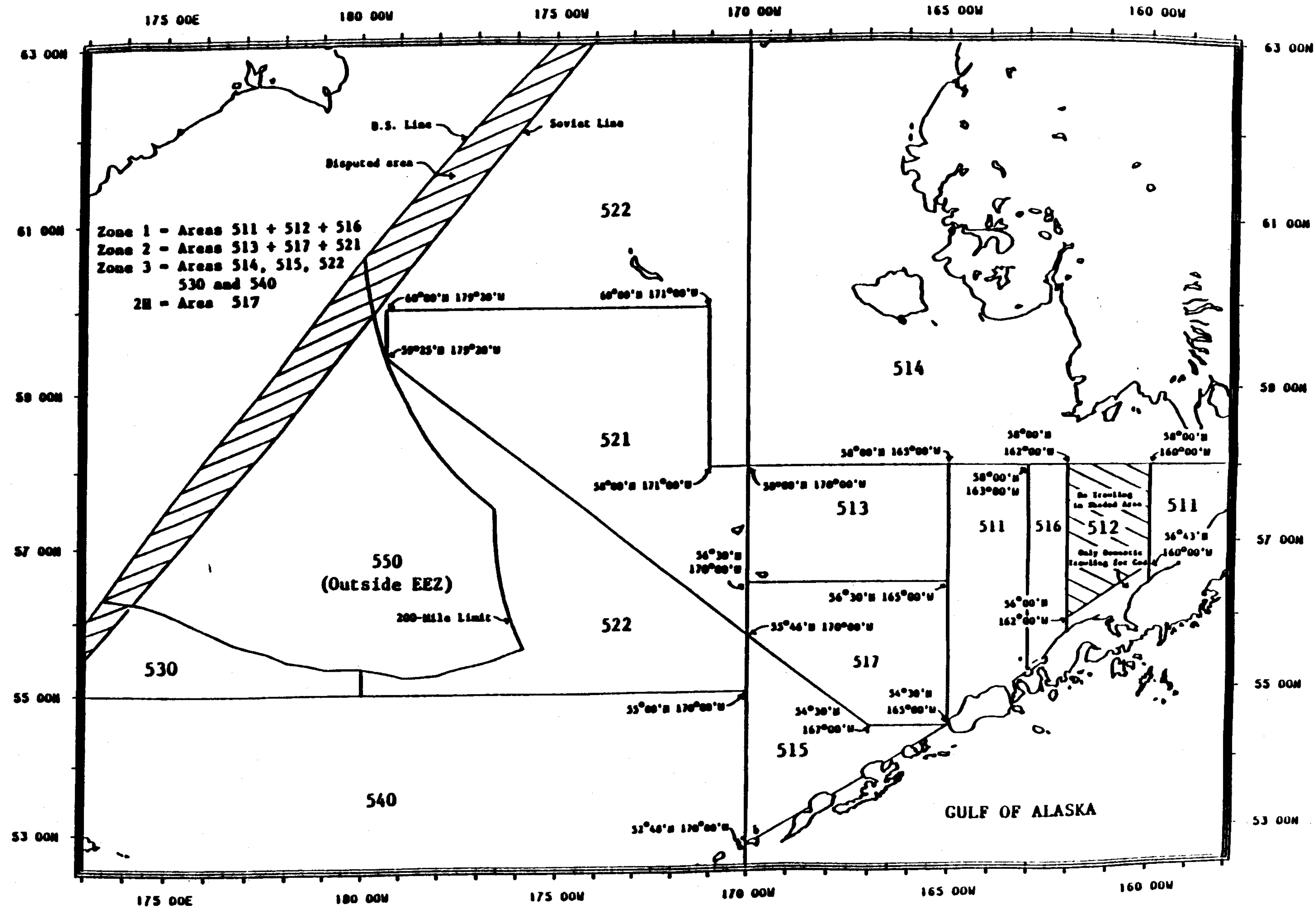


Figure 2-1. Bering Sea zones by which the restrictions on the incidental catch of king and Tanner crab apply.

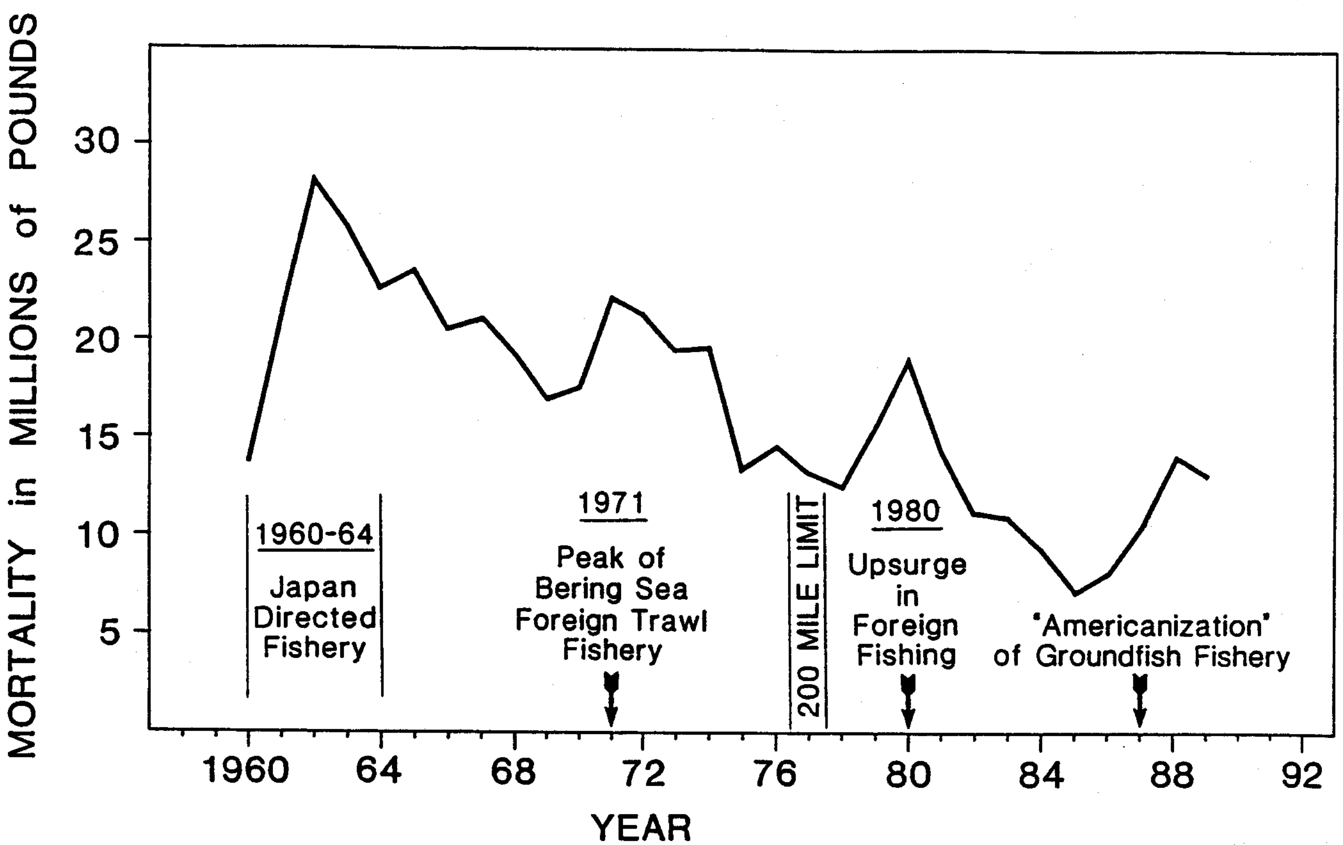


Figure 2.2 **Trend in incidental (bycatch) mortality of Pacific halibut coast wide since 1960.**
Source: Gregg Williams (IPHC).

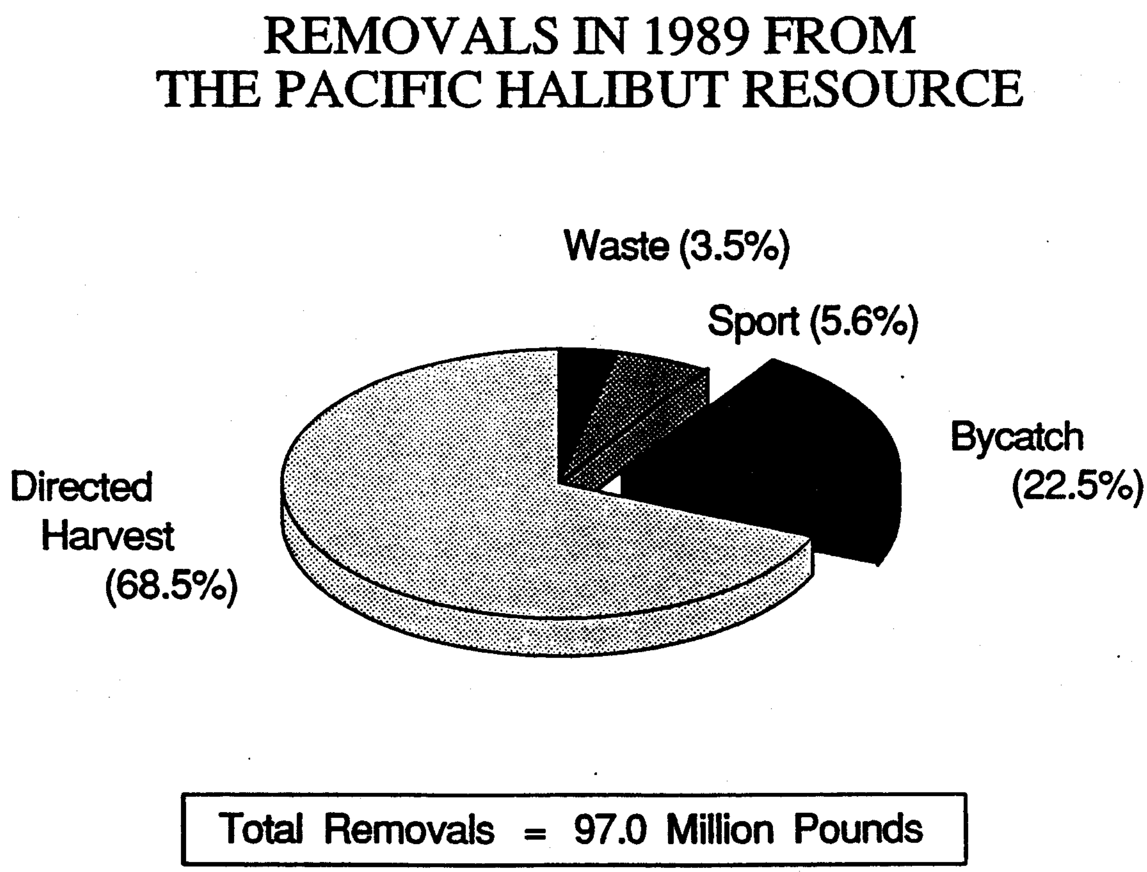


Figure 2.3 Breakdown of Pacific halibut Annual Surplus Production coastwide in 1989. Source: Gregg Williams (IPHC).

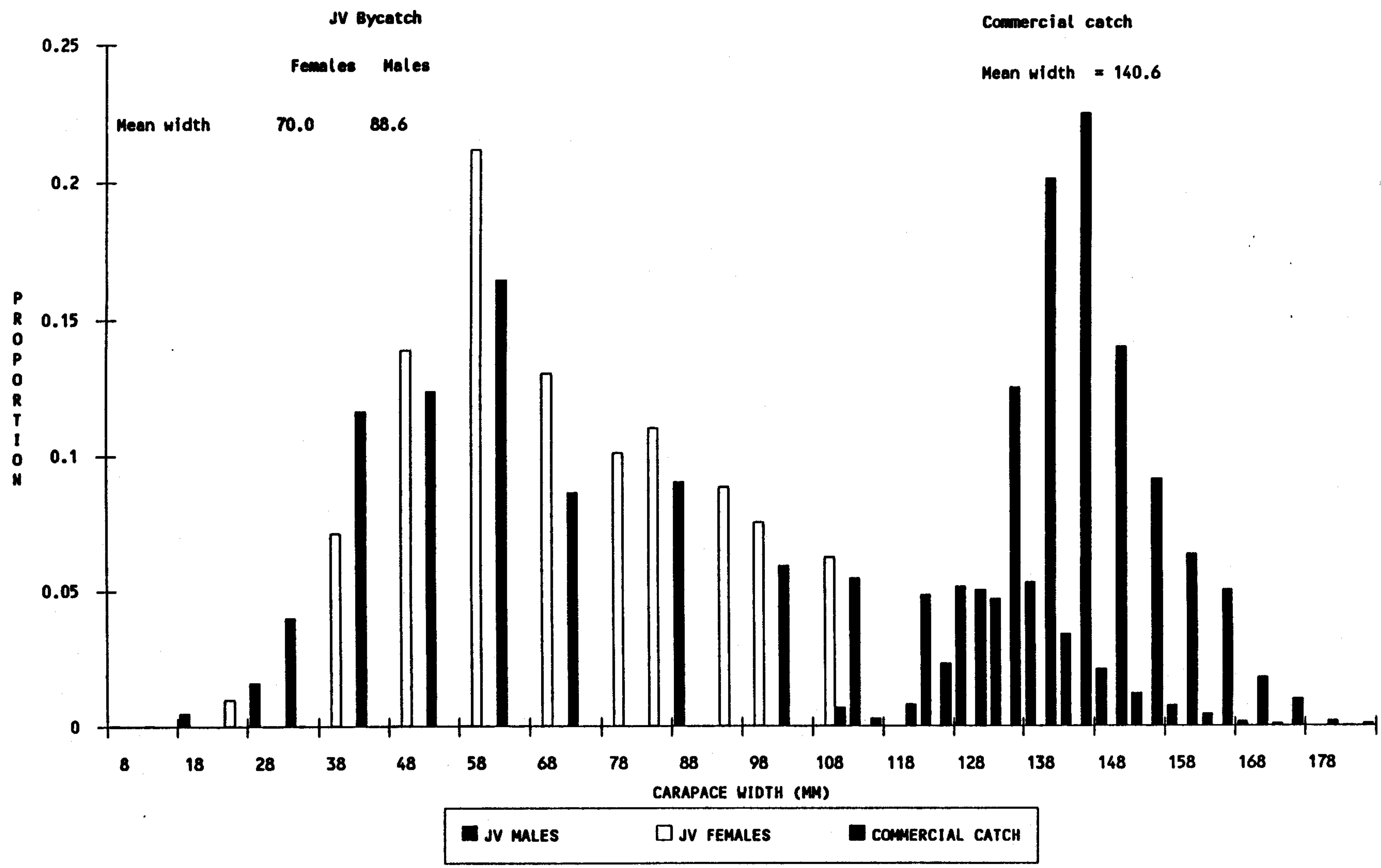


Figure 2.4 Size distribution of C. bairdi in the 1988 JV trawl bycatch and the 1988 commercial pot harvest. Sources: Jerry Berger (AFSC); Ken Griffin (ADF&G).

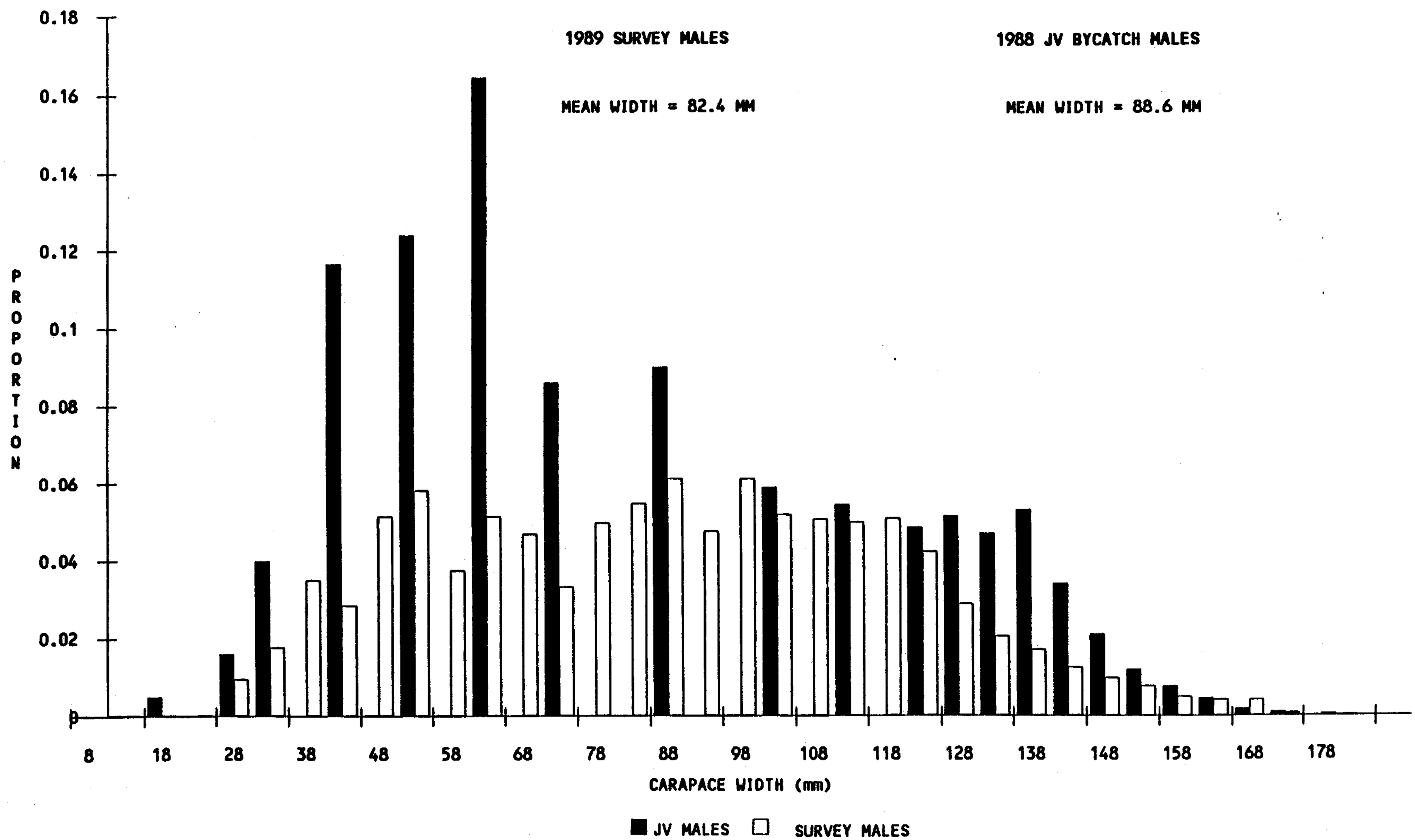


Figure 2.5 Size distribution of C. bairdi from the 1989 Bering Sea trawl survey population estimates and trawl bycatch in the 1988 JV fishery.
Sources: Brad Stevens (AFSC); Jerry Berger (AFSC).

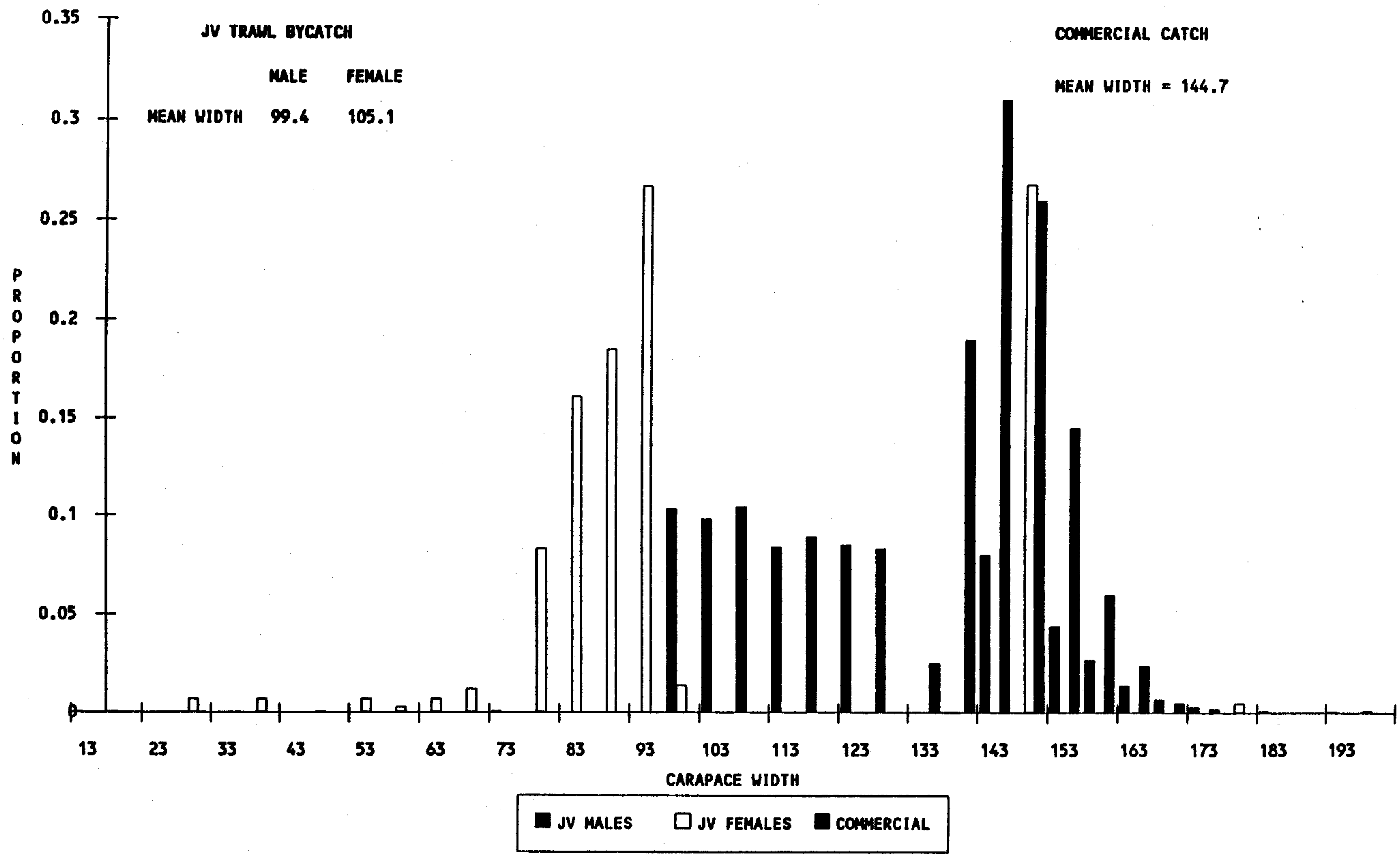


Figure 2.6 Size distribution of red king crab in the 1988 JV trawl bycatch and in the 1988 commercial pot harvest. Sources: Jerry Berger (AFCS); Ken Griffin (ADF&G).

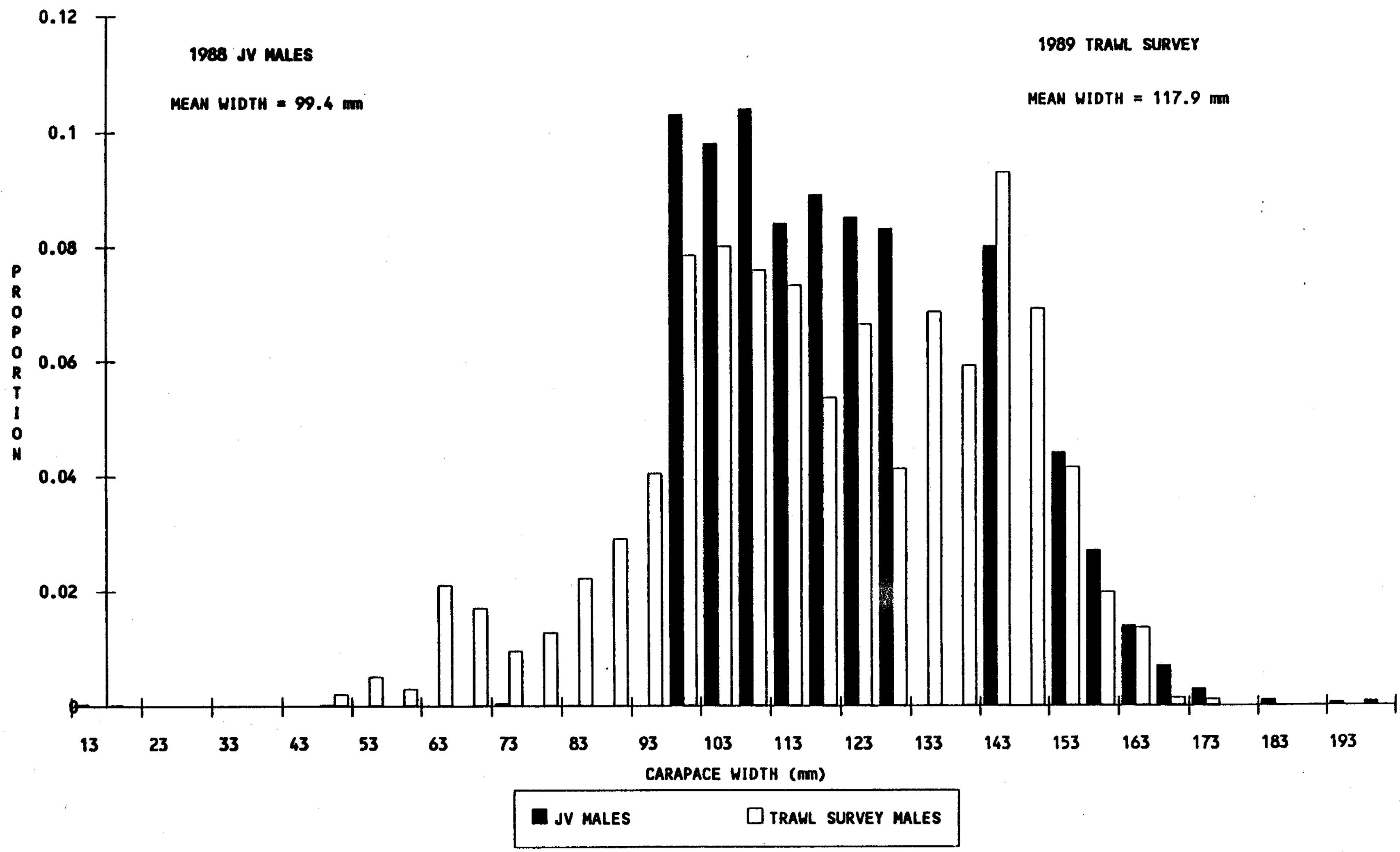


Figure 2.7 Size distribution of red king crab from the 1989 Bering Sea trawl survey population estimates and from the 1988 JV trawl bycatch.
Sources: Brad Stevens (AFSC) and Jerry Berger (AFSC).

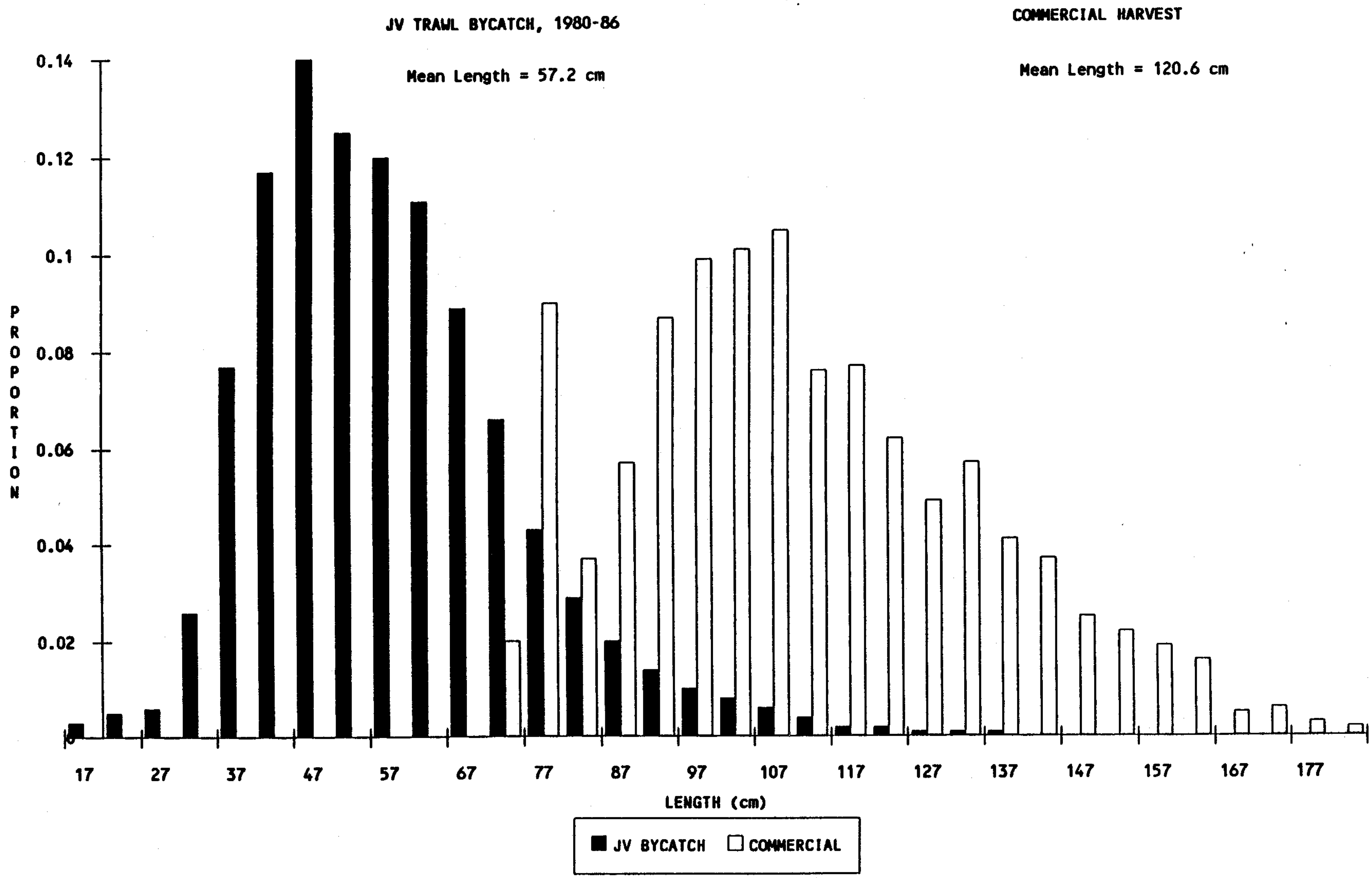


Figure 2.8 Size distribution of halibut in the 1980-86 JV trawl bycatch and in the 1988 commercial longline harvest. Source: Gregg Williams (IPHC).

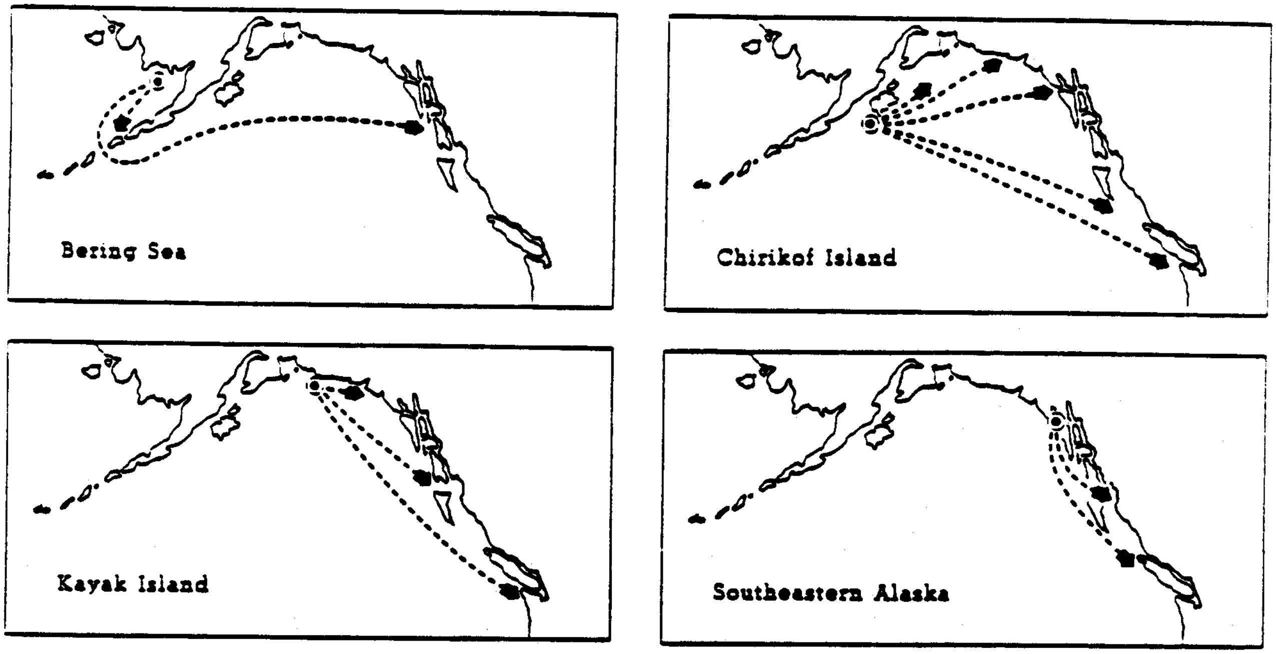


Figure 2.9 Migratory patterns of juvenile Pacific halibut from different tagging sites. Source: IPHC.

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 and foreign 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

	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	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

	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	0.042713	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

	JVP flatfish					DAP Deep				
Area	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Annual**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**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

	JVP flatfish					DAP Deep				
Area	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

	C. bairdi				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
b1- pollock	0	0	0.33948	0.45288	
b2 - cod	1.623739	5.48304	0	0	
b3 - y. sole	14.12925	1.045	6.845	1.6668	
b4 - o. flat.	12.43374	1.5194	2.3976	5.8105	

1990 DAP OBSERVED RATES USED IN 1st QTR

halibut				
Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual
b1- pollock	0.67527	1.811628	2.432976	1.787214
b2 - cod	8.149661	15.126228	6.338124	19.050252
b3 - y. sole	13.226367	0.4108	4.6134	7.2488
b4 - o. flat.	11.37752	6.391	1	2.2

C. Observer Data, 83-88

Herring

	DAP Other Bottom Trawl					DAP Midwater Trawl				
Area	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--Groundfish apportionments for 1990

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--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 2.10 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 2.11--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 Cost	$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 2.12--Estimates of bycatch impact cost per unit of crab and halibut bycatch, and gross revenue per unit of groundfish catch.

Bairdi Tanner Crab		$200/1,000 crab
Red King Crab		$12,200/1,000 crab
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 2.13--A comparison of bycatch model simulation results.

		Alternative 2	
	Alternative 1	Case 1[a]	Case 2[b]
Bycatch Amounts			
Red king crab (no.)	666,574	666,574	183,073
C. bairdi (no.)	3,457,997	3,457,997	2,075,693
Halibut (t)	5,293	5,293	5,299
Groundfish Catch (t)			
DAP Deep[d]	6,083	6,083	6,083
DAP rocksole	60,000	60,000	60,000
DAP flatfish	40,477	40,477	40,477
DAP other	504,414	504,414	505,099
DAP midwater	956,734	956,734	956,734
DAP subtotal	1,567,708	1,567,708	1,568,393
JVP flatfish	241,407	241,407	241,407
DAH total	1,809,115	1,809,115	1,809,800
Bycatch Impact Costs ($1,000s)			
Red king crab	8,132	8,132	2,233
C. bairdi	691	691	415
Halibut	17,467	17,467	17,487
Total	26,290	26,290	20,135
Gross Revenue ($1,000s)			
DAP	1,218,371	1,218,371	1,218,901
JVP	36,694	36,694	36,694
DAH	1,255,065	1,255,065	1,255,595
Gross Revenue-Variable Cost ($1,000s)			
DAP	785,763	785,763	786,293
JVP	13,236	13,236	4,500
DAH	798,999	798,999	790,793
Gross Revenue-Total Cost ($1,000s)			
DAP	437,969	437,969	438,499
JVP	710	710	-8,611
DAH	438,679	438,679	429,888

Table 2.13 (continued).

	Alternative 3	
	Case 1	Case 2[c]
Bycatch Amounts		
Red king crab (no.)	183,073	194,592
C. bairdi (no.)	2,075,693	1,672,768
Halibut (t)	5,299	4,032
Groundfish Catch (t)		
DAP Deep[d]	6,083	6,083
DAP rocksole	60,000	60,000
DAP flatfish	40,477	40,477
DAP other	505,099	505,099
DAP midwater	956,734	956,734
DAP subtotal	1,568,393	1,568,393
JVP flatfish	241,407	241,407
DAH total	1,809,800	1,809,800
Bycatch Impact Costs ($1,000s)		
Red king crab	2,233	2,374
C. bairdi	415	335
Halibut	17,487	13,305
Total	20,135	16,014
Gross Revenue ($1,000s)		
DAP	1,218,901	1,218,901
JVP	36,694	36,694
DAH	1,255,595	1,255,595
Gross Revenue-Variable Cost ($1,000s)		
DAP	786,293	786,293
JVP	4,500	4,500
DAH	790,793	790,793
Gross Revenue-Total Cost ($1,000s)		
DAP	438,499	438,499
JVP	-8,611	-8,611
DAH	429,888	429,888

a All flatfish fisheries begin January 1.
b Flatfish fisheries (except rock sole) begin May 15..
c Bycatch rates adjusted to reflect the effects of penalties on vessels with excessively high bycatch rates.
d New fishery designation, deepwater Greenland turbot/sablefish fishery.

Table 2.14--Comparison of differences between unconstrained and various constrained bycatch model results.

	Difference between Alternative 1 and Alt. 2 case 1	Difference between Alternative 1 and Alt. 2 case 2	Difference between Alternative 1 and Alt. 3 case 1	Difference between Alternative and Alt. 3 case 2
Bycatch Amounts				
Red king crab (no.)	0	483,501	483,501	11,519
C. bairdi (no.)	0	1,382,304	1,382,304	402,925
Halibut (t)	0	-6	-6	1,267
Groundfish Catch (t)				
DAP Deep[a]	0	0	0	0
DAP rocksole	0	0	0	0
DAP flatfish	0	0	0	684
DAP other	0	685	685	0
DAP midwater	0	0	0	0
DAP subtotal	0	685	685	684
JVP flatfish	0	0	0	0
DAH total	0	685	685	684
Bycatch Value ($1,000s)				
Red king crab	0	5,899	5,899	41
C. bairdi	0	276	276	80
Halibut	0	20	20	4,182
Total	0	6,155	6,155	4,303
Gross Revenue ($1,000s)				
DAP	0	530	530	5,225
JVP	0	0	0	0
DAH	0	530	530	5,225
Gross Revenue-Variable Cost ($1,000s)				
DAP	0	530	530	84,426
JVP	0	41,321	41,321	631
DAH	0	798,999	798,999	85,057
Gross Revenue-Total Cost ($1,000s)				
DAP	0	530	530	90,116
JVP	0	41,321	41,321	-1
DAH	0	40,791	40,791	90,115

a New fishery designation which includes deepwater Greenland turbot and sablefish.

Table 2.15--A comparison of bycatch from simulation results with Amendment 12A PSC caps by zone.

Area	12A Caps	Alt. 1	Alt. 2 Case 1	Alt. 2 Case 2	Alt. 3 Case 1	Alt. 3 Case 2
			Red king crab			
Zone 1	200,000	660,471	659,286	166,018	166,018	167,742
			C. bairdi			
Zone 1	1,000,000	2,563,605	2,563,605	724,926	774,926	627,853
Zone 2	3,000,000	894,393	885,881	1,340,767	1,330,767	1,044,915
			Halibut			
Zone 1, 2H	4,400 t	3,309 t	3,056 t	3,229 t	3,229 t	3,147 t
BS Wide	5,333 t	5,292 t	5,293 t	5,299 t	5,299 t	4,032 t

Table 2.16--Fishery closures as a result of exceeding bycatch apportionments.

Case	Closure	Cause	12A PSC Cap	Amount Exceeded bu
Alt. 2, Case 1	JVP flatfish	RKC[a], 1st Qtr.	50,000	465,887 crabs
		bairdi, " "	1,000,000	1,002,712 crabs
Alt. 2, Case 1	DAP flatfish	_bairdi_, " "	260,400	72,885 crabs
		halibut, " "	529 t	243 t

a Red King crab.

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

---

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.

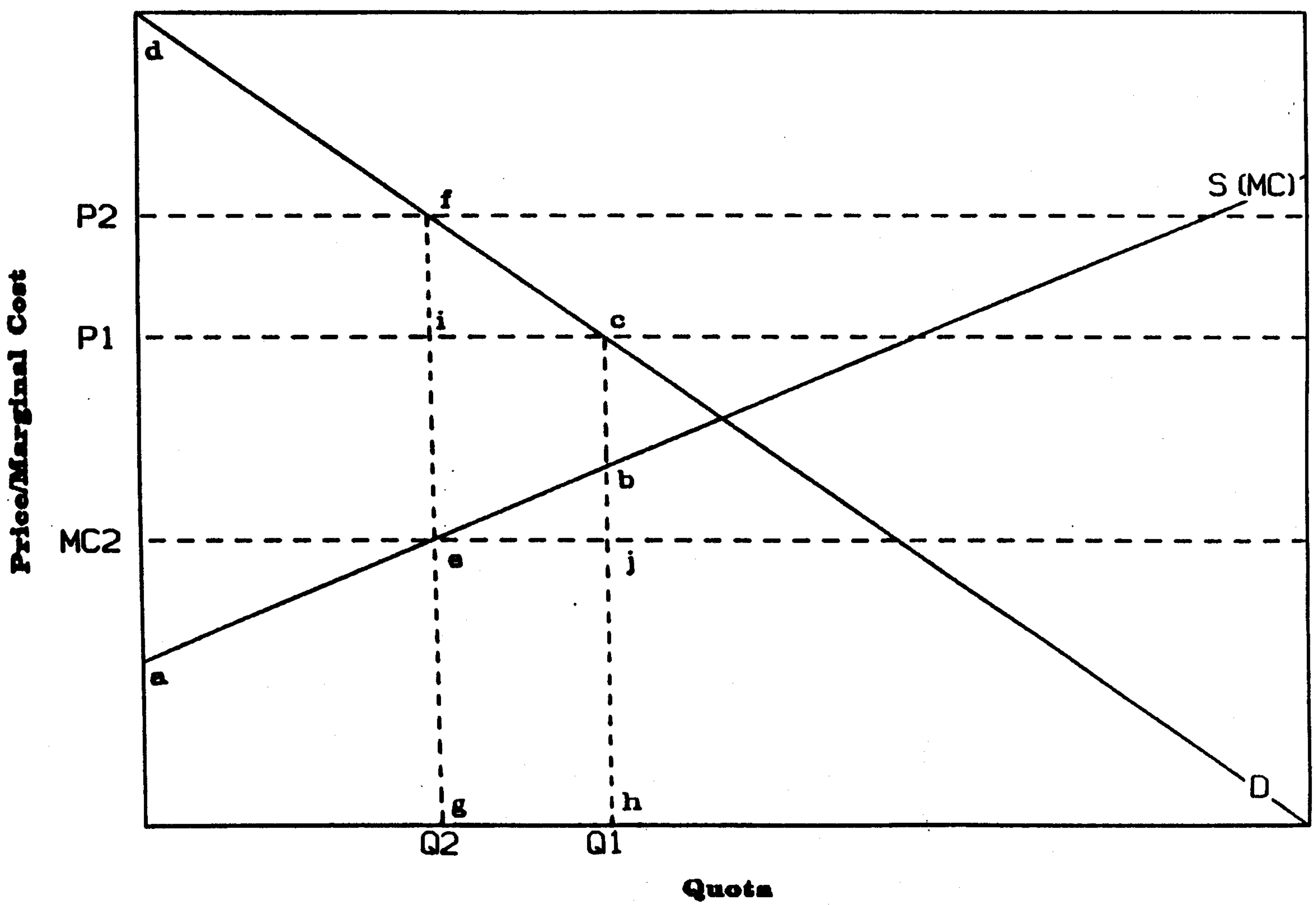


Table A2.1.1 Biological parameters used in estimating the potential impact cost of bycatch.

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

kg/crab	age	Catch years	Impact Discounted (lbs)	Exvessel Value ($) (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

kg/crab	age	Catch years	Impact Discounted (lbs)	Exvessel Value ($) (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.

Date: March 29, 1990

Prepared by: Janet Smoker, Alaska Regional Office
Consulted : Ron Berg, Alaska Regional Office
Janet Wall, Jerald Berger, Alaska Fisheries Science Center

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.

It is important to keep in mind 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.)

3.1.1 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 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 Council 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 lower 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 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 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.

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

$\underline{F_{MAX}}$ 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}).

$\underline{F_{0.1}}$ 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. For the sake of a more precise illustration, 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, it is important to understand that 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 (remember, 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; these are two fairly different concepts).

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 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 can it choose a more conservative definition? The Council is allowed to 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 that fishery 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, some of which (e.g., 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 can, 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: 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 (d).

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, sand 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 <u>relative</u> 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 <u>any</u> 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 ten stocks, as shown in Table 3.3. Of the seven 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.

3.6 References

Alverson, D. L., and W. T. Pereyra.
1969. Demersal fish populations in the northeastern Pacific Ocean--an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish Res. Board Can. 26:1985-2001.

Beddington, J. R., and J. G. Cooke.
1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242. Rood and Agriculture Organization of the United Nations, Rome. 47 p.

Beverton, R. J. H., and S. J. Holt.
1957. On the dynamics of exploited fish populations. Fishery Invest., Lond., Ser. 2, vol. 19, 533 p.

Clark, W. G.
1990. Choosing an exploitation rate on the basis of life history parameters. Unpubl. manuscr. International Pacific Halibut Commission, Seattle, WA 98145-2009. 11 p.

Deriso, R. B.
1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 37:268-282.

Deriso, R. B.
1987. Optimal $F_{0.1}$ criteria and their relationship to maximum sustainable yield. Can. J. Fish. Aquat. Sci. 44(Suppl. 2):339-348.

Kimura, D. K.
1988. Stock-recruitment curves as used in the stock-reduction analysis model. J. Cons. int. Explor. Mer 44:253-258.

Quinn, T. J. II, R. Fagen, and J. Zheng.
In press. Threshold management policies for exploited populations. Can. J. Fish. Aquat. Sci. 00:0000-0000.

Schnute, J.
1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42:414-429.

Shepherd, J. G.
1982. A family of general production curves for exploited populations. Math. Biosci. 59:77-93.

Thompson, G. G.
1990. Management advice from a simple dynamic pool. Unpubl. manuscr. 33 p. Alaska Fish. Science Cent., 7600 Sand Point Way NE., Seattle, WA 98115.

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.

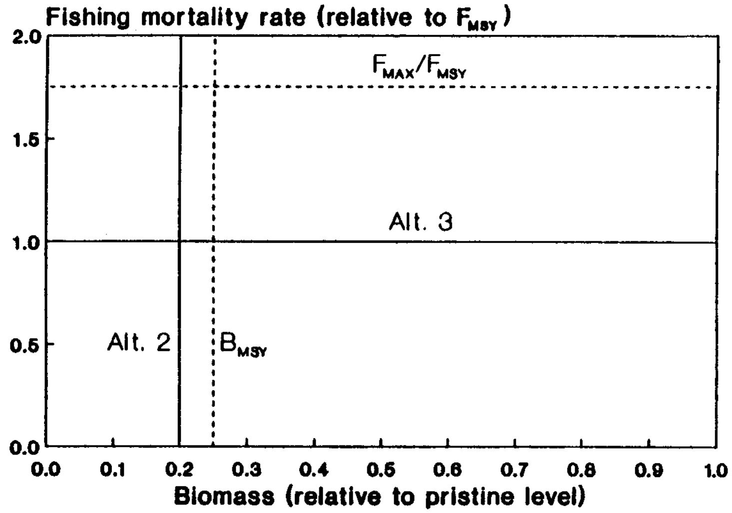


Figure 3.1a.

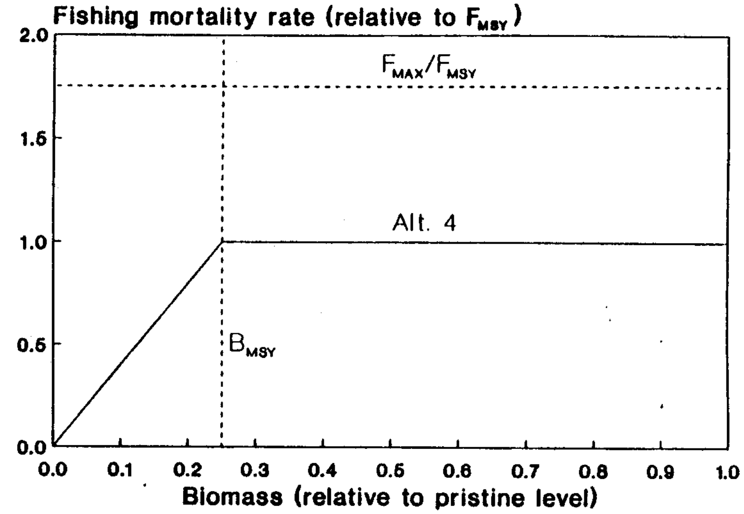


Figure 3.1b.

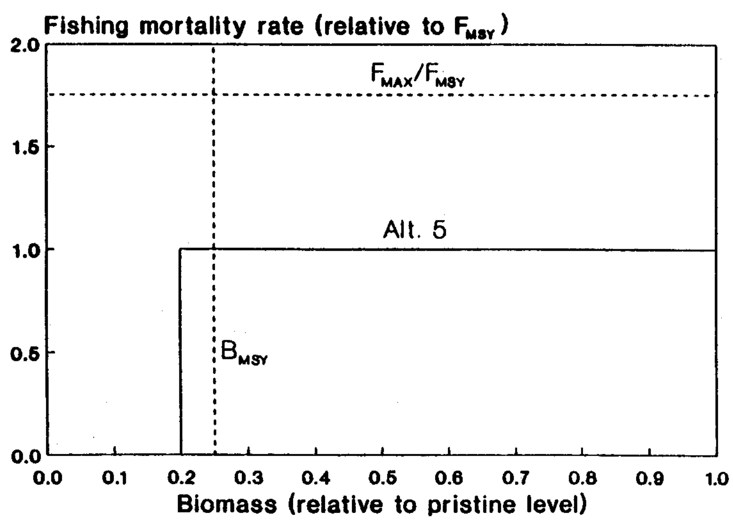


Figure 3.1c.

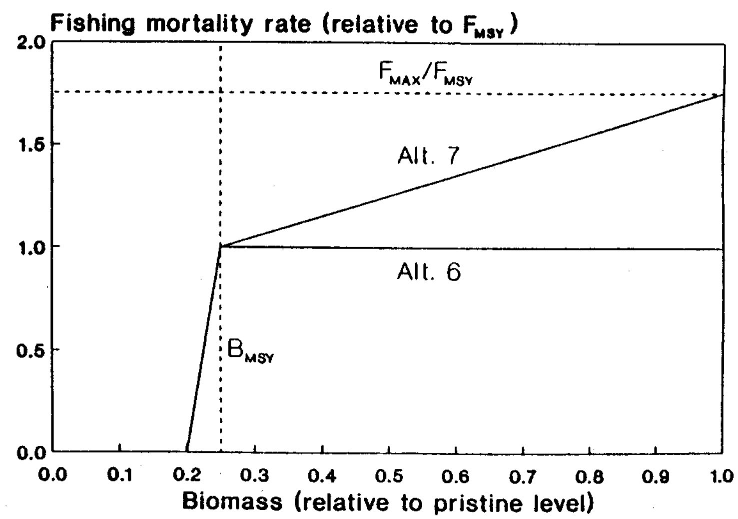
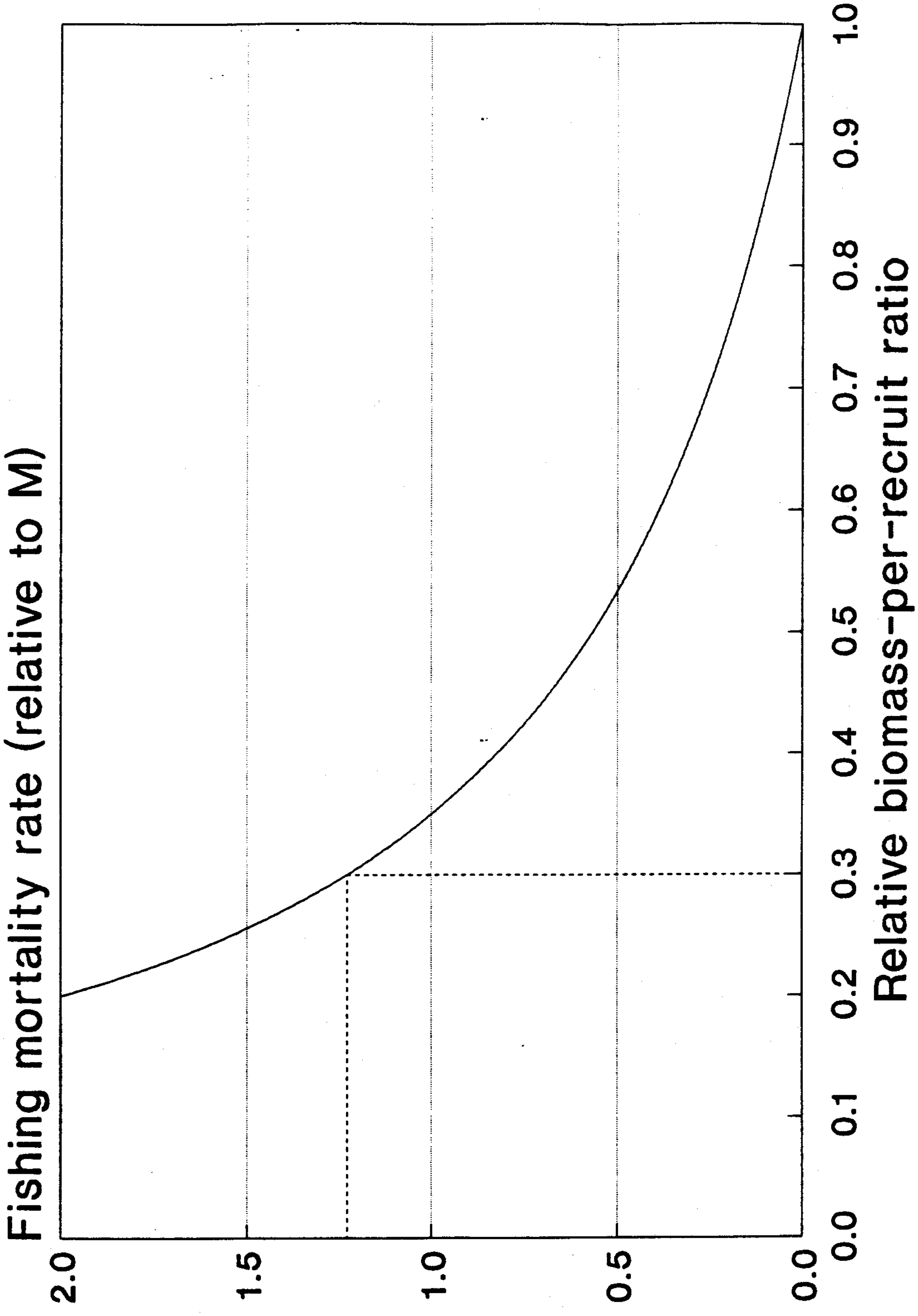


Figure 3.1d.



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

Grant G. Thompson

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
Resource Ecology and Fisheries Management Division
7600 Sand Point Way NE., Seattle, WA 98115-0070

Abstract

Among the various possible ways to define overfishing is the following: overfishing is any harvest policy that causes a stock to collapse. A depensatory generalization 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 such curves have been developed. These include three-equilibrium forms of the Ricker curve developed by Larkin et al. (1964) 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

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

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:

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

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

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

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 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 B_2 and B_3 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 recruits 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:

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

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

(11):

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

Fifth, define

$$\beta = B_t/B_p. \quad (16)$$

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

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

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

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

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 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.

<u>A Hypothesis Concerning Threshold Biomass</u>

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:

$$B_t \leq B_3. \tag{19}$$

Given Equation (19), Equation (18) can be made more specific by setting $f(r_3)=f_3(r_3)$, in which case β 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

$$\lim_{r_3 \to \infty} \beta = \frac{2-(3^{1/2})}{3-(3^{1/2})} \doteq 0.211. \tag{20}$$

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.

<u>Minimum Safe Biomass-per-Recruit Ratio</u>

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

$$B_e = [r_2(r_3-1)]^{1/r_3}. \tag{21}$$

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_R 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 other words, the goal would be to specify a maximum value for the ratio

$$\alpha = \frac{1/u_e}{1/u_p} = \frac{u_p}{u_e}. \tag{24}$$

This can be done by using Equation (19) to set the ratio R_3/B_3 as an upper limit to u_p, giving

$$\alpha = \frac{r_3[(r_3-1)f_3(r_3)]^{1/r_3}}{(r_3-1)[1+f_3(r_3)]} \tag{25}$$

as an upper limit to α. Equation (25) is plotted in Figure 5. Unlike β, α exhibits a maximum at a finite value of r_3. The α-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

$$\frac{df_3}{dr_3} = \left[\frac{f_3(r_3)}{r_3 + 2}\right]^2\left[\left[\frac{3r_3^2 + 2r_3 - 2}{r_3 + 1}\right]\left[\frac{3}{r_3^2 - 1}\right]^{1/2} - 6\right]. \tag{27}$$

The value of r_3 that solves Equation (26) is about 3.776, which results in an α 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.

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 be solved explicitly for F_{MSY}. 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. In this model,

$$u(F) = \left[\frac{1}{M(1+F')}\right]\left[1 + \frac{K''}{1+F'}\right], \qquad (28)$$

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:

$$F' = \frac{1 + \left[1+4\alpha K''(1+K'')\right]^{1/2}}{2\alpha(1+K'')} - 1. \qquad (29)$$

Equation (29) attains an upper limit of $(1/\alpha)-1$ when K"=0. It also exhibits the following lower limit:

$$\lim_{K''\to\infty} F' = \frac{1}{\alpha^{1/2}} - 1. \qquad (30)$$

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 B_{MSY}/B_p ratio 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 $0 \le q \le 1$. 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:

$$B(F) = \left[\frac{p}{M(1+F')}\left[1 + \frac{K''}{1+F'}\right]\right]^{\frac{1}{1-q}}. \tag{32}$$

Multiplying both sides of Equation (32) by F then gives the equation for equilibrium yield Y(F) shown below:

$$Y(F) = F\left[\frac{p}{M(1+F')}\left[1 + \frac{K''}{1+F'}\right]\right]^{\frac{1}{1-q}}. \tag{33}$$

Differentiating Equation (33) with respect to F and setting the resulting expression equal to zero gives the following equation for F_{MSY}:

$$\frac{F_{MSY}}{M} = \frac{-(q+1)K'' - (2q-1) + [(q+1)^2K''^2 + 2(3q-1)K'' + 1]^{1/2}}{2q}, \tag{34}$$

where $F'_{MSY} = F_{MSY}/M$.

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/$\underline{e}$ (=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.

The model also indicates that the F value corresponding to a B_{MSY}/B_p ratio of b (F_b) is given by the following equation:

$$\frac{F_b}{M} = \frac{1 - 2b^{1-q}(K''+1) + [4b^{1-q}K''(K''+1) + 1]^{1/2}}{2b^{1-q}(K''+1)}. \tag{35}$$

Equations (34) and (35) can be solved simultaneously to yield the following polynomial in K":

$$[4b^{2-2q}-(q^2+2q+1)b^{1-q}]K''^5+[16b^{2-2q}-(3q^2+10q+3)b^{1-q}]K''^4 +$$

$$+[24b^{2-2q}-(3q^2+18q+2)b^{1-q}-q]K''^3+[16b^{2-2q}-(q^2+14q-2)b^{1-q}-3q)]K''^2$$

$$[4b^{2-2q}-(4q-3)b^{1-q}-3q]K''+b^{1-q}-q = 0. \tag{36}$$

Equation (36) has at most one positive root, which is the value that sets B_{MSY}/B_p=b given q. This solution is plotted for b=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 b=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_b (Y_b) to MSY is given by

$$\frac{Y_b}{MSY} = \left[\frac{F'_b}{F'_{MSY}}\right]\left[\frac{[1+K''+F'_b](1+F'_{MSY})^2}{(1+K''+F'_{MSY})[1+F'_b]^2}\right]^{1/(1-q)}, \tag{37}$$

where $F'_b=F_b/M$ 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 (30) gives the parameter values that set F_{MSY} equal to the F level corresponding to a given value of α:

$$K'' = \frac{2\alpha(\alpha-q) + \left[\alpha(q-\alpha)\left[4\alpha(q-\alpha)-(q+1)^2+4\alpha\right]\right]^{1/2}}{a\left[(q+1)^2-4\alpha\right]}. \tag{38}$$

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:

$$\alpha = P^{1/2}, \tag{40}$$

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 α=0.316 and α=0.393, respectively. Thus, constraining F by the value that sets α=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 (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.

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 1990).

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.

References

Alverson, D. L., and W. T. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean--an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. Journal of the Fisheries Research Board of Canada 26:1985-2001.

Beddington, J. R. 1986. Shifts in resource populations in large marine ecosystems. Pages 9-18 <u>in</u> K. Sherman and L. M. Alexander, editors. Variability and management of large marine ecosystems. American Association for the Advancement of Science Selected Symposium 99. Westview Press, Boulder, CO.

Beddington, J. R., and J. G. Cooke. 1983. The potential yield of fish stocks. FAO Fisheries Technical Paper 242. Food and Agriculture Organization of the United Nations, Rome. 47 p.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. U.K. Ministry of Agriculture and Fisheries, Fisheries Investigations series 2, volume 19. 533 p.

Botsford, L. W. 1981. The effects of increased individual growth rates on depressed population size. American Naturalist 117:38-63.

Clark, C. W. 1973. The economics of overexploitation.

Science 181:630-634.
Clark, C. W. 1974. Possible effects of schooling on the dynamics of exploited fish populations. Journal du Conseil Internationale pour l'Exploration de la Mer 36:7-14.
Clark, C. W. 1976. Mathematical bioeconomics: the optimal management of renewable resources. John Wiley and Sons, New York.
Clark, W. G. 1990. Choosing an exploitation rate on the basis of life history parameters. Unpubl. manuscr. International Pacific Halibut Commission, Seattle, WA 98145-2009. 11 p.
Cushing, D. H. 1971. The dependence of recruitment on parent stock in different groups of fishes. Journal du Conseil Internationale pour l'Exploration de la Mer 33:340-362.
DeAngelis, D. L., S. W. Christensen, and A. G. Clark. 1977. Responses of a fish population model to young-of-the-year mortality. Journal of the Fisheries Research Board of Canada 34:2124-2132.
Deriso, R. B. 1987. Optimal $F_{0.1}$ criteria and their relationship to maximum sustainable yield. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 2):339-348.
Fowler, C. W. 1988. Population dynamics as related to rate of increase per generation. Evolutionary Ecology 2:197-204.
Gordan, H. S. 1954. Economic theory of a common-property resource: the fishery. Journal of Political Economy 62:124-142.
Graham, M. 1935. Modern theory of exploiting a fishery, and application to North Sea trawling. Journal du Conseil Internationale pour l'Exploration de la Mer 10:264-274.
Gulland, J. A. 1977. The stability of fish stocks. Journal du Conseil Internationale pour l'Exploration de la Mer 37:199-204.
Gulland, J. A., and L. K. Boerema. 1973. Scientific advice on catch levels. U.S. National Marine Fisheries Service, Fishery Bulletin 71:325-335.
Holling, C. S. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-22.
Hulme, H. R., R. J. H. Beverton, and S. J. Holt. 1947. Population studies in fisheries biology. Nature 159:714-715.
Jones, D. D., and C. J. Walters. 1976. Catastrophe theory and fisheries regulation. Journal of the Fisheries Research Board of Canada 33:2829-2833.
Kimura, D. K. 1988. Stock-recruitment curves as used in the stock-reduction analysis model. Journal du Conseil Internationale pour l'Exploration de la Mer 44:253-258.
Larkin, P. A., R. F. Raleigh, and N. J. Wilimovsky. 1964. Some alternative premises for constructing theoretical reproduction curves. Journal of the Fisheries Research

Board of Canada 21:477-484.
Le Cren, E. D., C. Kipling, and J. C. McCormack. 1972. Windermere: effects of exploitation and eutrophication on the salmonid community. Journal of the Fisheries Research Board of Canada 29:819-832.
Lewontin, R. C. 1969. The meaning of stability. Diversity and stability in ecological systems, Brookhaven Symposia in Biology 22:13-24.
May, R. M. 1977. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. Nature 269:471-477.
Murphy, G. I. 1977. Clupeoids. Pages 283-308 in J. A. Gulland, editor. Fish population dynamics. John Wiley and Sons, New York.
Neave, F. 1953. Principles affecting the size of pink and chum salmon populations in British Columbia. Journal of the Fisheries Research Board of Canada 9:450-491.
Parrish, R. H., and A. D. MacCall. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. California Department of Fish and Game Fish Bulletin 167.
Paulik, G. J. 1973. Studies of the possible form of the stock-recruitment curve. Conseil Internationale pour l'Exploration de la Mer, Rapports et Proces-Verbaux des Reunions 164:302-315.
Peterman, R. M. 1977. A simple mechanism that causes collapsing stability regions in exploited salmonid populations. Journal of the Fisheries Research Board of Canada 34:1130-1142.
Plourde, C. G. 1970. A simple model of replenishable resource exploitation. American Economic Review 60:518-522.
Quinn, T. J. II, R. Fagen, and J. Zheng. In press. Threshold management policies for exploited populations. Canadian Journal of Fisheries and Aquatic Sciences 00:0000-0000.
Ricker, W. E. 1954. Stock and recruitment. Journal of the Fisheries Research Board of Canada 11:559-623.
Schnute, J. 1985. A general theory for analysis of catch and effort data. Canadian Journal of Fisheries and Aquatic Sciences 42:414-429.
Shepherd, J. G. 1982. A family of general production curves for exploited populations. Mathematical Biosciences 59:77-93.
Smith, S. H. 1968. Species succession and fishery exploitation in the Great Lakes. Journal of the Fisheries Research Board of Canada 25:667-693.
Thompson, G. G. 1989. Analytic solution of a dynamic pool model incorporating constant marginal costs and discount rates. Mathematical Biosciences 95:139-159.
Thompson, G. G. In press. Management advice from a simple dynamic pool model. U.S. National Marine Fisheries Service, Fishery Bulletin 00:0000-0000.
Ulltang, O. 1980. Factors affecting the reaction of pelagic

fish stocks to exploitation and requiring a new approach to assessment and management. Conseil Internationale pour l'Exploration de la Mer, Rapports et Proces-Verbaux des Reunions 177:489-504.

Warren, C. E., M. Allen, and J. W. Haefner. 1979. Conceptual frameworks and the philosophical foundations of general living systems theory. Behavioral Science 24:296-310.

Wells, L. 1977. Changes in yellow perch (Perca flavescens) populations of Lake Michigan, 1954-75. Journal of the Fisheries Research Board of Canada 34:1821-1829.

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) Threshold 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 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 α=0.3 and α=0.4.

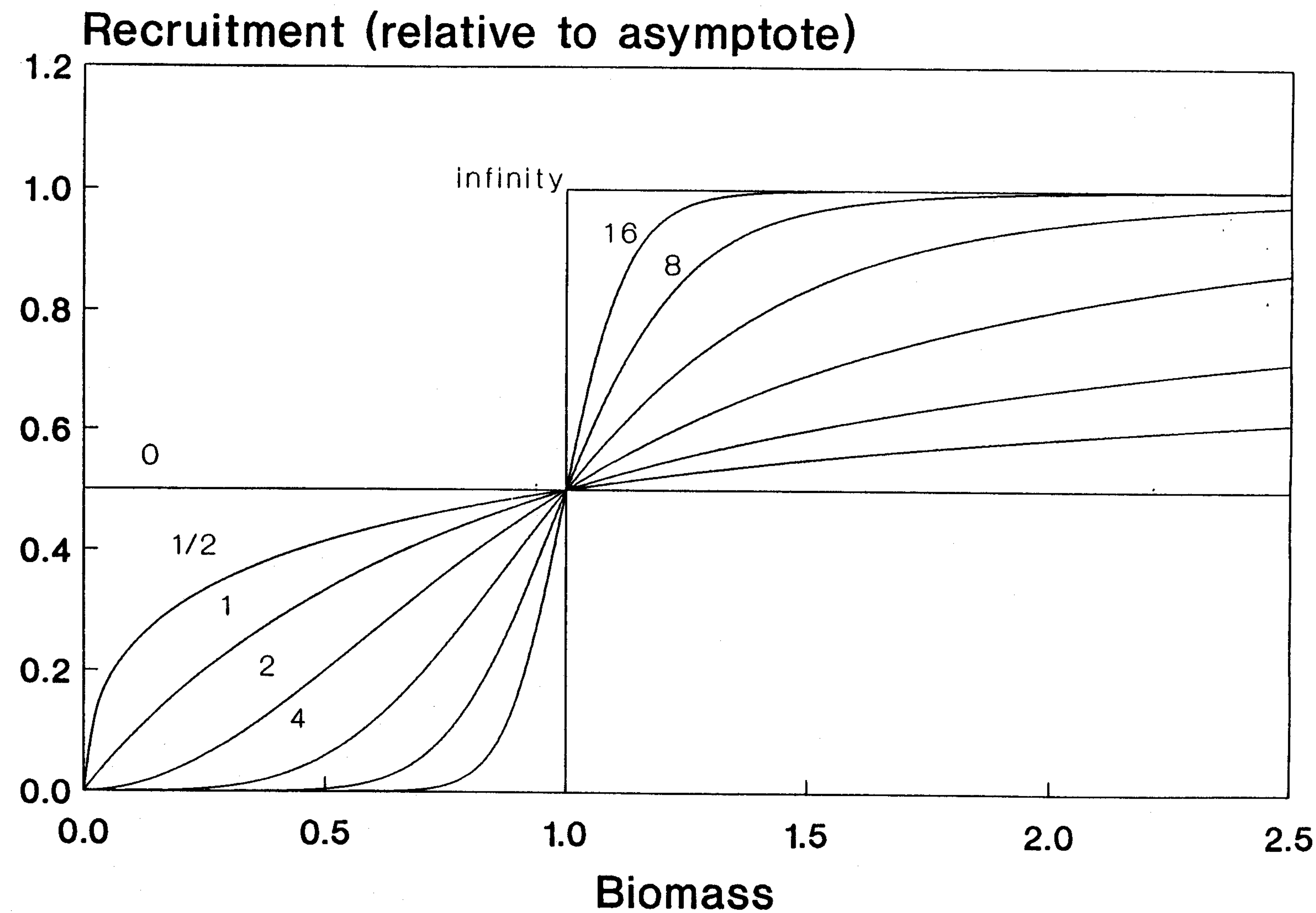

Recruitment (relative to asymptote)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
infinity
16
8
0
1/2
1
2
4
0.0
0.5
1.0
1.5
2.0
2.5
Biomass

Figure 1.

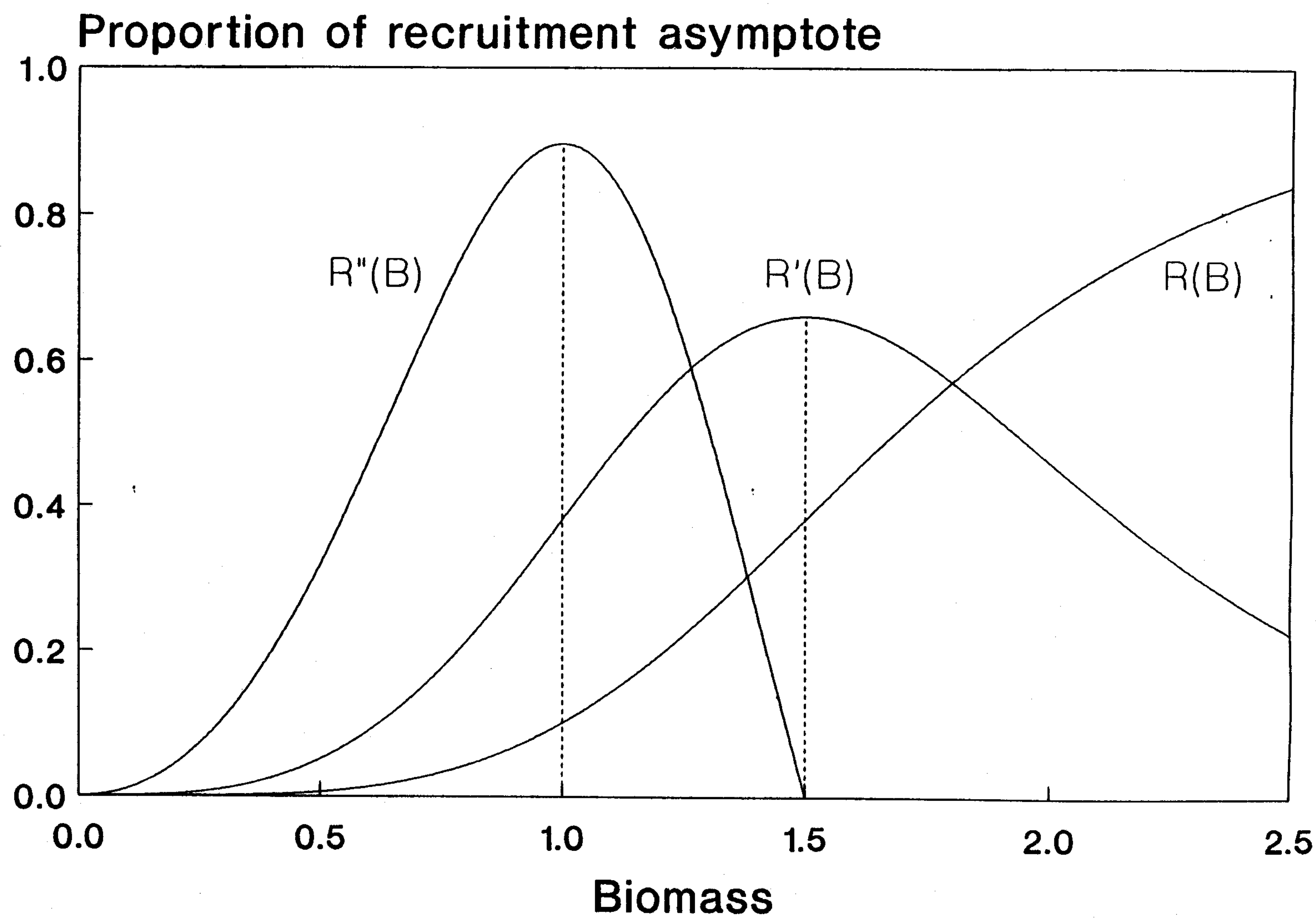

Proportion of recruitment asymptote
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Biomass
R"(B)
R'(B)
R(B)

Figure 2.

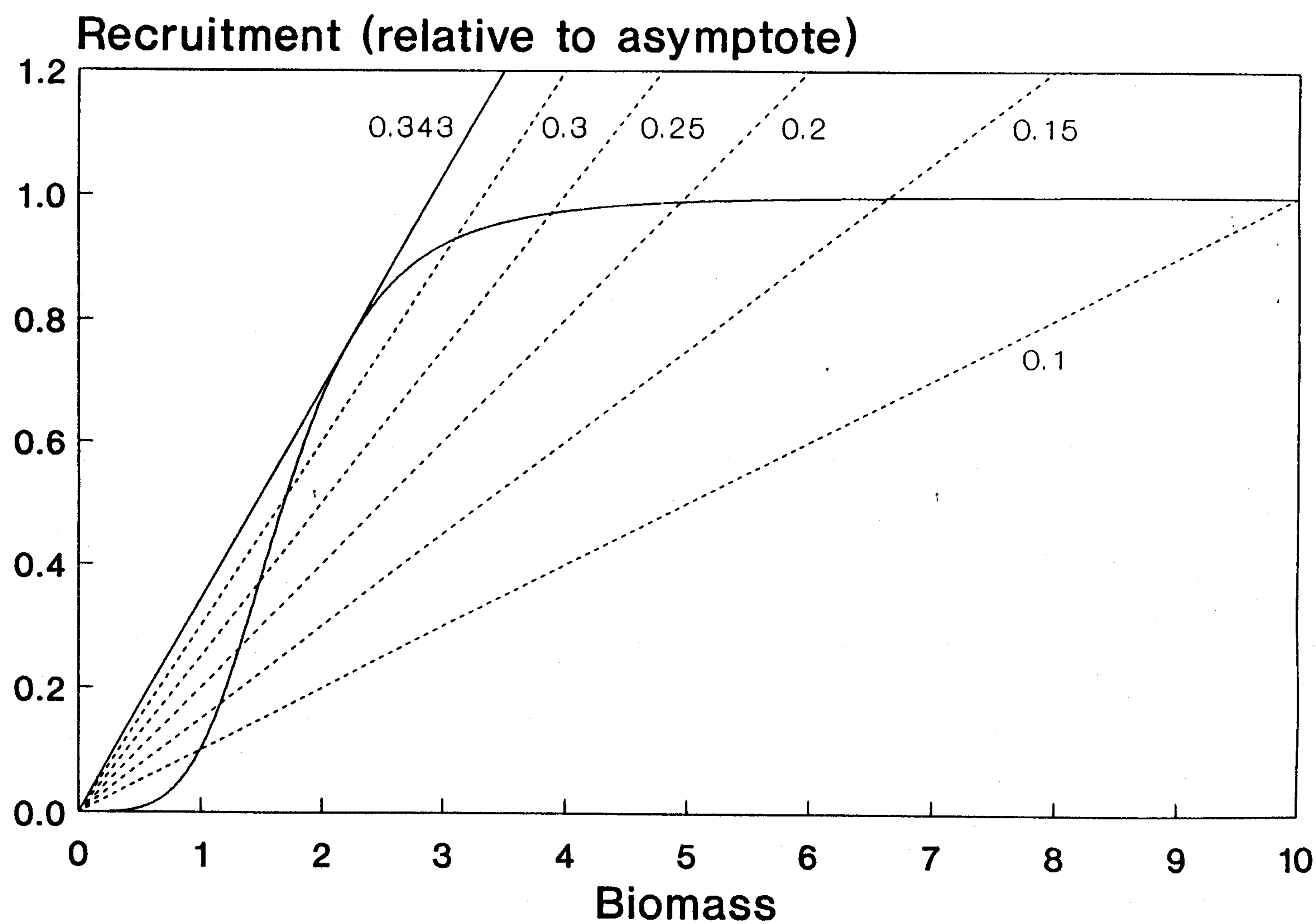

Recruitment (relative to asymptote)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.343
0.3
0.25
0.2
0.15
0.1
0
1
2
3
4
5
6
7
8
9
10
Biomass

Figure 3.

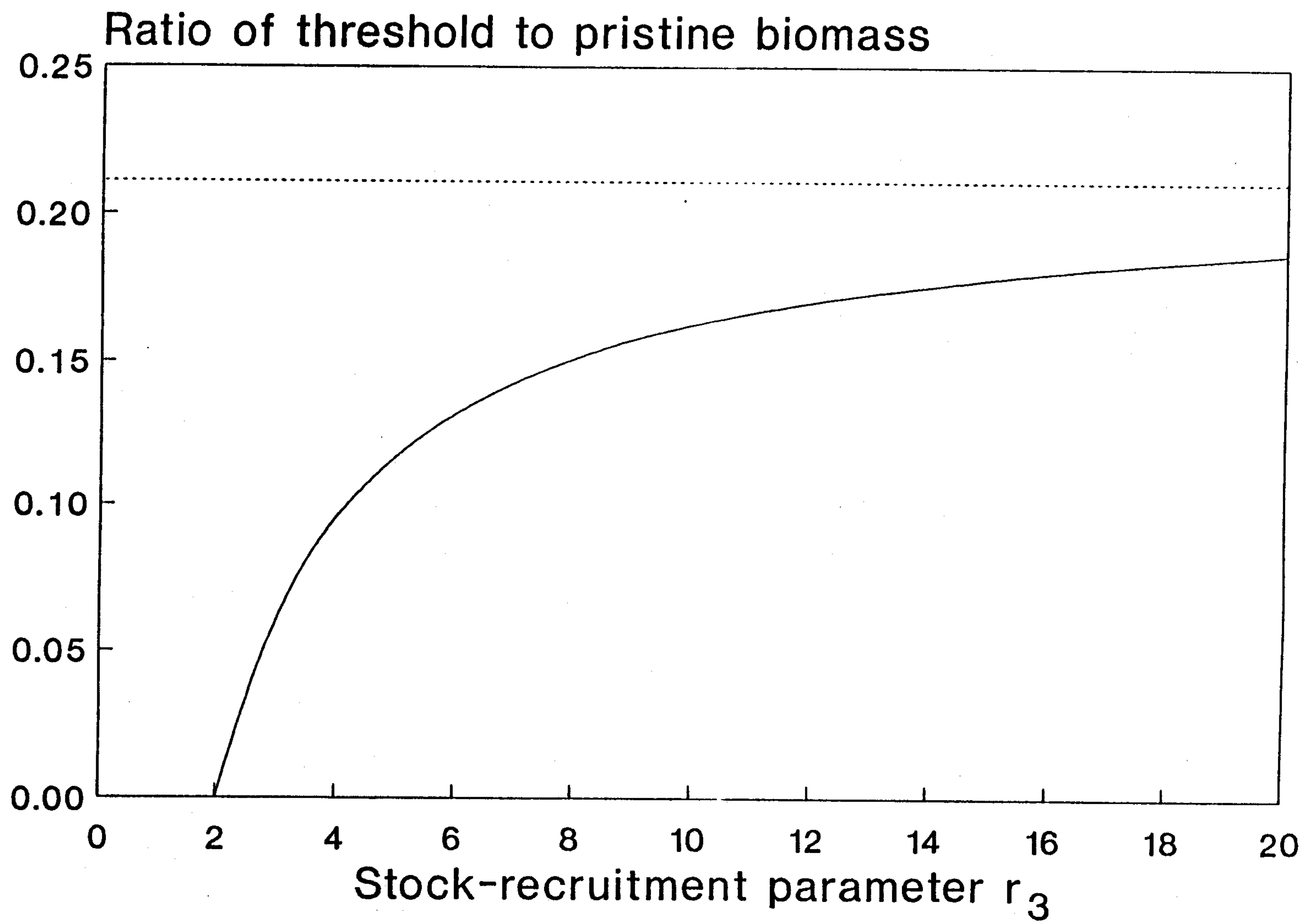
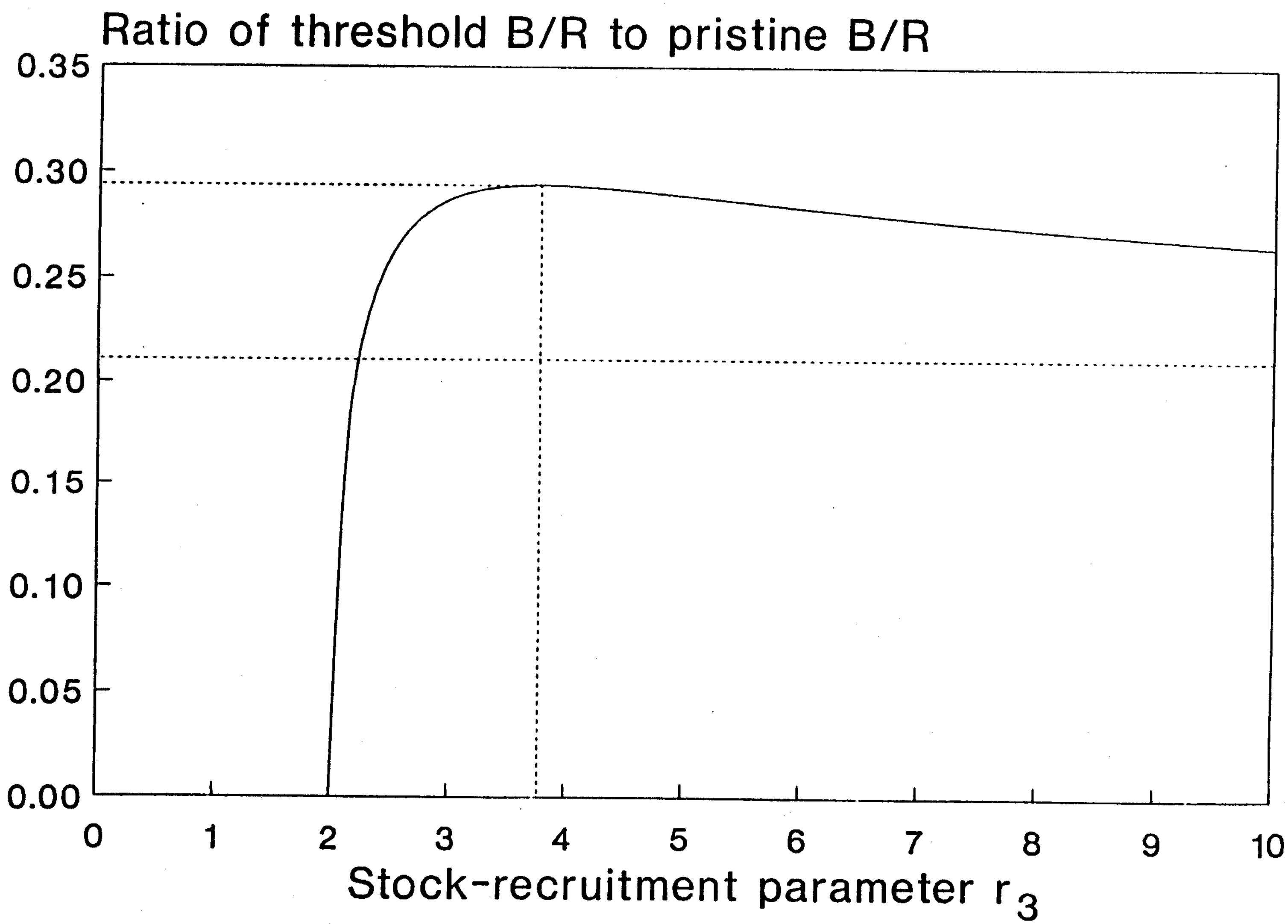
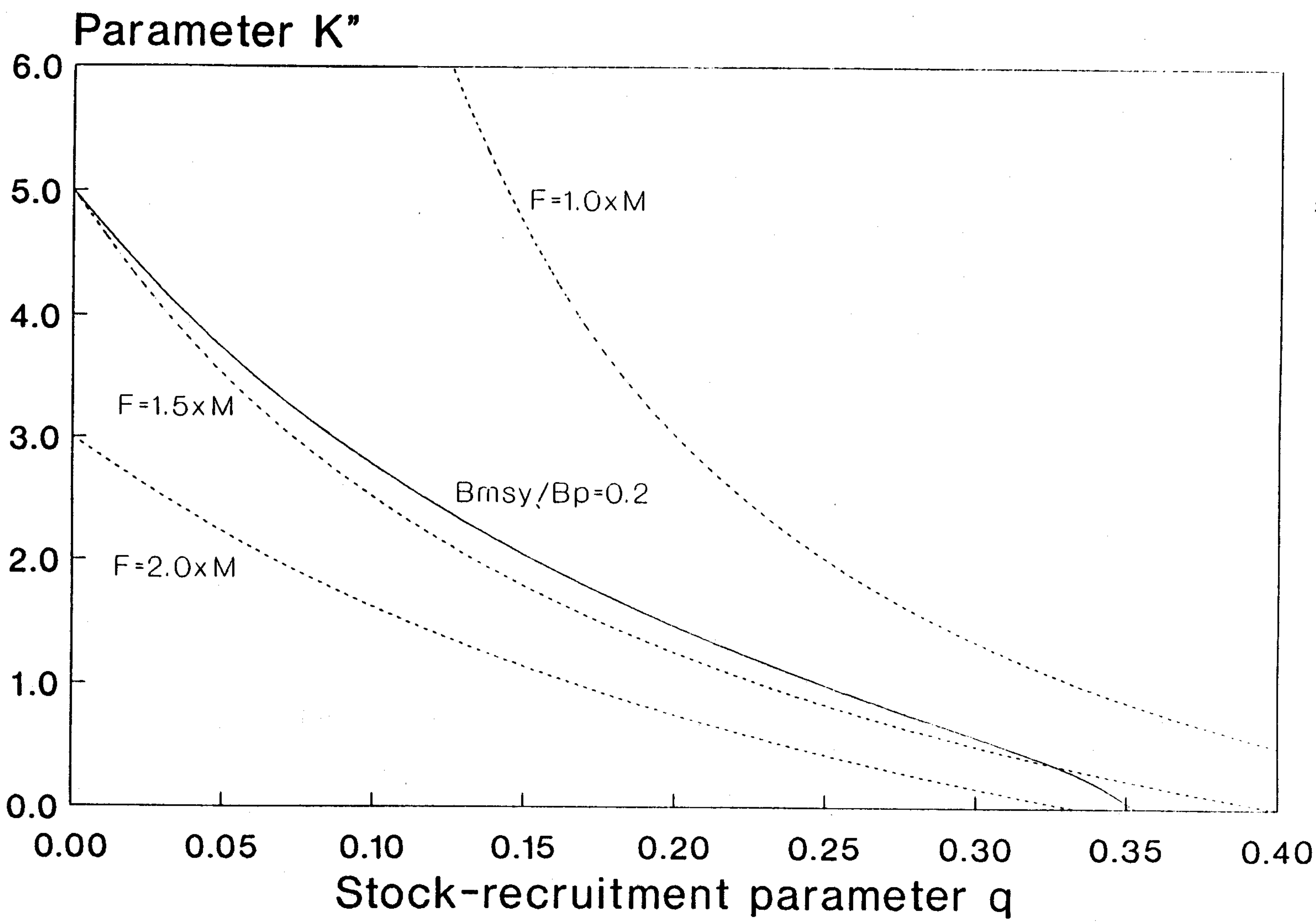

Ratio of threshold to pristine biomass
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14
16
18
20
Stock-recruitment parameter r3

Figure 4.



Ratio of threshold 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 r_3

Figure 5.



Parameter K"
6.0
5.0
4.0
3.0
2.0
1.0
0.0
F=1.0xM
F=1.5xM
F=2.0xM
Bmsy/Bp=0.2
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Stock-recruitment parameter q

Figure 6.

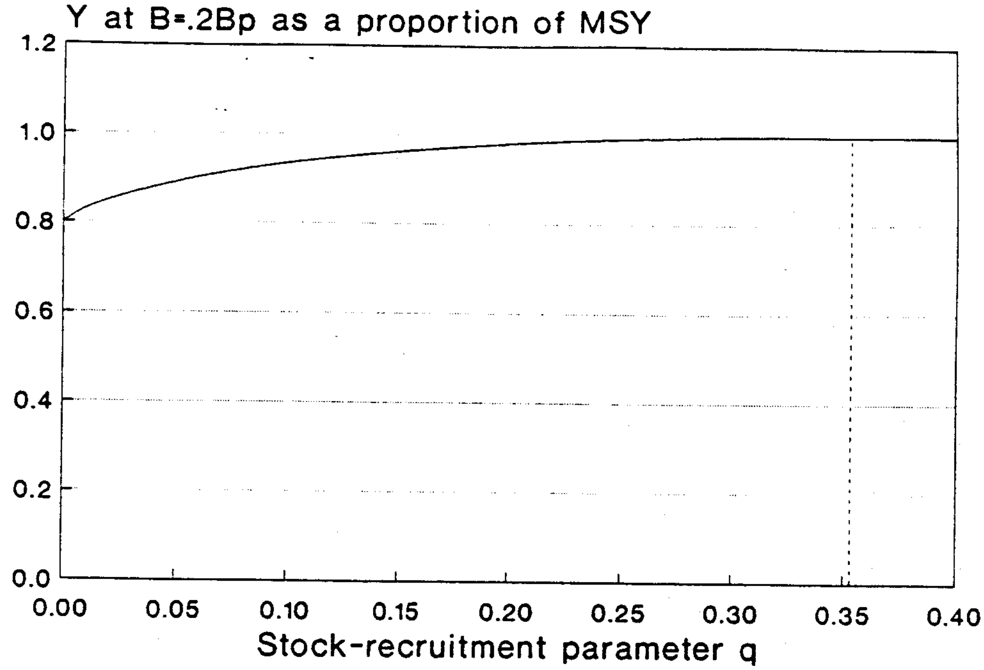


Figure 7a.

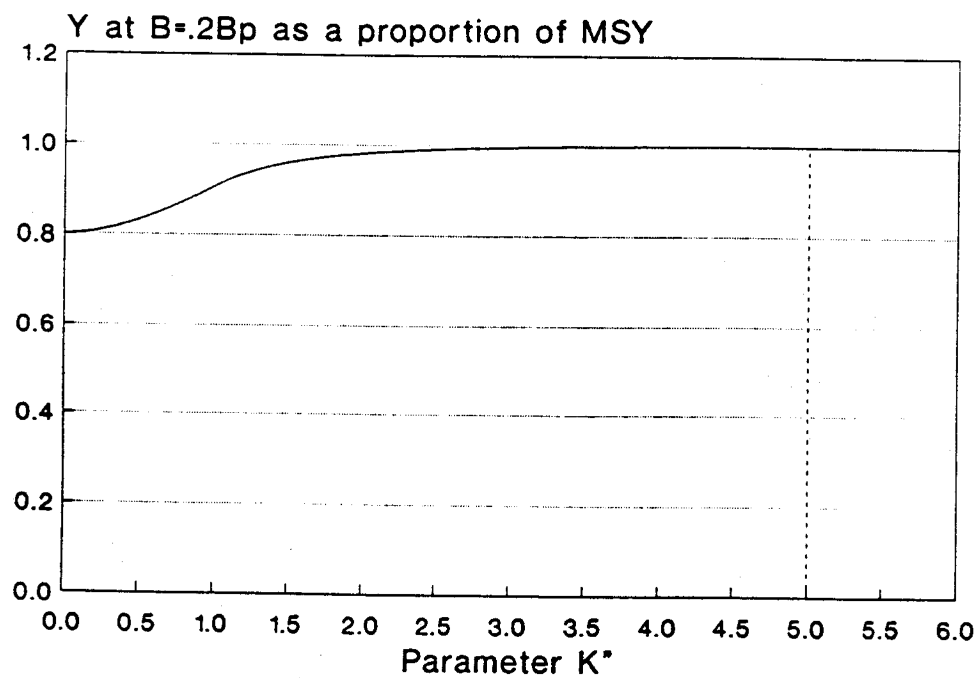
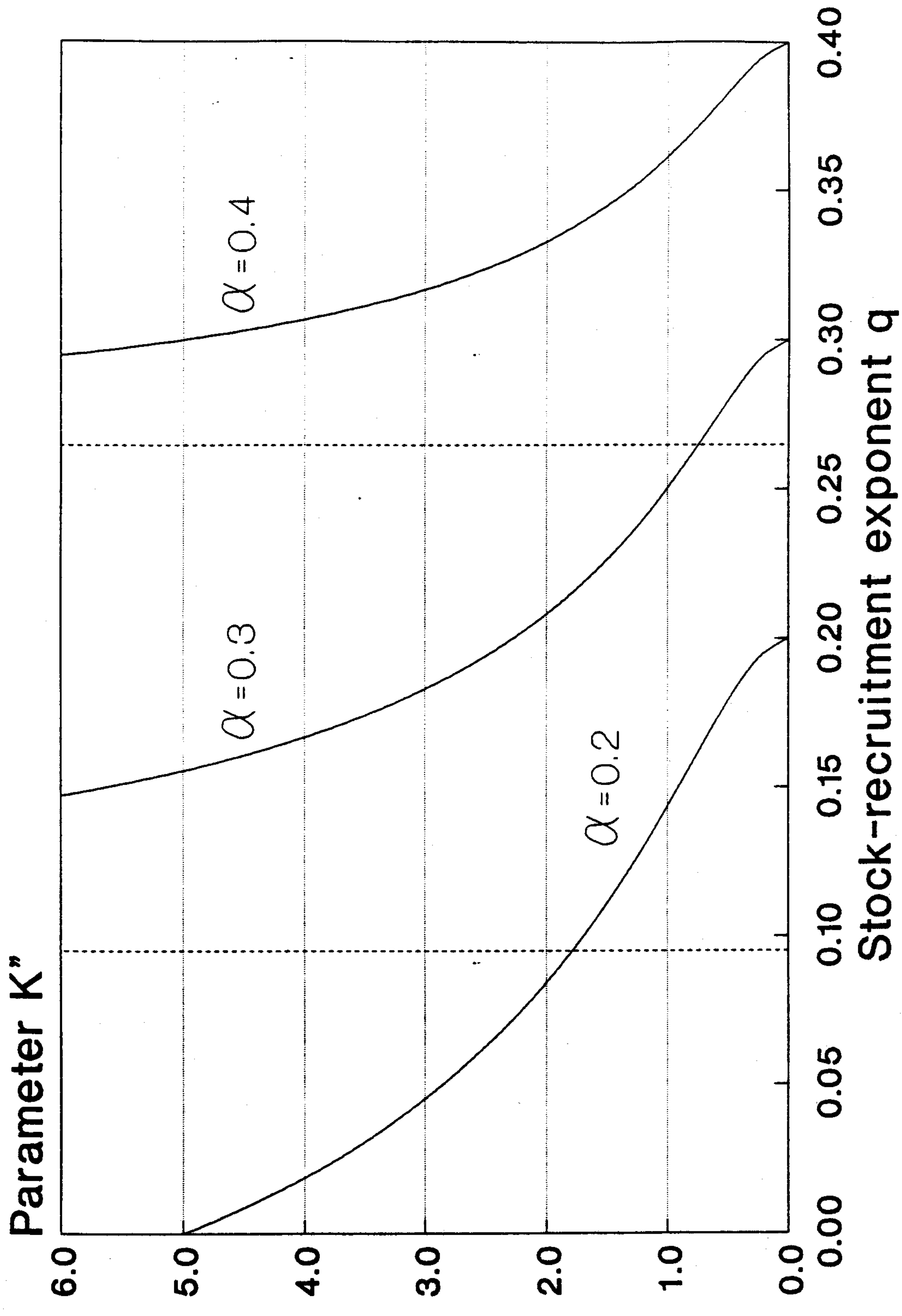


Figure 7b.



Parameter K"
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Stock-recruitment exponent q
α=0.2
α=0.3
α=0.4

Figure 8.

3.A.2 Appendix II: Simulation of Stock and Harvest Dynamics Under Four Alternatives

Grant G. Thompson

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
Resource Ecology and Fisheries Management Division
7600 Sand Point Way NE., Seattle, WA 98115

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.

References

Clark, W. G.
1990. Choosing an exploitation rate on the basis of life history parameters. Unpubl. manuscr., 11 p. International Pacific Halibut Commission, Seattle, WA 98145-2009.

Deriso, R. B.
1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 37:268-282.

Schnute, J.
1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42:414-429.

Thompson, G. G.
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.

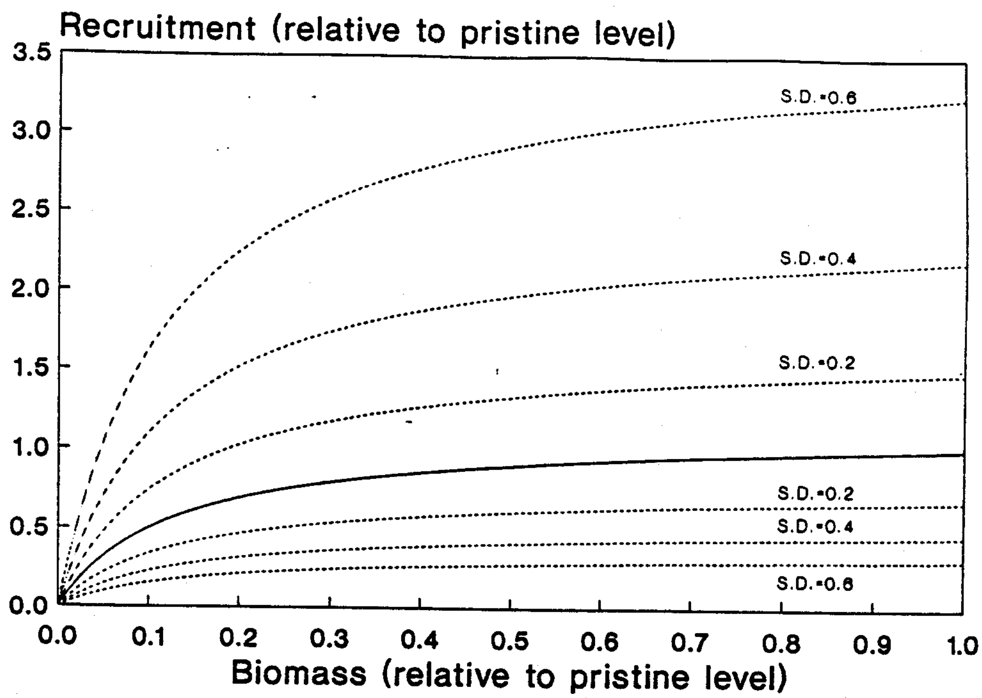


Figure 1a. Lognormal error

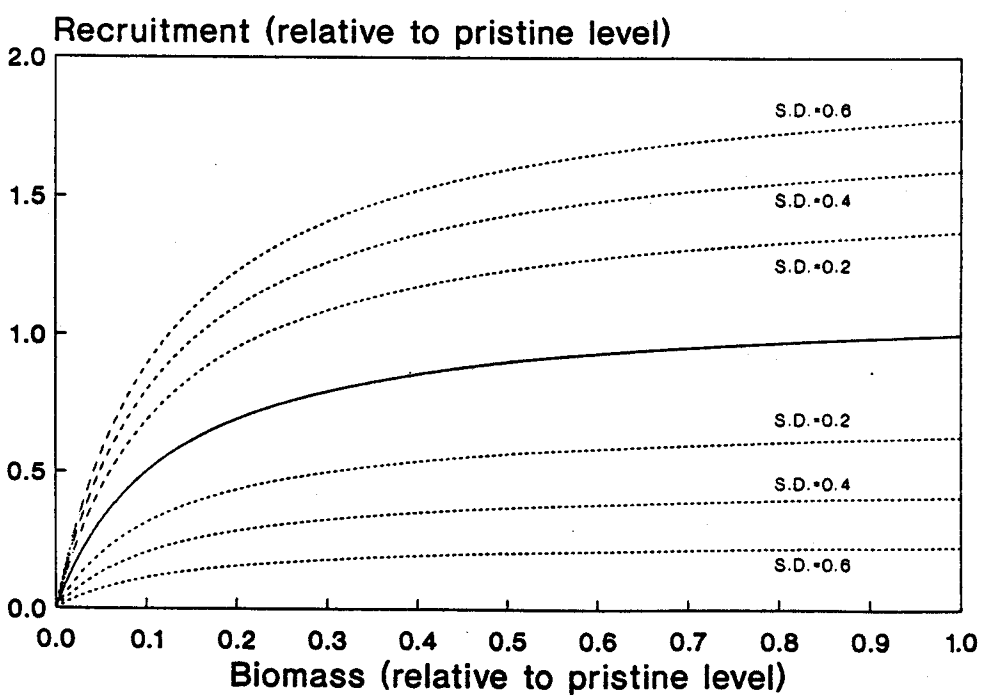


Figure 1b. Uniform error

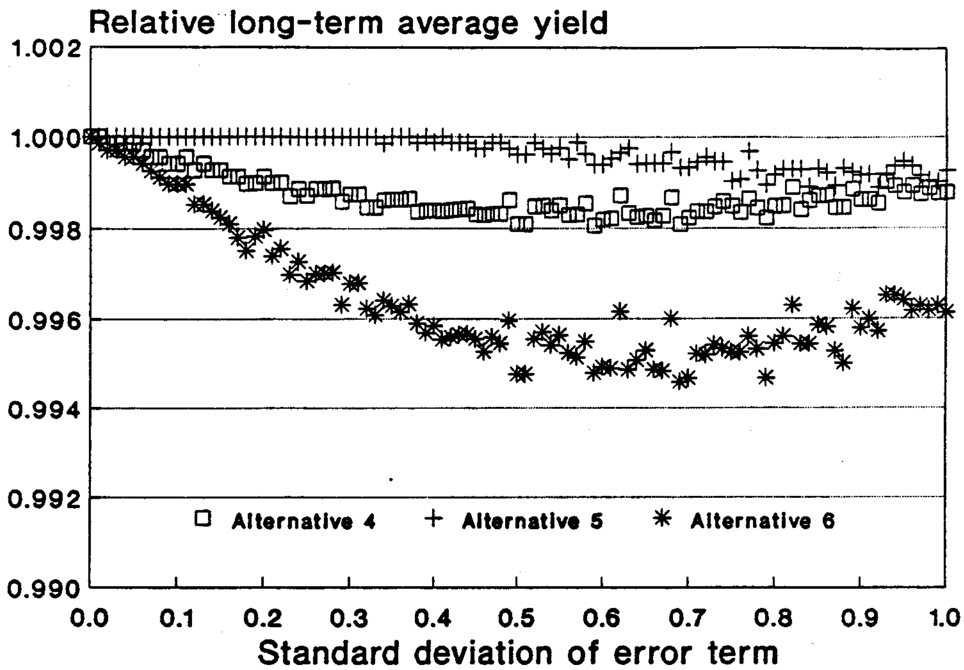


Figure 2a. Lognormal error

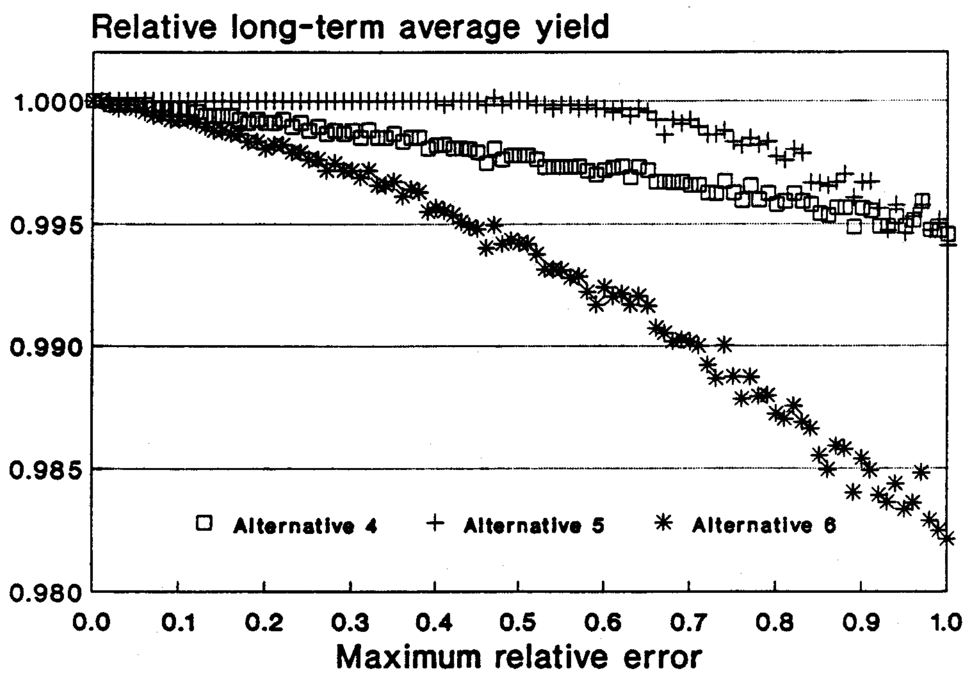


Figure 2b. Uniform error

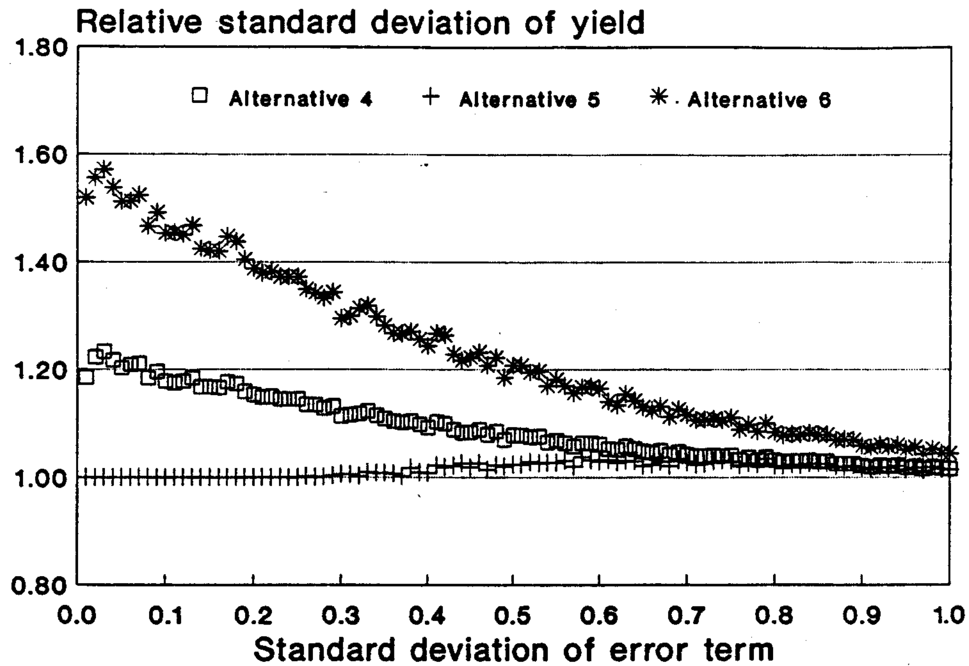


Figure 3a. Lognormal error

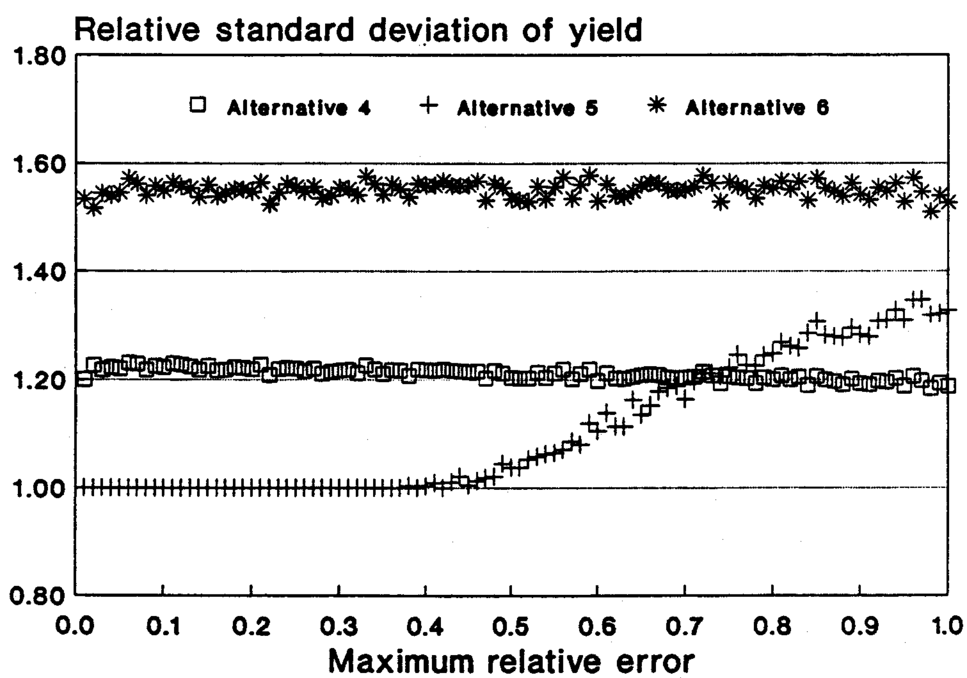


Figure 3b. Uniform error

3.A.3 Appendix III: A Comparison of Five Harvest Policies Applied to Sablefish in Alaskan Waters

Jeffrey T. Fujioka

National Marine Fisheries Service
Alaska Fisheries Science Center
Auke Bay Laboratory
P.O. Box 210155, Auke Bay, Alaska 99821

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

[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:

$$B_{MSY} = B_{0.1}, \text{ and } U_{MSY} = U_{0.1} \quad (2)$$

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

$$G = U_{MSY} \quad (3)$$

A Variable Exploitation Rate policy, is computed by setting T=0 and G_t equal to:

$$G_t = U_{MSY} \cdot B_t / B_{MSY} \quad \text{for } B_t < B_{MSY} \quad (4a)$$

$$G_t = U_{MSY} \quad \text{for } B_t => B_{MSY} \quad (4b)$$

A Constant Exploitation Rate with Threshold policy, is obtained by setting:

$$G = U_{MSY}/(B_t - T) \quad \text{for } B_t > T \quad (5a)$$

$$G = 0 \quad \text{for } B_t <= T \quad (5b)$$

A Variable Exploitation Rate with Threshold policy, where G_t is set to:

$$G = U_{MSY} \cdot B_{MSY}/(B_{MSY} - T) \quad \text{for } T<B_t<B_{MSY} \quad (6a)$$

$$G = 0 \quad \text{for } B_t<T \quad (6b)$$

$$G = U_{MSY}/(B_t - T) \quad \text{for } B_t > B_{MSY} \quad (6c)$$

A second Variable Exploitation Rate with Threshold policy is obtained by setting G_t to:

$$G = U_{MSY} \cdot B_{MSY} / (B_{MSY} - T) \quad \text{for } B_t > T \quad (7a)$$

$$G = 0 \quad \text{for } B_t < T \quad (7b)$$

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

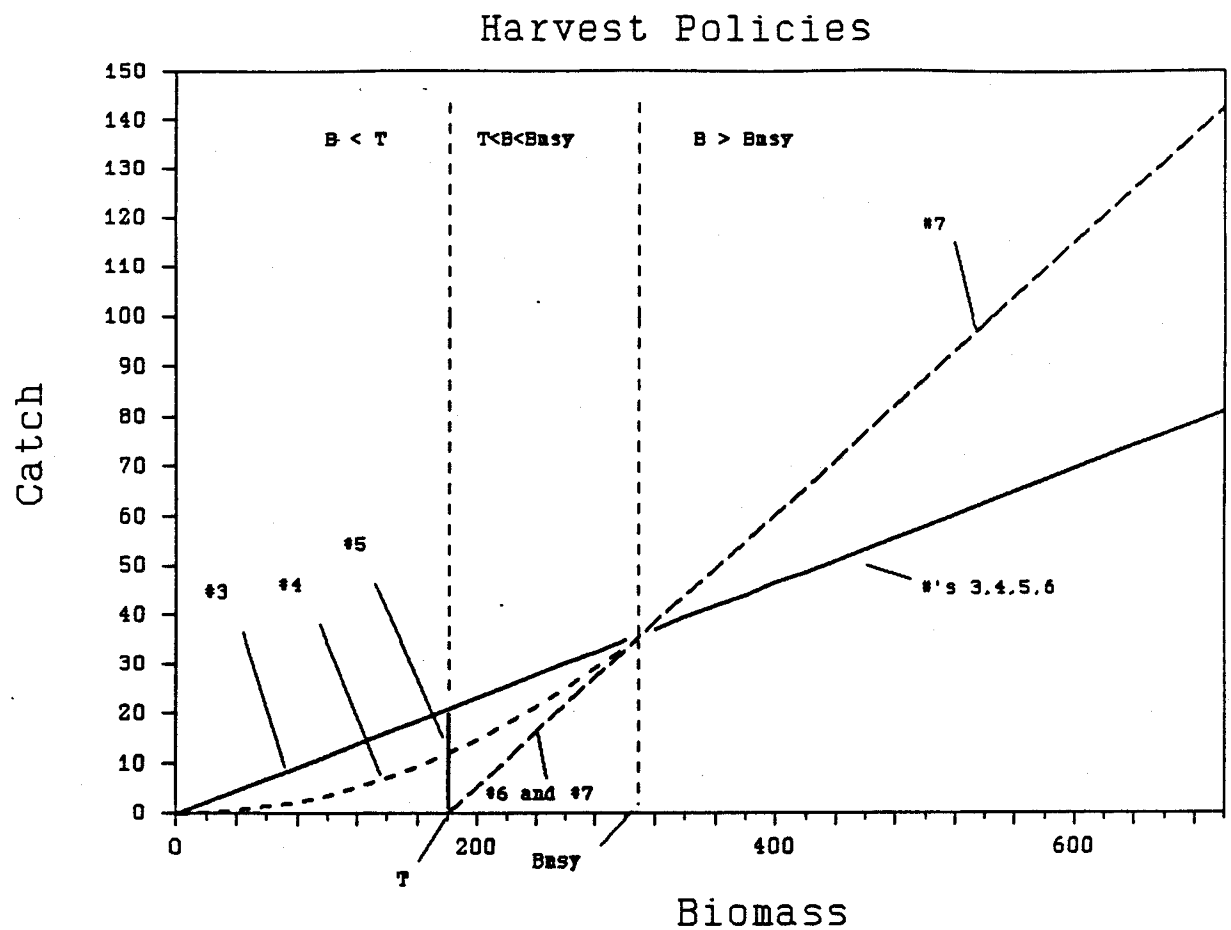


Figure 1. Recommended catch as a function of biomass under five harvest policies: constant rate (eq. 3); variable rate (eq. 4); constant rate w/threshold (eq. 5); variable $rate_1$ w/threshold (eq. 6); and variable $rate_2$ w/threshold (eq. 7).

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: 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: 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 State of Alaska's management jurisdiction **[regime]** for demersal shelf rockfish, in any of the Eastern Gulf of Alaska Regulatory Districts where this assemblage is recognized as an FMP species group, is directed at managing these rockfish stocks within smaller management units and quotas 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 MFCMA and the goals and objectives of the FMP and (2) **[limited to establishing smaller areas and quotas]**, result in a total harvest of demersal shelf rockfish in each FMP regulatory area at levels no greater than provided for in the FMP. Regulation changes proposed to the Alaska Board of Fisheries which are related to the management of demersal shelf rockfish will be reviewed by NOAA and the Council prior to adoption of the regulations to assure that any such proposed regulations are consistent with provisions of the MFCMA and the goals and objectives of the FMP. **[Such state regulations may apply only to those vessels registered/licensed under the laws of the State of Alaska.]**"

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 1900's. 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: 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: 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. Therfore 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.

REFERENCES

Bracken, B. E. 1988.

Commercial fisheries for demersal shelf rockfish in southeast Alaska, a review of management options. Alaska Dept. of Fish and Game Regional Information Report No. IJ88-49. 19p.

Bracken, B. E. 1989.

Biology and management of the demersal shelf rockfish resource in Southeast Alaska. Alaska Dept. of Fish and Game Regional Information Report No. IJ89-07. 15p.

Commercial Fisheries Entry Commission, 1989a.

Preliminary data on the Southeast Alaska demersal shelf rockfish "targeted fishery", 1979-1988. CFEC Report 89-9. Commercial Fisheries Entry Commission, P.O. Box KB, Juneau, Alaska, 99811. 9p.

Commercial Fisheries Entry Commission, 1989b.

A compilation of data on the Southeast Alaska demersal shelf rockfish "targeted fishery". CFEC Report 89-2. Commercial Fisheries Entry Commission, P.O. Box KB, Juneau, Alaska, 99811. 123p.

Love, M. S. 1980.

Isolation of olive rockfish, *Sebastes serranoides*, populations off southern California. Fish. Bull., U.S. 77(4)975-983.

Mathews, S. B. and M. W. Barker. 1983.

Movements of rockfish (*Sebastes*) tagged in northern Puget Sound, Washington. Fish. Bull., U.S. 81(4):916-922.

O'Connell, V. M. 1987.

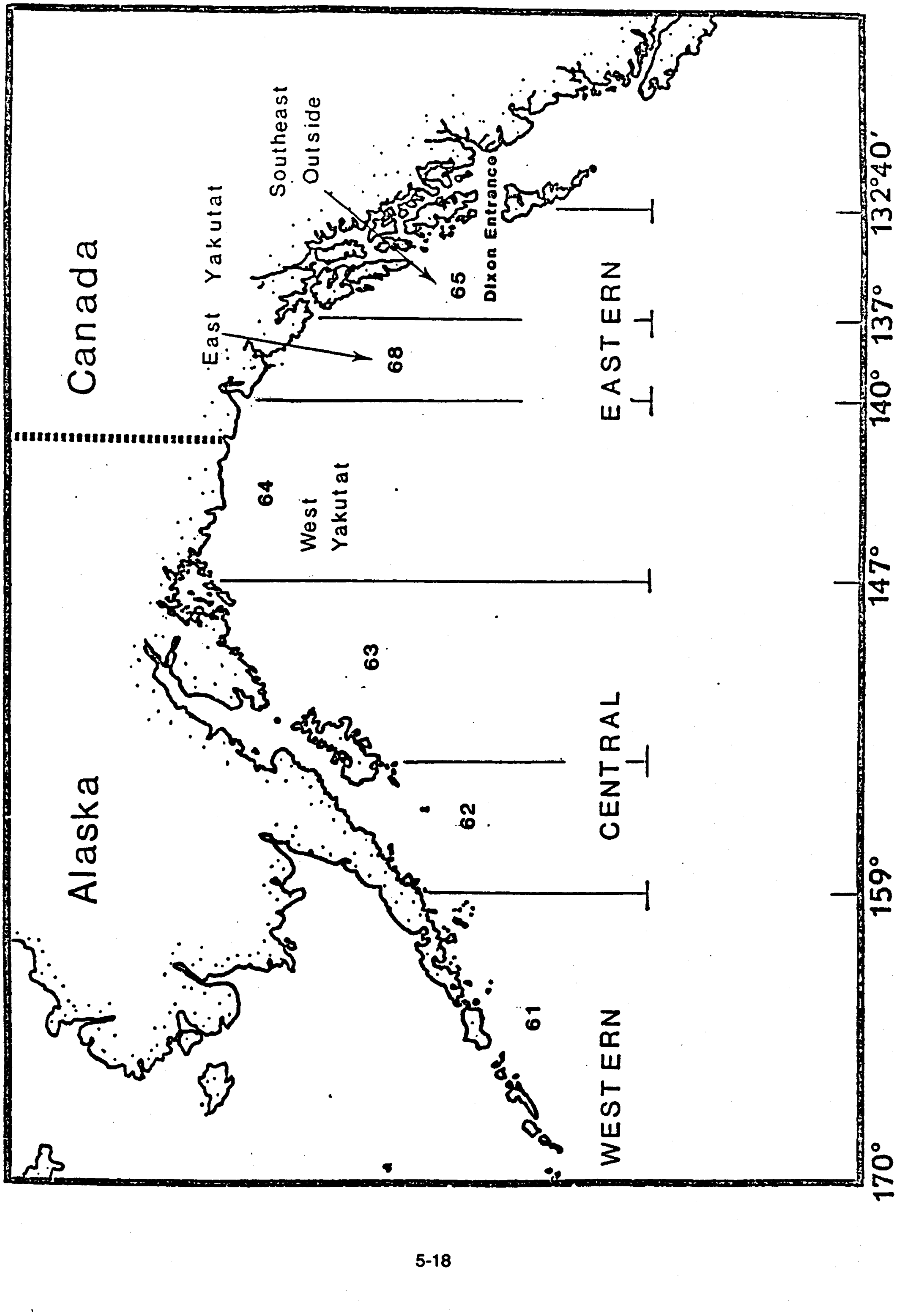
Reproductive Seasons for some *Sebastes* species in Southeastern Alaska. Alaska Dept. of Fish and Game Informational Leaflet No. 263. 21p.

O'Connell, V. M. and B. E. Bracken. 1988.

Condition of demersal shelf rockfish stocks in the Eastern Gulf of Alaska as assessed in 1988. Alaska Dept. of Fish and Game Regional Information Report No. IJ88-47. 13p.

O'Connell, V. M. and F. C. Funk. 1987.

Age and growth of yelloweye rockfish (*Sebastes ruberrimus*) landed in Southeastern Alaska. In B. R. Melteff (editor). Proceedings of the International Rockfish Symposium. Alaska Sea Grant Report No. 87-2. pp 171-185.



Canada
Alaska
East Yakutat
Southeast Outside
Dixon Entrance
65
68
64
West Yakutat
63
62
61
EASTERN
CENTRAL
WESTERN
170°
159°
147°
140°
137°
132°40′

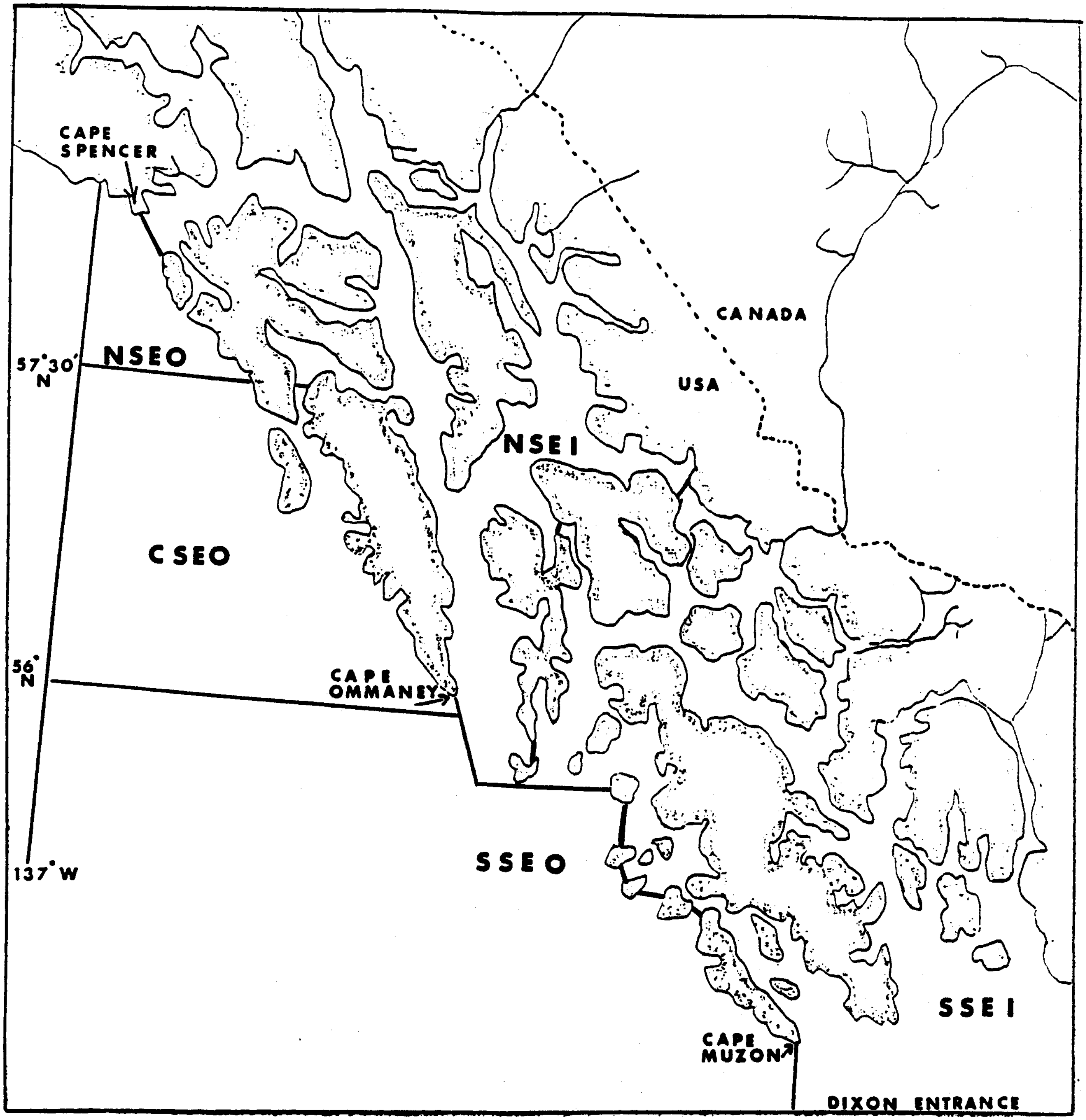


Figure 2. The Southeast Alaska coastline showing Alaska Department of Fish and Game groundfish management areas.

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*	GEAR: 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	.0%
146	CANARY	DSR	3,936	98.6%		0.0%	56	1.4%	3,992	0.1%
149	CHINA	DSR	3,179	100.0%		0.0%		0.0%	3,179	0.1%
138	COPPER	DSR	422	98.1%		0.0%	8	1.9%	430	.0%
147	QUILLBACK	DSR	105,414	98.8%		0.0%	1,309	1.2%	106,723	2.3%
158	REDSTRIPE	DSR	13	100.0%		0.0%		0.0%	13	.0%
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	0.1%
168	UNSP. DEMERS	DSR	85,555	99.7%		0.0%	283	0.3%	85,838	1.8%
140	UNSP.RED ROC	DSR	550	100.0%		0.0%		0.0%	550	.0%
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	18.3%
142	BLACK ROCK	PR	15,417	90.0%		0.0%	1,704	10.0%	17,121	0.4%
154	DUSKY	PR	3,282	4.0%	79,409	95.9%	97	0.1%	82,788	1.8%
169	UNSP. PELAGI	PR	200	40.0%	187	37.4%	113	22.6%	500	.0%
156	WIDOW	PR	37	100.0%		0.0%		0.0%	37	.0%
155	YELLOWTAIL	PR	522	66.6%	234	29.8%	28	3.6%	784	.0%
	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	8.6%
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 5.3. 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.

SPECIES CODE	SPECIES NAME	MANAGEMENT GROUP*	GEAR: SMALL TRAWLERS METRIC TONS	SMALL TRAWLERS PERCENT	LARGE TRAWLERS METRIC TONS	LARGE TRAWLERS PERCENT	ALL GEAR METRIC TONS	ALL GEAR 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

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 GOA and BSAI FMPs would be amended by retaining current section headings that relate to gear. General guidance and Council policy with respect to gear restrictions would be included in the FMP text. 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 types that are considered effective in harvesting groundfish stocks in the Gulf of Alaska [Bering Sea and Aleutian Islands area]. 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.

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. The number of pots on each vessel is about 70. 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 will attract other fish which will then enter the pot. Dead and live fish will also attract scavengers such as crab, which will enter the pot. This cycle continues indefinitely unless some way allows trapped fish to escape. Such fishing mortality is unaccounted for, which introduces uncertainty in 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 one time, 112 halibut would be caught, assuming each pot was modified to reduce halibut bycatch and 0.07 halibut/pot was a typical catch rate. For comparison, 600 halibut would be caught, using a higher rate that might occur if unmodified pots were used, e.g. 0.26 halibut/pot 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. Pollock move in schools of the bottom, which allows their capture by pelagic trawls. 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 and 1/2 fathoms off the bottom, but will dive toward the bottom when crowded by a moving trawl, diving 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. 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 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: 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. If any of these pots were lost, they would continue to fish. Mortality among fish species, including species of crab and groundfish, is a cost under this alternative with respect to economic losses to fishermen that might occur. Thirty-three fishermen may fish with pots in 1990. The average number of pots per vessel is about 70, although some vessel may use as many as 90 pots. Fishermen use fewer pots to catch groundfish than they do when fishing for crab, because they check the gear more frequently.

Numbers of pots that might be lost during a fishing year might be as high as 5 percent of the total pots per vessel. This number is considered by the Alaska Department of Fish and Game as being representative of the number of pots lost each year in the commercial crab fishery, which employs much higher numbers of pots per vessel. Using this number, however, all thirty-three fishermen might lose 132 pots during a year, assuming 4 pots lost per fisherman. Amounts of groundfish that might be caught while these pots are ghost fishing are not known, because groundfish are often consumed by sand fleas or other organisms.

Examples of costs are available, however. 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. The sale of these crabs by the Alaska Department of Fish and Game resulted in $70,000 gross revenue. Also, the 15,000 Tanner crabs that perished in a string of lost pots in Cook Inlet, referenced in the problem statement, might have been 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 on each groundfish pot. A panel would open eventually in the side of a lost pot, enabling any animals that enter to escape. Costs that would be imposed on fishermen would be minimal. All that is required is to open up the web on a pot for a length of at least 18 inches and then sew it back up with #30 untreated cotton thread. #30 cotton thread deteriorates in about 50-100 days. Alternatives to #30 thread include (1) #120 thread now required by the Alaska Department of Fish and Game on shellfish pots, (2) #18 thread that has been tried on sablefish pots used in Canada, and (3) metal rings, e.g. copper hog rings. #120 thread deteriorates too slowly, longer than 100 days. #18 thread deteriorates within 30-45 days, which may be considered too soon with respect to labor required to replace it. Metal rings also deteriorate too slowly.

Using an average of 70 pots per vessel, thirty-three vessel operators must replace the biodegradable panel on 2,310 pots at least about every two months. Replacing each panel might require ten minutes. Replacing panels on all pots would require 23,100 minutes, or 385 hours, about every two months, or 2,310 hours annually. Assuming $15 per hour for labor, total costs for all thirty-three vessel operators would be $34,650 annually. Each of thirty-three vessel operators, therefore, would spend $1,050 annually in labor costs to maintain biodegradable panels.

No administrative costs would not 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. Boarding officers would monitor pots on board a vessel to determine whether they were constructed in compliance with the definition of a groundfish pot. All enforcement would be accomplished by checking pots on board the vessel. 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 is 0.26 halibut per pot. 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.

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 vertical openings on 2,310 pots. Constructing the vertical openings might require 30 minutes. Constructing these openings on all pots would require 69,300 minutes, or 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 spend $525 in labor costs to maintain biodegradable panels.

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. Boarding officers would monitor pots on board a vessel to determine whether they were constructed in compliance with the definition of a groundfish pot. All enforcement would be accomplished by checking pots on board the vessel. Pots actually fishing could not be checked.

Benefits to halibut fishermen would accrue as a result of this alternative. Under the discussion for the status quo, 600 halibut might be caught, assuming an aggregate simultaneous set by all 33 fishermen of each of their 70 pots and each pot did not have an halibut exclusion device.

If each pot had the halibut exclusion device, 600 halibut ought not be caught, which represents a benefit to halibut fishermen. If halibut that are caught as bycatch in pots are 1.03 kilogram in size, they are assumed to be 4 year-old fish. If so, a metric ton of halibut of this size would have contributed 10,316 pounds in a directed halibut fishery if they had not been caught as bycatch, assuming they recruit into the fishery at age 8 years old. At a 5 percent discounted value, the loss of 10,316 pounds as bycatch would have had a wholesale value of $11,800. If the average size of halibut was 10.70 kilograms, which are 8 year-old fish, a metric ton of halibut would have contributed 2,205 pounds in a directed halibut fishery if they had not been caught as bycatch, again assuming they recruit into the fishery at age 8 years old. At a 5 percent discounted value, the loss of 2,205 pounds would have had a wholesale value of $3,065. Using these examples for perspective, 600 halibut at age 4 would have weighed 0.618 mt. At age 8, 600 halibut would have weighed 6.42 mt. At age 4, 0.618 mt of halibut would have been worth $7,290. At age 8, 6.42 mt of halibut would have been worth $19,677. The range of $7,290-$19,677 represents possible losses to the halibut fishery if all 33 vessel operators set their gear simultaneously, and each of 77 pots per vessel caught 0.26 halibut per pot.

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 a way is not available for trapped fish and shellfish to escape pots that are lost on the fishing grounds, these animals will continue to perish. They would be removed from the ecosystem. Their normal roles as predator or prey species would cease. Other predator species would consume the trapped animals and would receive nutritional benefits from them. As such predator species are attracted to the pots as a feeding site, they in turn may be fed upon by other predator species. Conversely, if some means to escape pots, e.g. biodegradable panels, are available, fish and shellfish would remain in the ecosystem where they would continue to play out their normal roles as predator or prey species. Actual effects on the ecosystem are not measurable but are considered to be insignificant compared to natural perturbations in the environment.

Option B: Halibut exclusion devices on groundfish pots.

Under this status quo, more halibut would enter lost pots, and therefore perish.

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 becomes more exacerbated by trawl technological developments that result in "midwater trawl" gear that can fish 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 7 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.

7.2 The Alternatives

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 regime 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 7 of this EA/RIR and will not be evaluated here.

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 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 annually determine:

(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: More fully implement and clarify the existing halibut PSC framework.

This alternative provides two options the Council may consider 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.

Both options are discussed below. Certain concerns have been raised by the NMFS Regional Office about implementation of either system in the Gulf of Alaska by 1991. The same concerns have been raised with respect to bycatch management planning in the Bering Sea/Aleutians. These concerns focus on the "doability" of these options. Doability is dependent on the following factors:

Observer data on which the incentive programs will be based must be dependable in 1991. Experience with the Observer Plan to date is insufficient to determine if quality information is being obtained on which to sanction individual vessels.

Enhanced reporting requirements must be implemented and tested to assure that timely bycatch reports can be received from vessels' observers to implement incentive programs on a real time basis.

Federal funding must be assured to acquire necessary NMFS personnel, estimated at four statisticians and one programmer, to develop the appropriate computer programs and to test them prior to program implementation. Because the new Federal fiscal year does not start until October 1, 1990, insufficient time is available to implement a program by January 1. The program could not be implemented until mid-1991.

Observer data on vessels with less than 100 percent coverage need to be statistically representative to warrant sanctioning a vessel. Establishing an administrative hearing process might be required to allow vessels that are in jeopardy of being sanctioned an opportunity to contest observer data.

Because of these concerns, the Council's Ad Hoc Bycatch Committee recommended that a program be implemented mid-1990 in the Bering Sea/Aleutian Islands to test the feasibility of an individual vessel monitoring system. Specifically, the Bycatch Committee recommended that a test program would be implemented for halibut bycatches in JVP flatfish fisheries which would be based on the PSC Reserve option. Therefore, the Council may determine that neither of the two options for incentive programs for the Gulf of Alaska be implemented until the test program for the Bering sea/Aleutians is completed. In light of these considerations, the Council may choose to delay final action on either of these options at the Council's June 1990 meeting.

The Council intends to review other bycatch options for the Bering Sea/Aleutian Islands at its June 1990 meeting. One of these options includes establishing a program that would sanction individual vessels that had exceeded a fleet average rate by a particular percentage. This option has been referred to as the "dirty dozen" rule or the "penalty box option." If the Council adopts this option and the Secretary of Commerce approves it, it could be implemented on January 1, 1991. The Council may decide to apply this option to the Gulf of Alaska as well with the intent that it control halibut catches in one or more defined fisheries, e.g. the Pacific cod fishery. If so, the Council may adopt such an option at its June meeting, and request the Plan Team to expand its analysis of this option to apply to the Gulf of alaska as well as the Bering Sea/Aleutians, with the intent that it would be submitted to the Secretary for implementation on January 1, 1991 as well.

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 7.0 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 longline or trawl fisheries.

Alternatively, a framework procedure could be developed for groundfish pots such that pots are excluded from the PSC limit if bycatch rates are below a specified level, but included if the rates are above a specified level.

7.2.3 Alternative 3: Implement a halibut PSC incentive program.

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).

The Council has received proposals from the industry and the International Pacific Halibut Commission (IPHC) for vessel incentive programs which would reduce halibut bycatch rates in the GOA groundfish fishery. The proposals suggest that an incentive program is desirable because groundfish catch can be increased for a given halibut PSC limit.

Past experience indicates the industry has attempted programs similar to the following options. In late 1989, Eagle Fisheries, Inc., Kodiak, petitioned the Council and RD to approve their program for using observed PSC savings to extend the fishing period of their flatfish fisheries in the Central Regulatory Area. Although initially disapproved by the RD, the Council and RD subsequently approved a small addition to the PSC limit (36 mt) for a deep water flatfish fishery with 100% observer coverage and an upper limit to the allowable bycatch rate.

Two options are proposed in this chapter. Either could be combined with one or both of the options analyzed in Alternative 2. It may be desirable to phase in either of these incentive programs due primarily to the time required by NMFS to develop the administrative structure, especially the data transfer and data management components. A credit or reserve system might be used only in one or two fisheries in 1991, with full phase-in occurring in 1992. The Council also may prefer using the seasonal PSC apportionment measure outlined in Alternative 2 for only the 1991 and 1992 seasons, phase in a PSC Reserve or Credit Program during that time period, and, then shift to the latter program entirely. It is not clear how efficiently a combined seasonal PSC apportionment measure will work in combination with a PSC Reserve or Credit System, although conceptually a Reserve or Credit Fishery could occur semi-annually so as to coincide with a semi-annual PSC apportionment.

Option A: Establish a PSC Reserve System

Under this option, a specified portion of the PSC limits would be set aside as a reserve. Each fishery, trawl and fixed gear, would be closed when the RD determined that the fishery had taken its PSC limit less the reserve amount. Closure would be based on the sum of the halibut bycatch recorded on observed vessels plus estimated halibut bycatch on unobserved or partially observed vessels.

The size of the reserve, as a proportion of the PSC limits, is to be determined by the Council using specified criteria. Such criteria may include, but are not limited to, the following:

(1) The current level of crab and halibut bycatch rates in the groundfish fishery relative to historic levels;

(2) The additional cost to the groundfish fishery associated with reducing bycatch rates;

(3) The potential increase in the groundfish harvest under a reduced bycatch rate;

(4) The current level of abundance of bycatch species; and

(5) The confidence of the RD in the accuracy of the bycatch estimates.

The Council will be limited to choosing a reserve between 20 and 50 percent of the PSC limit.

The reserve will be implemented annually through a regulatory amendment procedure and the size of the reserve will be specified in the regulations.

Once a fishery has taken its PSC limit minus the reserve amount, only those vessels with observed halibut bycatch rates less than the published preseason rate, and those vessels less than 60 feet length overall, would be permitted to continue fishing into the reserve. Some leeway may be granted in determining a vessel's qualifying bycatch rate, say ± 0.1 or 0.2 percent; industry should comment on what a reasonable amount of leeway around the published preseason bycatch rate should be. To prevent the reserve from becoming an olympic style "race for bycatch", vessels fishing in the reserve would be required to continue to fish with bycatch rates below the published preseason rate. Vessels failing to meet the bycatch rate requirements on a week-by-week basis during the reserve fishery would be excluded by the RD from further fishing.

Once the halibut bycatch reserve was taken, the fishery would close for the remainder of the year.

Option B: Establish a halibut Bycatch Credit System.

In this option, vessels would accrue halibut bycatch credit if they fish with a halibut bycatch rate below a published preseason rate. The Council may also grant some leeway when determining the vessel's "qualifying bycatch rate." Vessels which have documented bycatch credit through observer coverage may fish against the accrued bycatch credit in a Credit Fishery which will follow the closure of the initial "open" fishery. Vessels without observer coverage can be assumed to fish at rates similar to observed vessels in similar areas, seasons, fisheries, and if observed vessels can develop credit in a given fishery it is assumed unobserved vessels also can develop credit. All fishing in the Credit Fishery is conducted with 100% observer coverage.

Under this option, the Open Fishery will be closed by the RD when the sum of two calculations equals the PSC limit:

(1) For vessels with a halibut bycatch rate above the published preseason bycatch rate, bycatch is calculated as the product of the observed bycatch rate times the groundfish catch; and

(2) For vessels with a halibut bycatch rate equal to or below the published preseason bycatch rate, bycatch is calculated as the product of the published preseason bycatch rate times the groundfish catch. The difference between the actual observed bycatch rate times the groundfish catch and the aforementioned calculation is termed the **bycatch credit**.

At the point of closure of the "open" fishery, the actual amount of bycatch taken does not equal the estimated bycatch, due to the existence of the bycatch credit by those vessels that fished at lower rates. The "open" fishery is closed to allow these latter vessels the opportunity for additional fishing. Such additional fishing is conducted in the presence of an observer in order to monitor the bycatch to prevent the PSC limit from being exceeded. The RD will close the Credit Fishery when all vessels have exhausted their bycatch credit, although each individual vessel can only fish until its individual bycatch credit is taken. There is no requirement that vessels maintain the "open" fishery bycatch rate during the Credit Fishery.

The Council could choose to allow bycatch credits to be transferable. In this case, vessels which did not or could not accrue bycatch credit during a fishing year would be allowed to obtain credit from a vessel which did accrue credit. Such a system would be more equitable, allowing vessels which could not take observers an opportunity to continue fishing during the Credit Fishery.

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.

Published preseason bycatch rate is defined as the rate of halibut bycatch (mt of halibut per mt of groundfish) which will be applied to vessels fishing unobserved for purposes of accounting groundfish fishery closures to ensure a Reserve Fishery or Credit Fishery. This rate will be calculated and published annually by the RD as Standards and Conditions required to participate in the additional fisheries sanctioned under an incentive program. The published bycatch rate will be based on a moving average of bycatch rates observed in the trawl and fixed gear fisheries for the previous two years. For 1991 fisheries, published preseason rates will be determined by averaging the following rates, developed by the Council's Gulf of Alaska Groundfish Plan Team, with those observed in the 1990 groundfish fisheries. The Council may grant some latitude to vessels when calculating their bycatch rates for the purposes of qualifying for a Reserve Fishery or Bycatch Credits.

Bottom Trawl	
Deep water flatfish	2.5%
Other species	2.7%
Midwater Trawl	0.01%
Longline	
Sablefish	8.0%
Pacific cod	10.0%
Groundfish Pot	0.4%

Bycatch mortality is the sum of (1) mortality inflicted on prohibited species, such as halibut, during capture by a vessel, (2) additional mortality incurred through handling as the fish is returned to the sea but is not observed, and (3) undetected mortality of bycatch not captured. 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 has declined from 254.5 million pounds in 1986 to 232.9 million pounds in 1989, approximately 5-10 percent per year. 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 90 days by emergency rule effective February 15 through May 15, 1990. For 1991 and beyond, halibut bycatch PSC limits will be annually determined by the Council. If the Council returns to past policies, the only PSC limit will be 2,000 mt for bottom trawls. Alternately, the Council may choose a PSC limit (e.g. 2,000 mt or 2,750 mt) and apportion that limit to trawl and fixed gear for 1991, since Amendment 18 contains a provision which allows the Council to apportion the PSC limits to those two gear groups.

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: 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 0.4%, 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 7.0 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 7.0 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: Implement a halibut PSC incentive program.

Incentives to the industry encouraging them to reduce halibut bycatch would likely lead to reduced bycatch rates because of the economic benefits afforded the industry to change fishing practices in order to realize such benefits. Two options are analyzed below. These options provide the individual vessel an incentive to reduce bycatch rates and provide individual vessel accountability of a vessel's bycatch.

One option is a PSC Reserve (Option A). In this case, a specific proportion of the PSC limit for each fishery would be set aside at the beginning of the year. Only vessels that demonstrated lower-than-specified bycatch rates over the year could fish into the reserve until the reserve were exhausted.

The second option is a Bycatch Credit program (Option B), which would provide for giving "bycatch credit" to individual vessels that could prove lower-than-specified bycatch rates for the fishing year at the time that a fishery was closed due to attaining the PSC limit. The credit then could be used to extend the vessel's fishing opportunity until the credit was exhausted. The Council may also choose to allow transfer of credit from one vessel to another.

A problem associated with either of these options is that they tend to discriminate against smaller vessels due to their limited physical and financial ability to accommodate an observer. The observer is needed in order to document the bycatch rates exhibited by the vessel. Some vessels cannot physically accommodate an observer, and for those vessels that can, the ability to financially accommodate an observer tends to increase with the catch rate of the vessel. The latter problem is of course eliminated if the vessel is not responsible for any of the costs of an observer. Approaches to deal with the discriminatory aspects of both options are presented in the following sections.

The discriminatory effect is ameliorated somewhat, however, because the lack of an observer does not decrease the amount of a PSC limit that is available to vessels that cannot or for other reasons do not have observers. The fishery would not be closed to unobserved vessels until the full PSC limit is estimated to have been taken. Further, in the Bycatch Credit System, allowing vessels to obtain PSC credit they were observed to have accrued (by purchase or other means of transfer) would partially reduce the inequity to those vessels not required to be fully observed.

In 1988, the Council's Bycatch Committee was aware of discrimination problems in such a program and suggested that an "approved data gathering program" could be used in lieu of observers on small vessels. However, it is not clear what an acceptable alternative would be. The mandatory logbooks could be used to compare logged bycatch rate data on unobserved vessels to the same areas/fisheries where observed bycatch rate data are available. However, the logbooks are submitted on a quarterly basis, so a lag of perhaps 3 months would exist before the data could be made available, preventing a timely analysis. Examining target species and fishing locations on fish tickets could provide more timely information on bycatch rates between observed and unobserved vessels.

Both of these options require the monitoring of groundfish catch and halibut bycatch data for each vessel participating in the trawl and fixed gear fisheries. In 1989, 626 longline vessels, 114 trawl vessels, and 14 pot vessels took part in the GOA groundfish fishery (Table 7.3). Because of the large number of vessels involved in these fisheries and the large volume of bycatch data generated from weekly reporting by fishery observers, it is expected that a trawl or longline fishery will be shut down for a short period of time while the bycatch data for each vessel is reviewed and analyzed to determine its eligibility for Reserve or Credit fishing. It is anticipated that this closed period may last up to 21 days. Following this closed period, fishing will resume by those vessels which have met the required criteria for participation in Reserve or Credit fisheries. The RD would notify the eligible vessels in an expedient manner.

7.3.5.1 Option A: Establish a PSC Reserve System

Under this option, the Council would set aside a specified portion of the trawl and fixed gear halibut PSC limits as a reserve to be fished only by those vessels that demonstrate bycatch rates in an "open" fishery lower than a published bycatch rate established prior to the fishing year. The Council may allow some flexibility when calculating a vessel's "qualifying bycatch rate." In addition, each vessel would be required to maintain the reduced bycatch rate while engaged in the Reserve Fishery. PSC reserves would be established for the PSC limits in the trawl fishery and the fixed gear fisheries. PSC reserves could be further established for each Regulatory Area/District or by season if the Council so chooses; seasonal PSC reserves may be too administratively cumbersome to implement immediately, and the Council may choose to phase in this part of the System.

Biological and physical impacts of this option can be expected to result from the size of the reserve, the preseason published bycatch rates adopted as eligibility criteria for the Reserve fishery, the ability of partially observed and unobserved vessels to participate in the Reserve fishery, and the bycatch rates experienced by bottom trawl and fixed gear vessels during the fishery.

The size of the halibut PSC reserve will have an impact on the effectiveness of the reserve program. If the reserve is too small, fishing operations may believe that the amount of additional fishing opportunity available in the Reserve fishery would be too little to warrant reducing bycatch rates. Thus, bycatch rates will remain high and groundfish catches will continue to be constrained by the halibut PSC limits.

On the other hand, an overly large reserve results in a smaller proportion of the PSC limit available to the "open" fishery. Vessels may not have the opportunity to demonstrate reduced bycatch rates or to develop techniques to reduce halibut bycatch rates before the closure of the "open" fishery. At the extreme, the Open Fishery may close before some vessels begin fishing. Also, a large reserve would provide no incentive for clean fishing during the Reserve Fishery unless other restrictions are included. For this reason, vessels fishing the Reserve Fishery would be required to operate at a bycatch rate no higher than the rate demonstrated in the "open" fishery. Without this restriction, the "race for fish" is shifted from the "open" fishery to the Reserve fishery. Thus, a large reserve may constrain vessels in their attempt to demonstrate their ability to participate in the Reserve fishery.

The size of the reserve also impacts the size of the groundfish harvest. This is because as the bycatch rate is reduced, more groundfish can be caught for a given PSC limit. As more fishing is shifted to the Reserve fishery with its inherently lower bycatch rate, the overall groundfish catch will increase.

Fisheries which are prosecuted in a short period of time may require special provisions so that the observed bycatch does not exceed the initial PSC limit, i.e. total PSC limit minus the reserve amount. In these situations, groundfish and halibut bycatch are taken at such a rate that weekly reporting may not provide the RD with the necessary information to close the "open" fishery on a timely basis. As a result, the amount of observed bycatch may actually extend into that required for the Reserve fishery, thereby reducing the efficacy of the Reserve Fishery. The RD should have the ability to require daily reporting of bycatch by observers in order to prevent the PSC limits from being exceeded.

Eligibility for a vessel to fish in the Reserve Fishery is based on the demonstration of a halibut bycatch rate lower than a preseason published rate established by the RD, in consultation with the Council. This preseason rate would be derived using observer data from the previous two years. It is anticipated that the rate would be developed and adopted in the following manner. The Gulf Plan Team would review and analyze the available observer data for the previous two years prior to the September Council meeting and report the average halibut bycatch rates observed in the trawl and fixed gear fisheries in the SAFE Document. At its September meeting, the Council would review the rates noted by the Plan Team and would release the bycatch rates for public review. Review of the comments and the adoption of the preseason bycatch rates for the upcoming year would be undertaken at the December Council meeting. NMFS would then publish these preseason bycatch rates in the Federal Register as the Standards and Conditions for the fishery in the upcoming year.

The use of the aforementioned schedule to determine the preseason published halibut bycatch rates means that, while providing opportunity for input and comment, the Council would not have data for the previous full year available for its consideration and review. This could make the development of seasonal PSC reserves difficult because of a lack of appropriate information for the latter portion of the year. However, additional information covering the period through November would likely be available at the December Council meeting, which would alleviate part of this deficiency. Additionally, bycatch rate data for earlier years would be used for the latter portion of the year, which would also serve to dampen the annual variability that is noticed in bycatch rates. The lack of substantial observer data for 1989, however, means that only data from 1990 would be available for determining the preseason bycatch rate for 1991.

The change in fishing practices to achieve a reduced bycatch rate may mean some unknown amount of increase in vessel operation costs if down time was required to re-rig the fishing gear or to move to different fishing grounds. However, the resultant fishing with lower bycatch rates would also mean an increase in the groundfish catch because more groundfish could be caught during the "open" fishery. Also, the opportunity to fish the Reserve fishery would be enhanced, which would mean additional groundfish catch for the individual vessel.

Since one of the criteria for the Reserve Fishery is the demonstration of a reduced bycatch rate while an observer is on board, vessels without observer coverage, generally those less than 60 feet in length, have no opportunity to demonstrate whether their bycatch rates are high or low. Thus, no catch or bycatch data are collected from these vessels other than information normally recorded on the ADF&G fish ticket following each landing or in vessel logbooks submitted to NMFS each quarter.

Unobserved vessels have no opportunity to demonstrate that they are capable of fishing at reduced bycatch rates because (1) observers are not required for this size of vessel, and (2) vessels of this size may not be physically or financially capable of taking an observer. The alternative is to not allow unobserved vessels into the Reserve fishery because of a lack of bycatch rate information. There is no information to suggest that unobserved vessels have higher or lower bycatch rates than observed vessels, although it is not unreasonable to assume that the presence of an observer may have an effect on a vessel's fishing practices. Thus, little basis exists to deny unobserved vessels the opportunity to fish the Reserve Fishery on the basis of bycatch rate information. For these reasons, all vessels less than 60 ft in overall length would be allowed to fish in the Reserve Fishery without having to demonstrate reduced halibut bycatch rates. Vessels which are observed only part of the time (60-124' class) could qualify to participate in the Reserve Fishery if their bycatch rates were less than the preseason rate during the time they were observed. However, observers must be on board any vessel when the vessel is in the Reserve Fishery in order to prevent the PSC limit from being exceeded.

This presents an equity problem, in that some vessels are required to carry observers during the "open" fishery, at their own expense, and must demonstrate reduced bycatch rates in order to fish the Reserve Fishery. Unobserved vessels are essentially granted a waiver of this requirement and enter the Reserve Fishery unconditionally except for the observer required during the Reserve Fishery.

The number of vessels impacted by these eligibility criteria can be approximated by examining data from the 1989 Gulf DAP fishery. These data (Table 7.3) indicate that 48% of the longline catch was taken by vessels less than 60 feet in overall length. As well, 78% of the number of longline vessels that participated in the 1989 GOA groundfish fishery are less than 60 feet in length and will therefore likely have no observer coverage in 1990. In the trawl fishery, 3% of the harvest was taken by vessels in the unobserved size category. The number of vessels less than 60 feet in the trawl fishery was 16% of the 155 vessels fishing. In 1989, 128 longline and 63 trawl vessels were in the 60-124' vessel class; these vessels will be observed 30% of the time during 1990. Longline and trawl vessels 60-124' in length harvested 6.3% and 30% of the overall 1989 groundfish harvest, respectively (Table 7.3).

Consequently, a substantial portion of the longline harvest is taken by unobserved vessels, who would be admitted to the Reserve Fishery without fishing with reduced halibut bycatch rates. The number of potentially unobserved trawl vessels is significant, but these vessels catch a small portion of the total trawl catch and their halibut bycatch is probably a small amount of the total trawl bycatch.

Participation by vessels less than 60 feet in length in the GOA groundfish fisheries may decrease as fishing seasons shift to the winter months. Severe weather and sea conditions may limit the fishing opportunities of vessels of this size, resulting in a low number of vessels that go unobserved. However, the opposite may occur if seasons are shifted to the summer months, when weather and sea conditions are calmer.

The practical effect of using a PSC Reserve program to reduce bycatch rates of halibut in the GOA groundfish fishery is expected to be an increase in the groundfish catch for a given PSC limit. This would occur if vessels desired to fish the Reserve Fishery and reduced bycatch rates during the "open" fishery to be eligible for the Reserve Fishery. However, bycatch rate and groundfish catch data to demonstrate this premise are lacking due to the paucity of observer data from GOA fisheries prior to 1990. Therefore, an analysis of this option requires an illustration that increased groundfish catches are possible.

The PSC limit for the 1990 GOA trawl and fixed gear fisheries is 2,000 mt and 750 mt, respectively. The analysis focuses on the trawl fishery; however the outcome would be similar for the fixed gear fishery.

Because the reserve amount for each fishery will be determined by the RD, in consultation with the Council, and is therefore unknown, an analysis of a particular reserve amount to indicate the impacts would be misleading. Therefore, the analysis brackets the range of likely impacts by assuming a 20% reserve as a "low-end" reserve (Scenario 1) and a 50% reserve as a "high-end" reserve (Scenario 2). Specific reserve amounts under Scenario 1 are 400 mt and under Scenario 2 is 1,000 mt for a trawl PSC of 2,000 mt.

The catch of groundfish and bycatch of halibut in the two scenarios is based on assumptions of (1) the actual bycatch rates encountered by the fleet and (2) the distribution of halibut bycatch rates among vessels. In other words, halibut bycatch depends not only on the bycatch rates, but also on the proportion of "clean" fishing (low bycatch rates) and "dirty" fishing (high bycatch rates). The potential groundfish catch is therefore a result of these two bycatch variables.

For purposes of the analysis, it is assumed that halibut bycatch rates will range from 50% above the preseason rate, to 50% below the preseason rate. In reality, actual bycatch rates in the DAP trawl fishery in the Gulf may range from more than double the preseason rate (100% above) to practically zero, depending on the target species, area, gear, and season of fishing. However, information does not exist to illustrate the actual distribution of rates in the bottom trawl fishery in 1989, and 1990 data are too limited to be used here.

It is also assumed that the groundfish catch is taken in equal proportions by vessels exhibiting each bycatch rate, e.g. 33% of the groundfish catch is taken with the preseason bycatch rate, 33% is taken at a rate 50% below the preseason rate, and 33% is taken at a rate 50% higher than the preseason bycatch rate. Implicit in this assumption is that the species composition of the groundfish catch taken with each bycatch rate is the same. This is probably not completely true, as some target species have different bycatch rates (see 1989 GOA SAFE), with the differences dependant upon area, depth, or the season fishing takes place. However, under current regulatory provisions the reserve is established for the trawl fishery as a whole, so only one preseason bycatch rate will be used in this example to establish eligibility for the Reserve Fishery.

With the PSC reserve system, the preseason bycatch rate would be the rate achieved in the previous year's fishery. The following is an example of how an incentive system might work. The 1989 GOA trawl fishery harvested 176,000 mt (Table 7.3). Although the actual halibut bycatch is unknown, the closure of the fishery in September 1989 indicates that the halibut bycatch mortality reached 2,000 mt, or 4,000 mt of catch using a 50% mortality rate. Assuming the 72,000 mt pollock TAC was taken entirely by midwater trawls, which have an extremely low halibut bycatch rate, the bottom trawl harvest was approximately 104,000 mt. The overall halibut bycatch rate for all bottom trawl fisheries was 3.8%. Thus, a halibut bycatch rate of 3.8% is used as the preseason rate in the analysis. The high-end bycatch rate is 5.7%; the low-end rate is 1.9%. This reflects the status of halibut bycatch rates in the fishery without a reserve incentive program.

It is anticipated that the fleet will respond to the implementation of a PSC Reserve system by reducing bycatch rates to fish the Reserve fishery; an unknown proportion of the vessels will be successful, others will not. Thus, the 33%-33%-33% bycatch rate distribution assumed previously will change with the adoption of a Reserve program, but the amount of change is unknown. For illustrative purposes, it is assumed that one half of the vessels fishing at the high-end bycatch rate of 5.7% will reduce their rate to the preseason rate. Consequently, 33% of the catch is taken at the low-end bycatch rate of 1.9%, 50% of the catch is taken at the preseason bycatch rate of 3.8%, and 17% of the catch is taken at the high-end bycatch rate of 5.7%.

Scenario 1: 20% Reserve (400 mt). Under this scenario, the reserve is set at 20% of the PSC limit, or 400 mt out of the total PSC limit of 2,000 mt. The "open" fishery would therefore close when 1,600 mt of halibut mortality were caught, resulting in a groundfish catch of 91,400 mt, or

(1)

$$G = \left(\frac{P}{\Sigma(R_b f)}\right) x \left(\frac{1}{R_m}\right)$$

where G = estimated groundfish catch in mt,

P = PSC mortality limit in mt,

R_b = halibut bycatch rate (0.019, 0.038, 0.057)

f = fraction of the vessels demonstrating R_b (33%, 50%, 17%), and

R_m = mortality rate, i.e. 0.5 (assumed rate of 50% for trawls)

Vessels with a halibut bycatch rate at and below the preseason rate of 3.8% would continue to fish in the Reserve Fishery at a bycatch rate no greater than the rate observed during the "open" fishery. As a result, 40% of the catch in the Reserve Fishery is taken at a bycatch rate of 1.9%, whereas the remainder of the catch is taken with a rate of 3.8%. Given a reserve amount of 400 mt of halibut and these bycatch rates, the expected groundfish catch in the Reserve Fishery would be 26,700 mt using equation (1), yielding a total groundfish catch by the fishery of 118,100 mt. This contrasts with the expected groundfish catch of 105,300 mt. Thus, the increased catch of groundfish with the 20% reserve is 12,800 mt. In addition, the halibut bycatch rate for the year is reduced to 3.4% from the level of the previous year of 3.8%, a decrease of 11%.

Scenario 2: 50% Reserve (1,000 mt). In this scenario, 50% of the halibut PSC limit, i.e. 1,000 mt, is held back for a Reserve Fishery. Using the same procedure as above but with a halibut reserve amount of 1,000 mt, the groundfish catch in the "open" fishery is calculated to be 57,100 mt. The catch in the Reserve Fishery would be 66,700 mt. The total groundfish catch is 123,800 mt. In contrast, without a 50% reserve as an incentive to reduce bycatch rates, the groundfish catch would have been 105,300 mt as shown in Scenario 1. Thus, the increased groundfish catch with a 50% reserve amount is 18,500 mt. In addition, the halibut bycatch rate is reduced to 3.2% from the 3.8% level of the previous year, a decrease of 16%.

In the Reserve Fishery Program, it is likely the preseason assumed bycatch rates will decrease with time, eventually reaching some asymptote. This will occur because as fishermen lower their bycatch rates in order to qualify for the Reserve Fishery, calculation of the next year's assumed rates will be based on these lower fleetwide rates. At some point, rates will probably level off, however. It is conceivable that PSC amounts could be left at the end of a fishing year if bycatch rates decline far enough. In this instance the Council could lower the PSC limits accordingly.

7.3.4.2 Option B: Establish a Bycatch Credit System

Bycatch credit is a reward for fishing at low bycatch rates. Credit is calculated as the difference between observed bycatch and bycatch computed using a preseason rate established pre-season; credit is expressed in metric tons of halibut mortality. A fishing operation would be authorized to continue fishing for groundfish until its bycatch credit is used. The RD, in consultation with the Council, would establish the preseason bycatch rate and the fisheries affected and would notify the fishing industry of these criteria by publishing this information as Standards and Conditions prior to January 1 of the affected year. Any flexibility the Council may allow in calculating a vessel's "qualifying bycatch rate" would also be published.

The preseason bycatch rate for 1991 for the trawl and fixed gear fisheries is based on observer data from 1990 as observed by NMFS observers.

The same schedule for analysis and preparation of the observer data as described for Option A (Reserve System) would also be used for this option.

The same problems that exist with a PSC Reserve program regarding the ability of unobserved vessels to participate also exist with a Bycatch Credit program. These vessels have no opportunity to demonstrate the bycatch rates they encounter. In addition, in this program the vessel has no method to accrue credit, because the vessel's bycatch rate is unknown. Therefore, for the purposes of inseason monitoring of bycatch and calculation of bycatch credit, one option would be to assign to unobserved vessels the same bycatch rate observed on other observed vessels fishing in the same area, season, and on the same target species. This comparison of location, season, and species can be accomplished by reviewing available fish tickets for these data. It remains possible that the unobserved vessel will have a different bycatch rate than the observed vessel even though both vessels are fishing the same area and target species; however, the likelihood of a significant difference in the bycatch rates between the vessels is probably reduced.

The assumption of similar bycatch rates on common grounds and target species is somewhat uncertain. The behavior of some prohibited species causes the distribution to be patchy rather than uniform, so bycatch rates on neighboring vessels might not necessarily be similar. For example, halibut in the summer months are broadly distributed across the continental shelf. In contrast, during the winter months halibut are found in deeper water and are concentrated on the spawning grounds. However, anecdotal information indicates that trawl fishermen avoid large halibut bycatches because of the increase in sorting time necessitated when the catch contains a large amount of halibut. In this situation, the vessel would probably move just far enough to presumably avoid additional large halibut bycatches. Consequently, assuming a similar bycatch rate based on target species and fishing location is not without some risk, but the risk is likely minimal.

The trade-off the unobserved vessel is making by agreeing to this approach is to place his ability to accrue bycatch credit in the hands of another vessel over which he has no control. The unobserved vessel likely will not have any idea of the bycatch rates exhibited by neighboring vessels until some time after the fishing has occurred. For these reasons, unobserved vessels are given the opportunity to take observers in order to demonstrate their bycatch rates and to accrue bycatch credit under this program. To be a statistically valid observation, at least 30% of the fishing must be observed. Therefore, the potentially unobserved vessel must weigh the cost of taking an observer in order to obtain credit and gain additional fishing time, or accept the performance of vessels targeting on the same species in the same area.

The procedure for comparing fish ticket data from observed and unobserved vessels in similar areas, seasons, and fisheries so as to enable calculation of bycatch credit on unobserved vessels may be cumbersome. Administrative costs could render this option too unwieldy to be practical. Thus another option would be to disallow unobserved vessels in the Credit Fishery Program. In this case, smaller vessels would either have to take an observer to demonstrate, and therefore accrue, bycatch credit, or obtain bycatch credit through transfer from another vessel.

The Bycatch Credit System could be expanded to allow for the transferability of the individual bycatch credits earned by vessels that fished below the published rates. This would: (1) provide an even greater incentive for a vessel to have an observer and reduce its bycatch rate; (2) encourage the most efficient use of the earned credits; (3) provide information to fishery managers concerning the value of bycatch to specific fisheries; and (4) provide vessels that cannot physically accommodate an observer an opportunity to continue to fish once the fishery is limited to those who have earned or purchased the right to continue to fish. Such vessels would be assumed to continue to fish at the published bycatch rates. Transferable PSC credits would tend to increase the groundfish yield for a given PSC limit.

One weakness of the Bycatch Credit program is the danger that a groundfish TAC would be completely taken before a vessel was able to fish against its bycatch credit. If bycatch rates are reduced to a point where the preseason rate permits the full attainment of the species TAC, then any bycatch credit accrued by a vessel would be lost because of a lack of groundfish available for harvesting.

Under the Bycatch Credit option, the incentives to fish cleanly would be evaluated in a similar fashion to the PSC Reserve option. A vessel's groundfish catch would increase, thereby creating a positive incentive to fish cleanly, if the revenue generated by harvesting an additional amount of groundfish more than offsets the operating costs of fishing cleanly with 100% observer coverage when fishing into its credit. If the incentive program is effective in lowering the halibut bycatch rates of individual vessels, then the overall groundfish catch would increase, enabling the fishery to more completely harvest the available groundfish OY.

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 either of the incentive programs in 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 reduce halibut bycatch rates. An incentive program may also result in slowing down the rate at which groundfish are harvested if a reduction in halibut bycatch rates also reduces the catch rate of groundfish.

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 section 7.3.3.1 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: 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.

Currently, few vessels fish for groundfish with pot gear. 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: Implement a halibut PSC incentive program.

The largest share of the benefits and costs will be incurred by the groundfish fishery through the form of increased earnings from increased groundfish catch for the same amount of PSC limit and through the requirement of 100 percent observer coverage in a Reserve or Credit Fishery. Some of these increased earnings will be offset by slightly higher operating costs, because vessels will be at sea for longer periods, assuming that bycatch rates are successfully reduced. This reduction in bycatch rates would, in effect, lengthen the groundfish fishery in the number of days of operation. But it is expected that the increase in earnings will outweigh the increase in costs because vessel operators will not undertake additional cost to reduce bycatch unless they can profit from increased groundfish catches.

The amount of the increase in the groundfish catch is dependent upon the size of the reserve. Because the reserves will be set annually by the Council and are not fixed in the FMP, precise estimates of the increase cannot be ascertained. However, assuming the amount of the reserve will be between 20 and 50 percent of the PSC limit, a range can be determined within which the expected increase will likely fall.

In the analysis of Alternative 3 (Section 7.3.4.1), the effectiveness of 20 and 50 percent reserves in the GOA bottom trawl fishery was examined against the same fishery with no reserve. The 20 percent reserve provided an increase of 12,800 mt of groundfish, whereas the 50 percent reserve resulted in an additional

18,500 mt of groundfish. The value of this additional catch is dependent upon the species composition of the catch, which is unknown. With ex-vessel prices ranging from a low of $0.081 per pound[1] round weight for pollock to a high of $0.133 per pound[1] round weight for Pacific cod, the value of the additional groundfish catch would be fall somewhere within the range of $2.3 million to $5.4 million. However, catches in the bottom trawl fishery are composed primarily of Pacific cod and flounders; the latter had an ex-vessel price of $0.099 per pound[1] round weight. Thus, the true value of the additional groundfish catch would likely fall towards the middle to upper end of the range for the examples provided.

Since the halibut PSC limits remain unchanged, there is no change in the impact on halibut associated with the implementation of a PSC reserve system. The impact of a halibut PSC of 2,000 mt results in a loss to the U.S. and Canadian directed halibut fishery of 5.3 million pounds net weight (2,000 mt times 2,205 lbs/mt divided by 1.33 [round weight to net weight conversion] x 1.6 [IPHC adult equivalent factor]). Using a halibut ex-vessel price of $1.50 per pound net weight[2], a PSC of 2,000 mt results in a loss in ex-vessel revenue of $8.0 million to halibut fishermen.

Similarly, the expected benefits and costs under a Bycatch Credit program would be comprised of the revenues from the additional groundfish harvest, and offset to an unknown degree by the added costs of the necessary observer coverage and greater operating costs due to the longer fishing season.

The establishment of a PSC Reserve or Credit System can be used to provide an incentive for vessels to have observers on board and to develop techniques for reducing bycatch rates. If each vessel with an observer bears the full cost of the observer, the cost to the vessel could be in excess of $7,500 per month. This would be a large burden for some vessels. However, it would be a voluntary burden that a vessel would only be willing to pay if it provided net benefits to the vessel in terms of an increased opportunity to harvest groundfish. With this system, there would be costs imposed on vessels that could not continue to fish into the reserve after the PSC limit, less the reserve, is taken. By increasing observer coverage compared to the status quo, each option would tend to increase the credibility and equity of bycatch management and reduce the controversy concerning bycatch. The Bycatch Credit System probably ranks highest in terms of these benefits and if the Credit System includes transferability of the right to fish against bycatch savings, it would probably provide greater benefits of these types in addition to providing an increased opportunity for an optimal distribution of bycatch among the groundfish fisheries.

A unit of bycatch credit will have value to a vessel since credit will allow the vessel to continue to fish if quota is available. A measure of this value is the cost a vessel incurs in obtaining the credit, either through

---

[1]Ex-vessel prices in 1989 GOA trawl fishery from PacFIN Report #128, dated February 12, 1990.

[2]Average ex-vessel price for Pacific halibut in 1989 commercial fishery. From G. Williams, IPHC, March, 1990.

a change in fishing behavior to lower bycatch rates or through transfer. The Council would need to closely monitor the Bycatch Credit Program (a) to be sure each vessel has sufficient bycatch credit to cover its groundfish catch in the Credit Fishery, and (b) to track the value of credits in order to evaluate the validity of the PSC limits.

7.4.2 Reporting Costs

The observer costs borne by fishing vessels can be considered reporting costs. As noted above, these are voluntary costs that a vessel would pay if it provides an adequate opportunity to harvest additional groundfish. The cost would tend to be higher with the Bycatch Credit System than with the Reserve System because a vessel would have to have an observer to earn bycatch credits that can be used to continue to fish once bycatch, estimated based on the published bycatch rates and reported catch, equals the PSC limit. With the Reserve System, vessels would just be required to have observers when fishing against the 20-50% reserve. However, the savings associated with having observers only after the initial part of a PSC limit is taken would be offset, at least to some extent, by the cost of being prepared to meet a sudden demand for observers of an unknown number and duration once the initial part of the limits is taken. This cost would include those associated with: (l) either having a large number of observers on hand to serve for perhaps very few days or having vessels return to port until observers are available; and (2) the cost of returning to port for an observer. The cost per observer day could increase from about $250 per day for a three to four week trip to perhaps $750 per day for a one week trip. The increase in cost per day occurs because the fixed costs per observer trip are quite high. They include round trip travel costs, pre-trip briefing costs, post-trip debriefing costs, and perhaps a minimum guaranteed payment for the observer.

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 observed catch composition and prohibited species bycatch. This information is used to calculate prohibited species bycatch rates for halibut in the Gulf of Alaska that are then applied against extrapolated weekly catch amounts to derive weekly bycatch amounts of halibut for purposes of monitoring fishery apportionments of established halibut PSC limits.

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 two systems to allow specific vessels to accrue bycatch credit or to fish against a PSC limit reserve would increase the administrative and information burdens because it would be necessary to keep track of observer data for each individual vessel. It may be necessary to phase in such a program during 1991 such that it is fully operational in 1992. Some administrative burdens could be reduced by providing each vessel with a strong incentive to monitor its own bycatch and continue to fish only as long as it had the right to. If the Bycatch Credit System includes transferable rights, it would provide information that could be beneficial in identifying the value of additional bycatch to each fishery, and therefore in eliminating one of the major controversies concerning bycatch management.

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 vessel incentives are 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 2.0 of this EA/RIR, which also includes vessel incentives as options under alternatives to extending Amendment 12a. 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.

As mentioned above, 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 requiring individual monitoring would be a function of the usual number of boats participating in a fishery as modified by any limitation imposed by a PSC reserve or credit system. For example, if 20 vessels fish in the DAP trawl fishery, they would have to be monitored weekly to determine each vessel's bycatch rate. Once the portion of a PSC limit for halibut assigned to the open fishery is reached, only those vessels with average bycatch rates below a specified threshold would be allowed to continue to fish into the PSC reserve. If only 10 vessels met the criteria to fish in a reserve system, one staff person would be needed during a reserve fishery with daily monitoring.

Given the number of vessels that might fish in a reserve fishery, 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 incentive programs presented 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. Closure of areas to individual vessels based on either observed bycatch rates or statistical estimates of bycatch rates would complicate existing enforcement of fishery closures to directed fisheries or gear types. NMFS estimates that one additional person will need to be added to the existing enforcement staff to address the additional workload that would result from increased number of fishery citations that are anticipated for noncompliance with bycatch incentive programs (approximately $35,000 per year). Furthermore, individual vessels may choose to challenge information used to close them out of an area or fishery and request an adjudicative hearing. How often individual vessels or operations would challenge closure actions 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.

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.

PSC reserves or bycatch credit programs are not expected to 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 PSC bycatch credit or a reserve system would tend to benefit vessels that can physically and financially accommodate an observer at the expense of those that cannot. This would be less of a problem if vessels without observers could use logbooks to demonstrate low bycatch rates and therefore obtain a bycatch credit or gain the right to fish during the reserve fishery. This inequity also could be reduced if vessels without observers could obtain and use bycatch credits against which they could continue to fish.

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

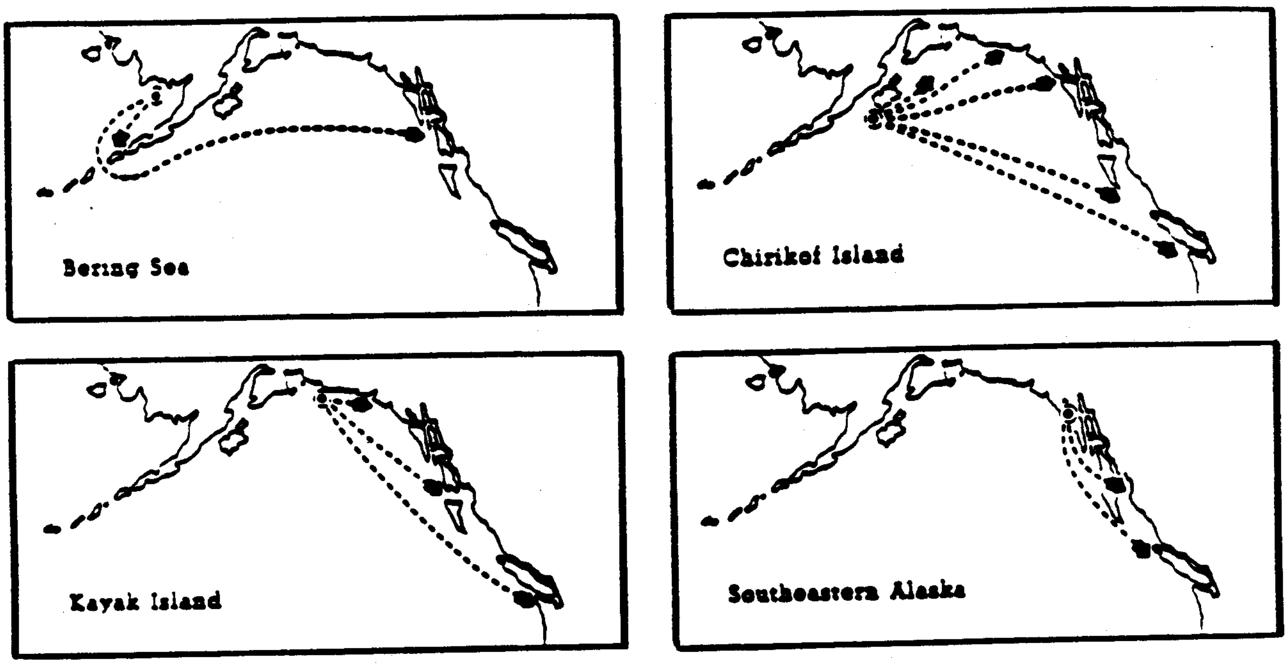


Figure 7.1 Migratory patterns of juvenile Pacific halibut from different tagging sites. Source: IPHC.

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.

____ ____________________

Assistant Administrator for Fisheries 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.

13.0 LIST OF PREPARERS

Harold J. Weeks, William J. Wilson
North Pacific Fishery Management Council
P.O. Box 103136
Anchorage, Alaska 99510

Jim Balsiger, Jerald Berger, Sandra McDevitt,
Grant Thompson, Joe Terry, and Tom Wilderbuer
Northwest and Alaska Fisheries Center
7600 Sand Point Way N.E., Bldg. 4
BIN C15700
Seattle, Washington 98115

Ron Berg, Jay Ginter, Sue Salveson,
and Janet Smoker
Fishery Management Division
National Marine Fisheries Service, Alaska Region
P.O. Box 21668
Juneau, Alaska 99802-1668

Fritz Funk, Phil Rigby, Robt. J. Wolfe
Alaska Dept. of Fish & Game
P.O. Box 3-2000
Juneau, AK 99802

Bob Trumble, Greg Williams
International Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145-2009

Barry Bracken
Alaska Dept. of Fish & Game
P.O. Box 667
Petersburg, AK 99833

Jeremy Collie
Juneau Center for Ocean Sciences
University of Alaska Juneau
11120 Glacier Highway
Juneau, Alaska 99801

Han-lin Lai
Washington Department of Fisheries
7600 Sand Point Way N.E., Bldg. 4
BIN C15700
Seattle, WA 98115

Sam Wright
Washington Department of Fisheries
115 General Administration Building
Olympia, WA 98504

Jeff Fujioka
National Marine Fisheries Service
Auke Bay Laboratory
P.O. Box 210155
Auke Bay, AK 99821

Brad Berman
Institute for Social and Economic Research
University of Alaska Anchorage
3211 Providence Drive
Anchorage, AK 99508

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

3 June, 1990

MEMORANDUM FOR: F/CM2 - Joe P. Clem

FROM: F/CM1 - Peter H. Fricke

SUBJECT: Draft Amendments 21 and 16 to BSAI and GOA Groundfish FMPs

I have reviewed the above amendments, which are largely of a biological or technical nature, and do not have any economic or social analyses of impacts. For these reasons, I have no comments to make at this time.

cc: F/CM-RSchaefer, DCrestin; F/CM1-HBlatt, RSurdi; F/CM2-MMillikin

CODE	SURNAME	DATE	CODE	SURNAME	DATE

FILE COPY

NOAA FORM 61-2

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, Maryland 20910

MAY 24 1990

MEMORANDUM FOR: Distribution

FROM: for Joe P. Clem *Donald J. Leedy*

SUBJECT: Draft Amendments 21 and 16 to the Fishery Management Plans (FMP's) for Groundfish of the Gulf of Alaska (GOA) and Groundfish of the Bering Sea and Aleutian Islands (BSAI)

Attached are the subject draft amendments for your review. Amendment 21 to the GOA FMP includes management measures and changes to the FMP pertaining to: (1) overfishing definitions, (2) procedures for the establishment of interim TAC's, (3) modifications in the language that authorizes demersal shelf rockfish management, (4) changes in fishing gear restrictions, and (5) an expanded program for halibut bycatch. Amendment 16 to the BSAI FMP contains management measures and changes to the FMP concerning (1) crab and halibut bycatch management, (2) overfishing definitions, (3) procedures for the establishment of interim TAC's, and (4) changes in fishing gear restrictions.

Please forward your comments to Mark Millikin by June 7, so that the Alaska Region will receive our input in plenty of time before the June meeting of the North Pacific Fishery Management Council.

Attachment

Distribution

GCF - Lauren Rogerson
F/CM2 - Don Leedy, George Darcy
F/CM1 - Peter Fricke
F/CM1 - Richard Surdi
F/CM2 - Paul Hooker
F/EN - Morris Pallozzi
F/PR3 - John Hall
F/PR2 - Charles Karnella