North Pacific Fishery Management Council

Richard B. Lauber, Chairman
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April 8, 1993

Dear Reviewer:

Enclosed is an advance draft of the analysis of rebuilding alternatives for Pacific Ocean Perch (POP) in the Gulf of Alaska. This document will be reviewed by the Council at the upcoming meeting during the week of April 21-24. It is expected that the document would be released for an official public comment period after the April meeting, with a final decision scheduled for the June meeting in Kodiak, AK. The document contains biological analyses of potential stock rebuilding alternatives and an economic assessment of the potential impacts of these rebuilding alternatives on associated segments of the fishing industry.

Standard Council operating procedures do not allow for draft amendment analyses to be released to the public prior to Council review. However, an exception is being made in this case because the information in this document may be relevant to a Council decision, during the April meeting, on the 1993 Total Allowable Catch (TAC) for POP. The Council made a TAC recommendation at the December 1992 meeting for the 1993 POP fisheries. NMFS has asked the Council to reconsider that recommendation, in part because the Council did not have a fully developed socio-economic analysis before them when they made that decision. Reconsideration of the 1993 TAC for POP will occur at the April meeting so that it can be in effect in time for the rockfish fisheries opening date of July 1.

Although a final decision on the overall rebuilding alternatives will not occur at this meeting, information contained in the analysis represents the best, most current information available and will likely be taken into account when considering the 1993 TAC. Therefore, the Council is making this document available to the public at this time so that meaningful public comment may be received by the Council at this meeting. Dave Witherell is the Council staff contact person on this issue if you have any further questions.

Sincerely,

Clarence G. Pautzke
Executive Director

ALASKA MARINE CONSERVATION COUNCIL

Box 101145 Anchorage, Alaska 99510
(907) 277-5357 (kelp) 274-4145 (Fax)

August 28, 1993

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mailed on 8/30/93

Mr. Richard B. Lauber, Chairman
North Pacific Fishery Management Council
Box 103136
Anchorage, Alaska 99510

Dear Mr. Lauber,

The Alaska Marine Conservation Council is a newly formed community-based organization of fishermen and women, biologists, coastal residents, subsistence users and other Alaskans whose way of life and livelihoods depend on healthy marine ecosystems. We are dedicated to protecting and restoring living marine resources and their habitat.

We wish to thank the North Pacific Fishery Management Council for its efforts to begin, in ernest, the long overdue rebuilding of Pacific ocean perch stocks. By reaffirming its decision to keep the Total Allow Catch to 2560 metric tons (bycatch only), the Council demonstrated its concern for this resource and acted in behalf of conservation.

We urge Council members to stay the course and adopt a rebuilding strategy that ensures Pacific ocean perch is viably restored in as short a time as possible.

We remain concerned, however, that strategies for harvesting and rebuilding rockfish will not be successful until more is known about the life histories and reproductive biologies of these long lived species. Current stock assessment approaches contain high degrees of uncertainty and must be reevaluated. We can no longer afford to apply traditional finfish management strategies to rockfish species that live to be 100 years old.

Pacific ocean perch is only one of several species of rockfish whose depressed population is of concern. In particular, shortraker/rougheye and thornyhead rockfish deserve special management attention due to increasing bycatch levels and their susceptibility to overexploitation. In order to restore and protect these unique and long-lived creatures and their habitat, conservation must be our number one priority in any management and rebuilding plans.

Sincerely,

Nevette Bowen

Nevette Bowen
Coordinator

RECEIVED
SEP - 7 1993

August 30, 1993

FAX CONFIRMATION
Sent_____ Rec'd 8/30/93

Richard B. Lauber, Chairman
North Pacific Fishery Management Council
P.O. Box 103136
Anchorage, AK 99510-3136

Dear Mr. Chairman:

I have written this letter in response to your request for comments on the draft EA/RIR of Alternative Harvest Policies for Rebuilding Pacific Ocean Perch (POP) in the Gulf of Alaska ("rebuilding plan"). As you are certainly well aware, the Fishing Company of Alaska (FCA) has a long-time history in the Gulf of Alaska rockfish fisheries, and we are currently facing severe economic impacts should the Council and NMFS continue with its current POP harvest policy.

We have testified and written on numerous occasions in the past on the importance of this fishery to our company and the sincere interest we have that this resource be properly managed for the long term.

It was FCA that first sat down with the Council's Plan Teams during the first years of the domestic fishery providing input for rockfish species identification, stock assemblage groups, commercial fishing CPUE data, species composition and bycatch information.

It was FCA that first volunteered to take domestic observers on rockfish vessels providing valuable information to managers and scientists.

It was FCA that first came to the NPFMC in 1988 with an industry funded rockfish ITQ pilot proposal (with majority consensus from the rockfish fleet) to help the Council move more expeditiously through a moratorium and comprehensive rationalization of the fisheries.

It was FCA that spearheaded the Pilot Slope Rockfish Survey With Industry for better stock assessment of the rockfish species in the Gulf of Alaska to be accomplished this month with NOAA scientists and the F/V Unimak Enterprise (Tyson Seafoods).

It is from this perspective and our history, that we recommend that you do not approve the draft rebuilding plan until the following comments have been carefully considered:

The Fishing Company of Alaska, Inc.
200 WEST THOMAS, SUITE 440 • SEATTLE, WASHINGTON 98119
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First, we are of the opinion that the rebuilding plan is flawed. We know that students of fisheries science learn early on that a rebuilding plan is comprised of three parts: (1) a discussion of the need to restore a stock to some desired level and the basis for such determination; (2) a description of the strategy to be followed to achieve the rebuilding objectives; and (3) an integrated and scientifically sound method of measuring the plan's performance and its success in meeting the rebuilding objective. I note that business restructuring plans share these same fundamental components.

(1) PURPOSE AND NEED

What are the Council's goals: to accelerate the rebuilding of POP stocks? Is an accelerated rebuilding schedule necessarily better than a gradual rate? It is clear from the document and the graphs that the POP stocks are rebuilding without policy change.

The Council and SSC can be commended for their previous management of these stocks. Even though stocks were reduced substantially since "pre-fished" levels, spawner biomass and the stocks have increased moderately. In fact, Aleutian stocks **have been rebuilt**, with no change in policy.

The authors of the document address the erroneous perception that most people have: the foreign fishery harvested a large standing stock of older fish. The analysis explained that the foreign harvests were comprised of several strong year classes of relatively young individuals. Therefore, it does not make sense to increase spawning biomass to a "pre-fished" total biomass level. Rather, managers should target a lower spawner biomass level (118,000 mt) and manage to enhance the spawner-recruit relationship. In addition, recent (pre-1993) management of these stocks has allowed for increase in total biomass. This is probably what led to an SSC member's statement: "The fish will die of old age before they are fished out under current management." I don't believe any scientist would argue that favorable environmental conditions will contribute more to increasing the likelihood of a strong year class, than a change in policy.

The Council has stated that POP TAC recommendations are based on information that show POP stocks to be below pre-exploitation levels and due to concerns over the high level of uncertainty associated with stock methodology. We agree that there exists a lot of uncertainty over current stock assessments. However, the Council fails to accept that most scientific experts are of the opinion that the current stock estimates are low and already err on the side of conservatism. Many of these same experts are now wondering why the Council has overreacted to this available information by taking a most extreme, ultra-conservative approach.

Stacking one conservative measure upon another will eventually kill a fishery. Again, we question the motives of those managers who support these extreme measures in light of scientific evidence surrounding current assessments of POP stocks.

The rebuilding plan presents no discussion on how the Council determined that additional rebuilding efforts are necessary. The Secretary's own notice implementing the 1993 POP specifications state that "NMFS agrees that POP are below historic 'unfished' levels and that they may be in need of rebuilding." We contend that no one has made a scientifically defensible determination. We also question if NMFS is now embracing the standard that since POP stocks are below "unfished" levels that we must take drastic efforts to rebuild those stocks at the expense of directed fisheries. If this is indeed the case, every species commercially exploited off Alaska fall into a similar category and those fisheries should be closed also. Most would consider this a ludicrous suggestion. We believe that eliminating the directed POP fishery in the Gulf of Alaska is just as unconscionable.

(2) STRATEGIES TO ACHIEVE REBUILDING SCHEDULE GOAL

Again, FCA contends that the stocks are rebuilding and we question the concern for such stringent policy measures. The author also points to the 1993 Triennial Survey currently being conducted, which will provide new biomass estimates of the POP population and age structure. Because this additional information should improve our ability to analyze the condition of the stock, in developing a **specific** strategy, regulatory flexibility is **required** as new information and analyses become available.

The rebuilding plan describes no other management alternatives that would allow for rebuilding other than the four policy alternatives. Regulatory flexibility must be included due to new information forthcoming. Not only will we have additional stock information, but it will soon be made apparently clear the additional economic and biological impacts upon other fisheries from a displaced rockfish fleet will need to be addressed. Quotas in other fisheries will be caught faster and prohibited species bycatch caps in other fisheries will certainly be reached earlier, affecting the entire trawl industry in the Gulf of Alaska.

Are there no viable alternatives to a no-directed fishing policy? Can't exploitation rates be recommended annually by our Plan Teams and SSC to the Council if better information becomes available on population changes of the POP stocks? Can't the Council adjust TACs below ABCs if stronger rebuilding or a threat of overfishing becomes reality?

Is the Council overly pessimistic because of disinformation? The scientists report the stock as **stable and increasing in abundance.** Even if a form of policy #1 were adopted, in 30 years the stock will be twice the biomass of the current population.

The EA/RIR presents four policy alternatives. The economic analysis is limited, but concludes that the price of the Council's preferred strategy is upward of $90 million. We believe this is a conservative cost estimate. Impacts to other fisheries, market gluts and higher bycatch of PSC species resulting from a displaced fleet moving into other fisheries has not been considered.

The primary focus of the rebuilding plan is biological, and we are presented with four hypothetical rebuilding scenarios with corresponding risk assessments. All four scenarios show a very high probability that in 20 years the spawning stock will be above 75,000 mt. A directed fishing strategy (Alternative 1) would still provide for rebuilding while exhibiting a level of risk of only 5% in terms of meeting the 20-year spawning stock objective.

Maintaining a directed fishing strategy (Alt. 1) would, according to the EA/RIR, achieve the rebuilding objective in 26 years. Alternative policy 2 would achieve this objective in 18 years. A no-directed fishing alternative (Alt. 3 and 4) would provide gains of only 3 to 5 years. We contend that this time-savings is not worth the $90 million+ price tag and putting fishing companies out of business.

(3) SCIENTIFIC AND ECONOMIC MONITORING

The May 20, 1993 rebuilding plan has no discussion whatsoever on measuring the plan's performance. There is no discussion on how adoption of the Council's preferred rebuilding strategy will be monitored. What methods will be employed? At what intervals will measurements be taken? How often will the plan be reviewed and possibly modified to assure that the rebuilding objectives are met? We recommend that this plan not be approved until all three sections of the rebuilding plan are fully developed.

We bring this significant issue to your attention because the EA/RIR describes the enormous cost borne by the U.S. rockfish industry for implementing the Council's rebuilding strategy. How can these costs be justified? Why should the U.S. eliminate a valuable fishery and precious market positions when the EA/RIR itself shows that biological and economic benefits can be realized by adopting the pre-1993 harvest policy? How is NMFS intending to measure the plan's performance and determine whether the real and measurable costs to the U.S. are being compensated by the hypothetical benefits?

The Council's 1993 harvest strategy eliminates a directed fishery on POP and a valuable source of biological information. Adoption of this strategy puts NMFS further into the "black hole" of knowledge on the POP stock without any routine monitoring of stock condition. Reliance on surveys is already highly questionable given current survey methods.

Putting our company and an industry out of business seems counter to the goals the current administration is striving to achieve. We seek a balanced approach to POP management: one that protects the long-term health of the resource while providing economic and market stability which to those dependent on it, can only be accomplished by preserving the POP fishery. Wiping out our fishery cannot be justified by the scientific information at hand. Putting us out of business will only add to our country's economic problems. Please take our comments seriously and take responsible management actions.

Sincerely,

Ms. Karena Adler, President & CEO
The Fishing Company of Alaska

cc: Ronald H. Brown, Secretary of Commerce
Nancy Foster, Acting Asst. Administrator for Fisheries
Washington Congressional Delegation
North Pacific Fishery Management Council Members

North Pacific Fishery Management Council

Richard B. Lauber, Chairman
Clarence G. Pautzke, Executive Director

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August 16, 1993

Dear Reviewer:

The enclosed analysis of rockfish rebuilding alternatives was originally released for public review in May, 1993, with Council consideration of the subject scheduled for their June 1993 meeting. However, because of time constraints, the issue was rescheduled for review during the Council's upcoming September 21-25 meeting and the public comment period extended to September 1. A general description of the issue and the proposed alternatives is found in the Executive Summary of the document.

Written comments should be sent to the North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510, to arrive no later than Wednesday, September 1, 1993.

Sincerely,

Chris Oliver for

Clarence G. Pautzke
Executive Director

Enclosure

North Pacific Fishery Management Council

Richard B. Lauber, Chairman
Clarence G. Pautzke, Executive Director

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May 21, 1993

Dear Reviewer:

The Council was scheduled to consider strategies to rebuild the depleted Pacific ocean perch stock in the Gulf of Alaska at their June meeting in Kodiak. This issue has been rescheduled for final action by the Council during a July meeting in Seattle. This meeting is tentatively scheduled for July 26-30, with the specific location in Seattle not yet determined. The enclosed analysis has been released for public review and comment. A general description of the issue and the proposed alternatives is found in the Executive Summary of the document.

Written comments should be sent to the North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510, to arrive no later than Thursday, June 22, 1993.

Sincerely,

Chris Oliver for

Clarence G. Pautzke
Executive Director

enclosures

North Pacific Fishery Management Council

Richard B. Lauber, Chairman
Clarence G. Pautzke, Executive Director

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MEMORANDUM

TO: Recipients of Rockfish Rebuilding Alternatives Analysis

FROM: Clarence G. Pautzke
Executive Director

DATE: June 11, 1993

SUBJECT: Schedule for Council Review

In our May 21 letter accompanying the rockfish rebuilding analysis we indicated that the subject would most likely be addressed at a special July meeting of the North Pacific Council. At this time it appears there probably will not be a July meeting, therefore the subject will be placed on the Council's September meeting agenda. That meeting is scheduled for the week of September 20, 1993 at the Hilton Hotel in Anchorage, Alaska. Written comments on the analysis will be extended through the summer, ending on September 1, 1993. If there are any changes in these plans you will be notified.

If you have any questions, please call Dave Witherell on my staff.

ENVIRONMENTAL ASSESSMENT / REGULATORY IMPACT REVIEW / INITIAL REGULATORY FLEXIBILITY ANALYSIS OF ALTERNATIVE HARVEST POLICIES FOR REBUILDING PACIFIC OCEAN PERCH IN THE GULF OF ALASKA

Prepared by
National Marine Fisheries Service
Alaska Fisheries Science Center
Alaska Regional Office

20 May, 1993

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EXECUTIVE SUMMARY

By the mid 1970's the biomass of Pacific ocean perch (POP) in the Gulf of Alaska (GOA) had been reduced to about 10% of the level during the early 1960's . For the period 1961-1977 the average annual catch of POP was 40,790 tons, thereafter, landings averaged 6,078 tons. Although fishing mortality has been greatly reduced, the stock has shown only modest increases; the current estimate of spawner biomass is between 15-20% of the level observed during the 1960's. This has raised concern that past management measures may have been inadequate to rebuild the stock of POP in the GOA. Consequently, the Council requested that a detailed analysis be performed to: a) identify optimal fishing rates for rockfish species such as Pacific ocean perch; b) identify the biomass level that would achieve an optimum yield; and c) evaluate the effect of alternative fishing policies on rebuilding POP. The purpose of this analysis is to provide the Council with information to assess alternative harvest policies and their effect on rebuilding the stock of POP in the GOA.

Based on re-analysis of spawner-recruit data, the optimal fishing mortality rate for POP in the GOA was determined to be 0.08 rather than the fishing mortality rate of 0.114 used to determine the 1993 ABC. In addition, the corresponding target female spawner biomass is 150,000 mt. This compares with a target of 118,000 mt used in previous analyses. Although the results presented in this study suggest different values for setting POP ABC than in the past, they have not yet been reviewed by the Plan Team or officially incorporated into stock assessment procedures.

Based on the new estimates for optimal biomass and fishing mortality rates, the following alternative fishing policies were developed and evaluated using a simulation model. In all cases the target biomass was taken to be 150,000 tons.

Alternative Policy 1: Status quo: Rebuilding of POP stocks would be attempted by harvesting the stock at the $F_{35\%}$ fishing mortality rate adjusted by the ratio of the current biomass to the target biomass. This adjustment is made until the target biomass is reached.

Alternative Policy 2: Rebuilding of POP stocks would be attempted by harvesting at the estimated optimal fishing mortality rate adjusted by the ratio of current biomass to the target biomass. This adjustment is made until the target biomass is reached.

Alternative Policy 3: Rebuilding of POP stocks would be attempted by harvesting at a fishing mortality rate intermediate to the optimal fishing mortality rate recommendation in Alternative 2 and a fishing mortality rate sufficient to supply POP bycatch needs (Alternative 4). This rate is adjusted by the ratio of current biomass to the target biomass until the target biomass is reached.

Alternative Policy 4: Rebuilding of POP stocks would be attempted by harvesting at a fishing mortality rate estimated to be sufficient to accommodate unavoidable bycatch of POP in the GOA groundfish fisheries based on 1992 bycatch rates. *Once the target biomass is reached the optimal fishing mortality used in alternative 2 would be applied.*

The ability to predict future stock levels with a high degree of certainty is poor. Clearly, the potential for stock rebuilding will be highest under the policy with the lowest fishing mortality rate, although in all cases there is no *guarantee* that rebuilding will occur. Factors that influence rebuilding include the natural and fishing mortality rate, individual growth, and, most importantly, recruitment.

Each policy alternative for rebuilding rockfish results in a different set of projected annual harvest levels, therefore income to industry participants over time varies. Under policy alternatives 3 and 4, harvest is foregone in the near future to achieve the target biomass sooner and to increase future harvest levels. To examine the economic trade-offs associated with these alternatives the present value of gross income over time was calculated. The present values indicate that, from the perspective of the industry members who harvest and sell POP and then reinvest that income, there is a higher value to policies with earlier harvests.

The stock of POP is expected to rebuild at a slow rate. All four policies alternatives are expected to rebuild the stock of POP. Based on an economic analysis that considers only the value of POP to harvesters and processors, policy alternatives that result in foregone catch in the near-term are less valuable.

Over time, policies 2-4 show similar mean rebuilding patterns over alternative hypotheses on the stock-recruitment steepness. Policy 1 shows an expected doubling of the current spawner biomass in about 30 years whereas policies 2, 3, and 4 indicate doubling in about 20, 15, and 13 years, respectively.

Under alternative policy 1 (status quo), the stock is expected to rebuild to the target biomass of 150,000 tons in about 26 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is 5%.

Alternative policy 2 results in the expectation that the stock would rebuild to the target biomass of 150,000 tons in about 18 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is about 1%.

Under alternative policy 3 the stock is expected to rebuild to the target biomass of 150,000 tons in about 14 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is less than 1%.

The impact of adopting alternative policy 4 is very similar to policy 3. The stock is expected to rebuild to the target biomass of 150,000 tons in about 14 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is less than 1%.

The fleet of offshore vessels that harvests POP in the GOA is relatively small. Although 17 vessels are categorized as having targeted POP in 1991, during either of the past two years, only 6 vessels received more than 3.5% of their overall income from the catch of all species in POP-target weeks. These vessels received between 6% and 17% of their earnings from all species caught while fishing POP. POP accounted for more than 80% of the poundage caught during most of these target weeks, although it was not uncommon for 30-40% of the revenue earned to come from other species. Given available information, it is difficult to assess how the overall amount and composition of catch will change for these vessels, if POP made available to the fishery is reduced.

When viewing the economic projections of this study it should be noted that, even if the biological predictions of the model accurately reflect the true probabilities of occurrences 30 years into the future, the economic values that have been attached to them are extremely speculative. According to the bio-economic simulation model developed for this analysis, adopting more restrictive harvest policies for the GOA POP fishery is expected to reduce the income generated by the fishery in nearly every year of the next thirty years. The difference between the present value of income under the status quo and the most restrictive policy amounts to roughly $40 million if future values are not discounted, and $22 million if they are discounted at a rate of 7% per year. This estimate reflects changes in gross earnings and is based on the assumption that prices remain constant over the 30-year period. Subtracting variable costs would likely reduce the difference between the alternatives by an estimated 30-40%, based on cost formulas developed for other offshore fisheries. The simulation does not address any changes in earnings except for those derived from POP directly. Without considerable additional information and model building, little can be reliably concluded about the net effect on income from other species harvested by POP vessels, or the remainder of the trawl fleet. The economic results projected by the simulation model also do not include any economic benefits that might result from ecosystem enhancement, or any non-market benefits from achieving relatively larger stock sizes.

If some of the POP fleet redirects effort toward flatfish, the PSC caps will be reached at a lower level of groundfish catch, due to the higher halibut bycatch rate in those fisheries. Additionally,

since many species of flatfish are of equal or lesser value, opportunities in those fisheries may not offset reductions in revenues generated from POP harvest. Perhaps most importantly, increased fishing for flatfish may reduce the amount of higher-valued species, such as Pacific cod, that can be taken by all trawl vessels, given the PSC caps.

Although it is not the only objective of accelerating the rebuilding schedule, the simulations suggest that the more restrictive harvest policies are not likely to provide an increase in catch and earnings over the next 30 years that will more than offset the economic sacrifices made in the short term. The only economic conclusion that can be drawn is that under the recruitment scenarios examined, reductions in the POP harvest rate will result in reductions of gross earnings from the POP fishery, which would not likely be made up for by increased gross earnings anytime during the next 30 years. Other important economic considerations were not quantified.

The model used in this analysis assumes that the Gulf-wide stock of POP is harvested uniformly throughout it's geographic range. This is probably not true. There may be areas within the GOA where harvests are significantly out of proportion to the distribution of biomass. That is, fishing mortality may be distributed unevenly with respect to the distribution of the population. The effect this may have on the stock is not known. In the past, the ABC recommendation has been divided among three subareas (the eastern, central and western GOA) in proportion to the biomass estimated from NMFS surveys.

This study represents an analysis based on the current stock assessment. In 1993, there will be another NMFS survey which will provide a new biomass estimate of the Pacific ocean perch population and an estimate of the population age structure. Additional information should improve our ability to analyze the condition of the stock and to make future projections. This indicates that, in developing a specific rebuilding strategy, regulatory flexibility may be required as new information and analyses become available.

1. INTRODUCTION

1.1. Background

The Gulf of Alaska (GOA) groundfish fisheries in the U.S. exclusive economic zone (EEZ) are managed under the Fishery Management Plan for the Groundfish Fishery of the GOA. The fishery management plan (FMP) was developed by the North Pacific Fisheries Management Council (NPFMC, Council) under the Magnuson Fishery Conservation and Management Act (MFCMA, Magnuson Act). The FMP was approved by the Secretary of Commerce (Secretary) and became effective in 1982.

This Environmental Assessment, Regulatory Impact Review (EA/RIR) presents an analysis of the efficacy and the potential biological and socioeconomic impacts of alternative harvest policies for Pacific ocean perch (POP), *Sebastes alutus*. The Council reviewed this EA/RIR at the April 1993 meeting and recommended that it be released for public review for further comments.

1.2. Purpose of Document

This document provides background information and assessments necessary for the Secretary to determine if the alternatives being considered by the Council are consistent with the Magnuson Act and other applicable law. It also provides the public with information to assess the alternatives that the Council is considering and to comment on the alternatives. These comments will enable the Council and Secretary to make a more informed decision concerning the resolution of the management problems being addressed.

1.2.1. ENVIRONMENTAL ASSESSMENT

The EA is required by 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 environmental impact study (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; (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 the proposed changes will have significant impacts on the human environment and proceed directly with the preparation of an EIS.

1.2.2. Regulatory Impact Review

The RIR is required for all regulatory actions undertaken by the National Marine Fisheries Service (NMFS) or for significant Department of Commerce or NOAA policy changes that are of 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 record-keeping requirements. This Act requires that the head of an agency must certify that the regulatory and record-keeping requirements, if promulgated, will not have a significant economic impact on a substantial number of small entities or provide sufficient justification to receive a waiver.

1.3. Purpose and Need for the Proposed Action

The domestic and foreign groundfish fisheries in the Exclusive Economic Zone of the GOA are managed by the Secretary according to the GOA FMP, which was prepared by the Council under

the authority of the Magnuson Act. The FMP is implemented by regulations for the foreign fishery at 50 CFR Part 611 and for the U.S. fishery at 50 CFR Part 672. General regulations that also pertain to the U.S. fishery are implemented at 50 CFR Part 620. At times, amendments to the FMP and /or its implementing regulations are necessary to respond to fishery conservation and management issues.

By the mid-1970's the biomass of POP had been reduced to about 10% of the early 1960's level. For the period 1961-1977 the average annual catch of POP was 40,790 tons; since that time the average is 6,078 tons. Even though the amount of fishing has been greatly reduced, the stock has shown only modest increases. The current estimate of spawner biomass is between 15-20% of the level observed during the 1960's. This caused the Council to be concerned that past management measures may have been insufficient to rebuild the POP stock. Consequently, the Council requested that a more detailed analysis be performed to: a) review and identify optimal fishing rates for rockfish species such as POP; b) identify the biomass level that would achieve an optimum yield; and c) evaluate the effect of alternative fishing policies on rebuilding POP. This proposed amendment, if adopted and implemented by the Secretary, is anticipated to result in a assessment/management program for rebuilding the GOA POP over time.

1.4. Alternative Policies Examined

The alternative policies examined here are intended to provide contrast sufficient for setting total allowable catches (TAC's) and for making future acceptable biological catch (ABC) recommendations. Each policy represents a different level of fishing intensity; Policy 1 has the highest exploitation rate and Policy 4 has the lowest. These policies are examined extensively through a bio-economic simulation model, the results of which are presented in subsequent sections. Under all alternatives, the target biomass was taken to be 150,000 tons of female spawner bioamass.

Alternative Policy 1: Status quo: harvesting the stock at the $F_{35\%}$ fishing mortality rate adjusted by the ratio of the current biomass to the target biomass. This adjustment is made until the target biomass is reached. This policy represents an F35% rate, adjusted by the fraction $B_{current}/B_{target}$ to augment population growth when $B_{current}$ is less than B_{target}. In this analysis the target biomass was estimated directly as B_{msy}, i.e., the biomass that yields the maximum sustainable yield on average (section 2.3.3.).

Alternative Policy 2: Rebuilding of POP stocks would be attempted by harvesting at the estimated optimal fishing mortality rate adjusted by the ratio of current biomass to the target biomass. This adjustment is made until the target biomass is reached. This rate was determined in an analysis presented in section 2.3.3. and is based on available data for the Gulf of Alaska POP.

Alternative Policy 3: Rebuilding of POP stocks would be attempted by harvesting at a fishing mortality rate intermediate to the optimal fishing mortality rate recommendation in Alternative 2 and a fishing mortality rate sufficient to supply POP bycatch needs (Alternative 4). This rate is adjusted by the ratio of current biomass to the target biomass until the target biomass is reached.

Alternative Policy 4: Rebuilding of POP stocks would be attempted by harvesting at a fishing mortality rate of 0.023 adjusted by the ratio of current biomass to target biomass. This rate was estimaated to provide sufficient harvests of POP to accommodate unavoidable bycatch in the GOA groundfish fisheries based on 1992 bycatch rates. Once the target biomass is reached the optimal fishing mortality of 0.08 would be applied.

2. ENVIRONMENTAL AND BIOLOGICAL IMPACTS

2.1. Pacific Ocean Perch Biology and Life History

2.1.1. DISTRIBUTION

Pacific ocean perch is primarily an offshore species that inhabits the outer continental shelf and upper slope regions along the North American coast from southern California to the Bering Sea, and along the Asiatic coast from Cape Navarin to the Kuril Islands (Balsiger et al. 1985). In the GOA, POP are found at depths less than 500 meters (m) with commercial quantities mostly found between 100-300 m (Clausen and Heifetz 1989). The depth and type of bottom substrate and topography that POP are associated with depends on life stage (Clausen and Heifetz 1989, Krieger 1993). Juveniles are usually found in the shallower part of the depth range less than 100 m associated with rugged habitat (cobble, boulders, pinnacles, and coral). Adults are mostly found at depths greater than 100 m over flat pebble substrate.

2.1.2. NATURAL MORTALITY, LENGTH AT AGE, LENGTH WEIGHT RELATIONSHIP

Pacific ocean perch are long-lived and slow growing. Most of the growth occurs during the first 20-25 years of life. Longevity has been estimated at 90 years. This species begins to recruit to the commercial fishery at about age 5 and becomes fully recruited between 10 and 15 years of age. The maximum recorded length is 54 cm, however, the bulk of the commercial catch is comprised of individuals ranging from 25 to 45 cm. Archibald et al. (1981) estimated total instantaneous rate of mortality (Z) for POP to be 0.05. This estimate of Z was from lightly exploited stocks and is used as an estimate of natural mortality (M). Heifetz and Ianelli (1992) investigated the consequences of having natural mortality increase with age and found that it could be interchanged with the assumption of decreasing availability to the fishery with age. They also found that using an increasing mortality rate resulted in an overly optimistic estimate of sustainable harvest levels. For the purpose of this analysis, M was fixed at 0.05.

The age-length relationship was estimated by Clausen and Heifetz (1989) from age samples collected during the 1984 and 1987 triennial trawl surveys conducted bye NMFS. Based on the break-and-burn method of aging (Archibald et al. 1981) the fitted von Bertalanffy growth model used in this analysis was:

$$L_a = 41.1\left(1-e^{-0.207(a+0.32)}\right)$$

where L_a is the length (cm) at age a (years). Mean length at age is different between sexes with females typically being larger at older ages. In this analysis, however we do not consider differences between sexes.

The length weight relationship for POP used here was from Archibald et al. (1981) and can be expressed as

$$W = 1.54\text{x}10^{-5} L^{2.96}$$

where L is length in cm and W is weight in kg.

2.1.3. MATURE BIOMASS AND FECUNDITY

The reproductive biology of POP is complex and not well understood. Females are viviparous, retaining eggs in the ovary after fertilization until yolk sac absorption. Mating takes place in late fall or early winter, with subsequent larval extrusion occurring in late winter or early spring.

In this analysis, the proportion of mature adults at age was calculated as a logistic function:

$$PM_a = \frac{1}{1+e^{-(\rho a-\beta)}}$$

where PM_a is the proportion mature at age and the parameters, ρ and β were set at 1 and 7, respectively. This relationship was approximated from data in Chikuni's (1975) findings which indicated that approximately 50% of the population is mature at about 29 cm, or around age seven, and no fish less than 32 cm or about nine years old were found to be immature. This maturity schedule was based on information on maturity at size.

This analysis assumes that mature biomass is proportional to total fecundity. Ianelli and Ito (1991) found that, for mature fish, this assumption is supported by the near linear relationship between fecundity and body weight. Leaman (1987) evaluated different indices of reproductive value and suggested alternative measures that are more sensitive to the reproductive potential of the population than mature biomass. Chikuni (1975) reviewed studies on fecundity at size and age and found significant differences between different areas. For this analysis we do not consider geographic differences.

In this analysis a 1:1 relationship between numbers of males and females was assumed (Ianelli and Ito 1991). In some species of rockfish (e.g. the yellowtail, *S. flavidus*) females have been shown to die off at a faster rate with age (Tagart 1991). Possible differential mortality by sex over age was examined. Data from NMFS surveys from 1984-1990 stratified by 25-year age groups did not show a trend in the proportion of males and females :

Age Group	Male	Female	N
1-25	55.15%	44.85%	18,182
26-50	45.08%	54.92%	1,972
51-75	53.26%	46.74%	552
76+	75.00%	25.00%	8

2.2. Pacific ocean perch Fishery

2.2.1. Rockfish Management

At least 30 rockfish species of the genus *Sebastes* inhabit waters of the GOA (Eschmeyer et al. 1983), and many are commercially valuable. Since 1988, the Council has divided these species into three general assemblages based on their habitat and distribution in the GOA: demersal shelf rockfish (DSR), pelagic shelf rockfish, and slope rockfish.

Slope rockfish are defined as those species of *Sebastes* that, as adults, inhabit waters of the outer continental shelf and continental slope of the GOA, generally in depths greater than 150-200 m. In contrast, shelf rockfish inhabit shallower, more inshore waters of the shelf. Based on these criteria, 20 species of rockfish are classified into the slope rockfish assemblage (Heifetz and Clausen 1992). The assemblage is dominated by POP which has historically been the most abundant rockfish in this region and has provided most of the past commercial catch.

The slope assemblage in the GOA is divided into four management subgroups: POP, shortraker/rougheye rockfish, northern rockfish, and all other species of slope rockfish. These subgroups were established to protect POP, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most valuable commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual total allowable catch (TAC), whereas prior to 1991, a single TAC was assigned to the entire assemblage.

2.2.2. History

A POP trawl fishery by the U.S.S.R. and Japan began in the GOA in the early 1960s (Heifetz and Clausen 1992). This fishery developed rapidly, with intensive effort from the Soviet and Japanese fleets. Catches peaked in 1965, when an estimated 350,000 metric tons (mt) was caught. Subsequent to these estimated harvests, the fishery experienced a precipitous decline in catches by the late 1960s. Catches by the foreign fleet dominated the fishery from 1977 to 1984 with most of the harvest being taken by Japanese vessels (Carlson et al. 1986). During this period annual landings generally declined and by 1985, reached a minimum. The domestic fishery first became important in 1985, and expanded each year until 1991. This fishery has been composed almost entirely of factory-trawlers that process the fish at sea for export to Japan. Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; slope assemblage quotas increased from 3,702 mt in 1986 to 20,000 mt in 1989. In 1991 (the first year that management subgroups took effect), the Gulfwide TAC for POP was exceeded, and 2/3 of the TAC's for the shortraker/rougheye and "other slope rockfish" subgroups were taken. The under utilization of shortraker/rougheye in 1991 was apparently caused by bycatch closures of the fishery and did not reflect a lack of interest on the part of fishermen in catching these species. In 1992, the Gulfwide TAC for POP and shortraker/rougheye was exceeded.

2.2.3. Age Composition of the Catch

The estimated historical age composition of POP catch from Ianelli and Heifetz (1992) is dominated by strong year classes (Fig. 1). In terms of absolute numbers, the early fishery was comprised of relatively young individuals. This is contrary to the common perception that the early fishery harvested a large standing stock of older fish. Young individuals which were

abundant due to strong year classes in the 1950's and early 1960's were dominant in the catch. A similar pattern has been observed for the Aleutian Islands region and off the west coast of the continental U.S. (Ianelli and Ito, 1992, Ianelli et al. 1992).

2.2.4. Bycatch of Prohibited Species, Other Allocated Groundfish, and Marine Mammal Forage Species by POP

The bycatch rates of other species in the rockfish fishery was determined from NMFS observer reports for 1990-1992. Observed trawl hauls were designated as "rockfish hauls" based on the proportion of rockfish found in the tows. If the total catch of rockfish was greater than 30% by weight of the haul, then that haul was included for analysis of bycatch. Table 1 shows the percent by management group of rockfish, and associated bycatch rates of other allocated groundfish species and prohibited species found in these hauls.

Table 1. --- Estimated species composition and bycatch rates in rockfish hauls in the GOA by year. The values for allocated and prohibited species are in kilograms per metric ton of rockfish except for king crab, tanner crab, and salmon, which are given in numbers of individuals per ton of rockfish.

Rockfish:

Year	Pacific ocean perch	Short-Raker Rougheye Rockfish	Demersal Shelf Rockfish	Pelagic Shelf Rockfish	Other Slope Rockfish
1990	61%	25%	0%	4%	9%
1991	44%	10%	1%	6%	39%
1992	42%	10%	0%	8%	40%

Allocated Species:

Year	Pacific cod	Pollock	Sablefish	Flat Fish
1990	29	60	84	220
1991	35	51	39	245
1992	46	41	47	233

Prohibited Species

Year	Halibut	Tanner Crab	King Crab	Herring	Salmon
1990	41	0.147	0.129	0	0.184
1991	61	0.227	0.029	0	1.336
1992	44	0.334	0.034	0	0.277

The bycatch rates of marine mammal and seabird forage species were low in rockfish fisheries. Squid were caught at a rate of less than 4kg/mt of rockfish from 1990-1992 while octopus, Pacific sandlance, and smelt, were all under 1kg/mt rockfish for the same period.

2.3. Development of Alternative Policies

This section presents the analyses of optimal fishing rates and target biomass based on the available information for POP. First, background on how quotas are calculated depending on available information is provided. Then the key to evaluating stock productivity, namely the stock-recruitment relationship, is presented along with an explanation of why the method used for this analysis was selected. Finally, using the population dynamics model presented in Appendix A, the optimal fishing rate and target biomass are identified to develop alternative fishing policies. These alternative polices are then evaluated using a bio-economic simulation model, the results of which are presented in section 2.4.

2.3.1. BACKGROUND

The Plan Team for the GOA has guidelines for overfishing definitions depending on how much information is available about the particular groundfish species or management group. These guidelines are commonly presented as five levels, presented here in order of ascending information requirements[1] :

A) Biomass data not available:
ABC = average catch

B) Biomass and rudimentary demographic information available:
F = M

C) Biomass, somatic growth, fishing mortality, and natural mortality information available:
F = value for *exploitable* biomass-per-recruit which gives 35% of pristine level

D) Biomass, somatic growth, fecundity, maturity, fishing mortality, and natural mortality information available:
F = value for *spawning* biomass-per-recruit which gives 35% of pristine level

E) Biomass, **stock-recruit** relationship, somatic growth, fecundity, maturity, fishing mortality, and natural mortality information available:
$F = F_{msy}$ for biomass $> B_{msy}$
$F = F_{msy} * \text{biomass}/B_{msy}$ for biomass $< B_{msy}$

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[1] For an explanation of terms refer to the glossary in Appendix C.

In Heifetz and Ianelli's (1992) assessment, they felt that without conducting a more detailed analysis, the best policy was essentially a hybrid of those set out in guidelines D) and E) above. In this current analysis, the policy proposed in guideline E) is investigated more fully. In particular, the consequences of uncertainty in the stock-recruitment relationship were explored.

2.3.2. STOCK-RECRUITMENT RELATIONSHIPS

The stock-recruitment relationship describes the influence of the current biomass level on recruitment, and consequently, future biomass levels. The nature of this relationship is critical in analyses on stock productivity. Preliminary investigations on the generation of recruitment levels in simulations for policy analysis indicated that incorporating recruitment uncertainty influenced the results (Heifetz et al. 1992). Therefore, a range of hypotheses on the true form of the stock-recruitment relationship was needed. This process involved using the uncertainty in results from the assessment to make future projections under different fishing policies, and to establish optimal or risk-averse fishing rates.

It can be argued that the data on the stock-recruitment relationship for POP are exceptionally good. Ideally, data to best describe the stock-recruitment relationship should be available over a broad range of stock sizes at different times. The data for POP are unusual for the North Pacific in that an order of magnitude change in spawner biomass has been observed during the period 1961-1992. This gives us a relatively high level contrast for estimating the critical parameters of the stock-recruitment relationship.

All stock-recruitment analyses have potential problems. For example, in typical stock-recruitment analyses it is implicitly assumed that the relationship is *stationary*. This assumption of stationarity means that the underlying relationship does not change over time (Hilborn and Walters 1992). As the spawning biomass for POP increases in the future, we expect recruitment strengths to be similar to what was observed in the past at those same spawning biomass levels. The assumption of stationarity in this analysis, however, may be questionable. The GOA POP data on stock-recruitment show a downward trend over time for both spawner biomass and absolute recruitment level. With the data available, it is not possible to assess the stationarity of the stock-recruitment relationship.

There are two parameters of the stock recruitment relationship. These are the virgin biomass (B_0) and a measure of steepness (A). The most important parameter for the purposes of this analysis is steepness. If a low value of steepness is assumed then recruitment is proportional to total egg production and there is no density-dependent mortality response. If steepness is equal to 1, then recruitment is constant over most of the range of possible spawning stock sizes and there is very strong density-dependent mortality response. The relative fit of the stock-recruitment model to the data using fixed A parameter values can provide approximate probability values which can be

applied to the simulation runs (which are also performed with fixed A values) to obtain the expected value of a particular outcome. Outcomes are presented in terms of yield, biomass, and risk. The details of the simulation and the assignment of probabilities to different hypotheses are given in Appendix A.

Clark (1991) investigated optimal exploitation rates over a range of biologically reasonable models with different natural mortality, growth rate, and mean stock-recruitment relationship combinations. In this section we present a similar analysis for a single species, POP, with some important modifications. Clark's (op. cit.) work uses a family of plausible stock-recruitment relationships as average curves and ignores recruitment variability. As demonstrated below and pointed out by Hilborn and Walters (1992), the variability about the average stock-recruitment relationship is more important than the average recruitment levels for policy analysis. For example, the estimated recruitment coefficient of variation (CV)[2] about the mean level for GOA POP is 1.08 (log scale). Simulations carried out for fishing mortality rates from 0 to 0.25 for CV's of 1.4, 1.08, and 0.35 show that the absolute yield is considerably higher for the high CV and that the optimum fishing mortality also changes (Fig. 2). This implies that the range of the underlying *average* stock-recruitment curve can have shapes that are considerably "less productive" than previously considered. That is, without considering the recruitment variability, a stock-recruitment curve with low density-dependent mortality has little surplus production available to support a fishery. By taking into account the high magnitude of variability in recruitment, however, the overall productivity of the stock increases. The point here is that, stock-recruitment relationships with low density-dependent mortality values may be plausible, even though analyses that do not consider recruitment variability would suggest otherwise.

2.3.3. Evaluation of an Optimal Fishing Mortality Rate

A specific request made by the Plan Team and SSC during presentations of the POP assessment for the 1993 fishery was that future assessments evaluate the fishing mortality rate best suited to the life history of this species. Specifically, they wished to determine if the $F_{35\%}$ rate, which has been used as a default value in recent years, is in fact appropriate for POP and other rockfish species. In this part of the analysis, exploitation rates are investigated only in terms of yield; economic considerations are presented in the projection analysis. This analysis is based only on POP because information in sufficient quantity was not available for other rockfish. Note that this analysis involves a rate, and thus does not depend on current, estimated biomass levels.

Using the posterior probability distribution presented in the appendix, extreme values for the stock recruitment steepness (the A parameter) were obtained by choosing the values which

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[2] The coefficient of variation is defined as the standard deviation divided by the mean value.

included 90% of the probability. This resulted in A values of 0.43 and 0.90, respectively. To evaluate the appropriate fishing mortality rate, yield curves were examined for models using these stock-recruitment parameter values, and for several intermediate values to compute the expected value of the yield curve. The high and low values of A were used for evaluating the maxi-min yield (Clark 1991) and the expected value of the yield curve. The maxi-min yield was defined by Clark (op. cit.) as that which maximizes the minimum yield over a range of plausible stock-recruitment relationships. The full-selection fishing mortality rate which provides this yield is denoted F_{mmy}.

Yield was computed in both biomass and monetary value so that the possible effect of different population age structure/price differential could be taken into account. Figure 3 shows the relative dollar yield and relative yield in weight under alternative values for the stock-recruitment parameter (A). The expected value (EV) of the relative yield is the weighted average of the alternatives. Results from this exercise show that the F_{mmy} for the monetary yield is slightly below a full-selection fishing mortality rate of 0.08, and the F_{mmy} for the yield in weight is slightly higher than F=0.08. Given the estimate of current fishery selectivity, a refined appropriate F level of 0.08 was chosen as the best rate. Note that if this fishing mortality rate is not exactly optimal, i.e., F_{msy} is lower or higher, but within the bounds specified, then at least 90% of MSY will still be attained. Also, F=0.08 is close to the optimum suggested by the expected value of the yield curve. Compared to the commonly used $F_{35\%}$ rate, the value of F=0.08 corresponds to the fishing mortality that would reduce the spawning biomass per recruit to 43.8% of its pristine level. Using the notation analogous to that for $F_{35\%}$(=0.114), gives $F_{43.8\%}$=0.08.

Plotted together, the expected yield curve attributed to weight alone and the yield due to dollar value show a slight difference (Fig. 4). This indicates that there is a monetary advantage to fishing at a slightly lower rate to increase the value of the harvest because the lower harvest rate will result in a slightly larger size composition in the catch.

2.3.4. TARGET BIOMASS

Target biomass was refined by monitoring the yield and spawner biomass as fishing increased. This essentially was used to set the new B_{target} equal to B_{msy}. The expected value of the relative yield plotted against spawner biomass indicates that the maximum yield is attained when the female spawning biomass is about 150,000 tons (Fig. 5). This is larger than the target currently used in adjusting the ABC (B_{target}= (35% of B_{1960})=118,000 tons. Low stock-recruitment steepness parameter values (A) shift the maximum yield to higher fractions of pristine spawner biomass (Fig. 6).

2.3.5. INTERMEDIATE POLICY

For contrast, an intermediate policy set at a rate half-way between the bycatch only policy (Alternative Policy 4) and the refined F policy (Alternative Policy 2) was considered. This resulted in a full selection fishing mortality rate of 0.05. This rate was adjusted by the ratio of current spawner biomass to a target spawner biomass of 150,000 tons as was used in the other policies.

2.4. Alternative Policy Analysis

2.4.1. PERFORMANCE CRITERIA

The performance criteria needs to be defined and should adequately reflect the multiple objectives of the policy decision process. The following sections describe and report on the results for different attributes in the rebuilding analysis. Decision tables are presented in each of the sections, and a brief description of the tables is provided.

The approach used in this document is based on risk analysis. Risk analysis typically refers to the probabilistic analysis of expected outcomes of alternative decisions in the face of uncertainty. In this study, a Bayesian decision analysis is performed. The format of a decision table is presented below.

—Example decision table—

	Possible Characteristics of the Stock			**Expected Value over all possible realities (EV)**
	Lower Productivity	Med. Productivity	Higher Productivity	
Probability of possibilities:	0.25	0.50	0.25	
Alternative Policy 1	low	mod-low	mod	mod-low
Alternative Policy 2	mod	mod-high	high	mod-high
Alternative Policy 3	low	mod	high	mod
Alternative Policy 4	low	low	low	low

—Example—

There are five parts to this table:

1) the possible states of nature (possible characteristics of the stock);

2) the probability of the stock characteristics, typically determined from an actual stock assessment;

3) the alternative policy actions;

4) the outcomes (indicated by shaded cells), these are typically values of specific interest, e.g. yield or level of spawner biomass, and

5) the expected value of a particular policy.

This approach differs from traditional assessments in many important ways. First, the uncertainty is specified by having multiple columns to evaluate. In traditional analysis, a single column would typically be presented. This allows for a more thorough presentation of the trade-offs. Decision makers should not feel compelled to select the policy that gives the highest expected value for an attribute as a rule. It is rarely the case that a single attribute is desired. The users of these tables are advised to look for dominant policies across the multiple objectives. That is, a good policy might be one that is good under all possible stock characteristics. Policy 2 in the above table is an example of a dominant policy. Also, policies that are robust to different objectives may be appropriate. In these policies, the outcome may not be high for all different indicators but the risk may be within acceptable limits agreed upon by the decision makers.

2.4.1.1. Yield

Yield in this analysis is reported two ways, in terms of absolute biomass and in terms of dollar value. In both cases yield refers to either the weight or value of the harvest based on the various policy alternatives. In other words, quotas or Total Allowable Catches (TAC) are assumed to equal ABCs and equal actual harvest. If, in the future, the Council continues to set TACs lower than ABCs, the projections presented in this analysis will underestimate both stock rebuilding and economic impacts.

Biomass Yield

The yield in biomass is computed as the gross numbers of fish caught at each age multiplied by the mean age-specific whole weights. Table 2 and Fig. 7 show the trajectory of the mean expected value of yield for the four policy alternatives. The average yield in weight of the simulations increases over time for all policies. Alternative policy 1 starts with a yield or harvest of 4,734 mt and increases to about 19,500 mt in 30 years. Policy alternative 2 starts with a lower yield of 3,378 mt and increases to about 17,800 mt in 30 years. Both alternative polices 3 and 4 begin with lower yields (about 2,100 mt in 1993). Policy alternative 3 allows for higher harvests than alternative 4 for the first fifteen years of the rebuilding plan. Once the target biomass is reached in policy alternative 4, the fishing mortality rate is increased from 0.023 to 0.08 and harvests under alternative 4 increase. By the end of the 30 year period, alternatives 3 and 4 result in similar harvest levels. Over the entire time trajectory, the average expected annual yield is over 10,000 tons for all policies (Table 3).

Table 2. --- Trajectory of mean expected value of yield (metric tons) for different policy alternatives.

Year	Policy 1	Policy 2	Policy 3	Policy 4
1993	4,734	3,378	2,107	2,100
1994	5,553	4,057	2,563	2,347
1995	6,365	4,762	3,068	2,706
1996	7,153	5,470	3,589	3,094
1997	7,906	6,140	4,164	3,531
1998	8,602	6,765	4,734	4,034
1999	9,237	7,335	5,282	4,379
2000	9,796	7,866	5,860	4,921
2001	10,305	8,359	6,517	5,287
2002	10,779	8,825	7,048	6,133
2003	11,230	9,281	7,629	6,865
2004	11,692	9,727	8,258	7,631
2005	12,161	10,174	8,823	8,318
2006	12,648	10,647	9,470	8,867
2007	13,132	11,130	10,069	9,622
2008	13,611	11,622	10,711	10,220
2009	14,128	12,134	11,313	11,292
2010	14,683	12,643	11,991	12,019
2011	15,220	13,149	12,674	12,649
2012	15,758	13,647	13,399	13,951
2013	16,294	14,142	14,168	14,704
2014	16,795	14,627	14,833	15,175
2015	17,246	15,090	15,439	15,896
2016	17,662	15,524	16,087	16,534
2017	18,021	15,941	16,555	16,974
2018	18,332	16,337	17,025	17,781
2019	18,613	16,679	17,587	18,199
2020	18,871	16,997	17,968	18,413
2021	19,089	17,279	18,486	18,667
2022	19,297	17,541	18,855	19,157
2023	19,489	17,803	19,209	19,653
Total	414,403	355,073	335,484	331,123

Table 3. --- Average annual yield (round weight tons) over the next 30 years. A = the value of the stock-recruitment parameter which governs productivity, P{A} is the estimated probability associated with that value of parameter A, and EV represents the expected value computed as the weighted mean over the different values of the A parameter.

	A=0.43	A=0.67	A=0.90	EV
P{A}	0.13	0.71	0.16	
Policy 1	7,939	12,953	19,932	13,368
Policy 2	6,979	11,155	16,669	11,454
Policy 3	6,090	10,634	15,757	10,822
Policy 4	5,124	10,547	16,084	10,681

Economic Yield

Yield in dollar value is calculated by applying estimated 1992 wholesale prices for POP to the mean expected value of yield presented above. This information is summarized in Table 4 and shown in Figure 8. In recent years, prices for POP have varied by size of fish with higher prices associated with larger fish. Table 5 shows the three price categories based on the FOB Alaska wholesale value of frozen at sea, headed-and-gutted POP sold in Japan. This analysis assumes a constant set of prices over the 30 year rebuilding period. Although this is an assumption that is unlikely to hold, it is the least arbitrary choice of assumptions in the absence of a model to predict future price changes in response to changing harvest and market conditions.

Each policy alternative for rebuilding rockfish results in a different set of projected annual harvest levels and, therefore, a different stream of income to industry participants. Policy alternatives 3 and 4 forego harvest in early years to achieve the target biomass sooner and to increase future harvest levels. Analysis of the economic tradeoffs associated with these alternatives require calculation of the present value of the various income streams. Comparing present values acknowledges that the sooner income is earned the sooner it can be reinvested. From the perspective of the industry members who harvest and sell POP and then reinvest that income, there is a higher value to harvests that occur sooner rather than later.

For each policy alternative, the present value of estimated gross revenues from the POP fishery was calculated using the formula:

$$V_i = \frac{V_t}{(1+d)^i}$$

where V_i is the first gross wholesale value of the fish i years in the future, V_t is the value of a commodity today, and d is the discount rate. These are values of estimated gross revenues and are not net of the operating costs associated with POP harvests. The discount rate measures the value of earnings from POP over time. A 7 percent discount rate is mandated by the Office of Management and Budget (OMB) for analysis of federal government project. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years (OMB, 1992). In addition, discount rates of 0 percent (undiscounted), 5 percent, and 9 percent were examined to provide a range of potential net present values. Constant dollars, unadjusted for inflation, were used in all cases.

Table 4. --- Trajectory of mean expected value of dollar yield (millions) for different policy alternatives.

Year	Policy 1	Policy 2	Policy 3	Policy 4
1993	$5.3	$3.8	$2.4	$2.3
1994	$6.1	$4.5	$2.8	$2.6
1995	$7.2	$5.4	$3.5	$3.1
1996	$8.0	$6.1	$4.0	$3.5
1997	$8.9	$6.9	$4.7	$4.0
1998	$9.7	$7.7	$5.4	$4.6
1999	$10.6	$8.4	$6.1	$5.0
2000	$11.3	$9.1	$6.8	$5.7
2001	$11.9	$9.7	$7.5	$6.1
2002	$12.4	$10.2	$8.2	$7.1
2003	$12.9	$10.8	$8.9	$7.9
2004	$13.4	$11.3	$9.6	$8.8
2005	$13.9	$11.8	$10.2	$9.6
2006	$14.5	$12.3	$10.9	$10.3
2007	$15.1	$12.8	$11.6	$11.1
2008	$15.6	$13.4	$12.3	$11.8
2009	$16.2	$14.0	$13.1	$13.0
2010	$16.8	$14.6	$13.9	$13.9
2011	$17.4	$15.1	$14.7	$14.6
2012	$18.0	$15.7	$15.5	$16.1
2013	$18.6	$16.3	$16.4	$16.9
2014	$19.2	$16.9	$17.2	$17.5
2015	$19.7	$17.5	$17.8	$18.3
2016	$20.2	$18.0	$18.6	$19.0
2017	$20.6	$18.4	$19.2	$19.6
2018	$21.0	$18.9	$19.7	$20.6
2019	$21.4	$19.3	$20.4	$21.2
2020	$21.7	$19.7	$20.8	$21.5
2021	$22.0	$20.0	$21.4	$21.7
2022	$22.2	$20.3	$21.8	$22.3
2023	$22.4	$20.7	$22.3	$22.8

Table 5. --- Estimated dressed value per pound by weight category for Pacific ocean perch. The conversion to round weight used in this analysis was 0.55.

Weight	Value/lb
<0.5 kg	$0.75
0.5-0.8 kg	$0.85
>0.8 kg	$1.05

Source: NMFS Alaska Region, Juneau, AK.

Discounting affects rebuilding strategies in predictable ways. If catch is foregone for a number of years in order to increase average catch in the future, even moderate discount rates will demand a high return in future catches in order to realize the same value from the fishery. POP is a slow growing species so rebuilding occurs at a slow rate. Given the choice between four policies that all offer the possibility of rebuilding POP, economic analysis that considers only the value of POP to harvesters and processors, indicate a lower present value of policy alternatives that result in foregone catch in the near-term.

Table 6 presents a decision table on the present value of the fishery over the next 30 years. This table allows comparison of the present value of the four policy alternatives under various assumptions about stock-recruitment steepness (the A parameter).

The present value is highest for high values of stock-recruitment and the differences are magnified when a higher discount rate is used. This is because the benefit of increased future yield is offset by higher discounting factors. For example, with the positive discount rates examined, the present value of future annual yields reaches a maximum and then declines for all policies (Fig. 9). The expected cumulative present value of the policies indicate that higher exploitation rates produce greater economic yield from the POP resource (Fig. 10).

Table 7 summarizes the comparison of present values for the expected value of the stock-recruitment parameter using four discount factors. Potential economic tradeoffs between the various alternative policies can be illustrated by subtracting the present value of any alternative policy from the status quo. For example, if alternative policy 1 is considered the status quo and a 7 percent discount factor is used, alternative 2 results in a $27 million difference in present value ($165 million - $138 million), alternative 3 results in a $44 million difference in present value, and alternative 4 results in a $51 million difference in present value. However, if alternative 2 is considered status quo, then alternative 3 results in a $17 million difference in present value ($138 million - $121 million) and alternative 4 results in a $24 million difference in present value.

These differences in present value do not reflect the change (loss) in net national benefits as a result of the alternative policies. The values presented here are for estimated gross revenues only. Net benefits from the alternatives would consider changes in net revenues including information about both operating costs in the POP fishery and the potential for making up lost income in other fisheries.

The observed recruitment variability affects our ability to make economic projections. Figure 11 shows the distribution of simulated outcomes under with and without discounted. Clearly, this indicates that the economic outcome of any policy has a broad distribution of possibilities. This distribution is based solely on the biological component of the model and does not account for uncertainties in future economic conditions.

Table 6. --- Present first gross wholesale value (millions) of the Pacific ocean perch fishery 30 years into the future. A = the value of the stock-recruitment parameter which governs productivity, P{A} is the estimated probability associated with that value of parameter A, and EV represents the expected value computed as the weighted mean over the different values of the A parameter. A discount rate of 7% was applied.

	A=0.43	A=0.67	A=0.90	EV
P{A}	0.13	0.71	0.16	
Policy 1	$108	$158	$251	$165
Policy 2	$88	$132	$202	$138
Policy 3	$70	$116	$180	$121
Policy 4	$61	$110	$182	$114

Table 7. --- Comparison of present value of estimated gross revenues (millions) from POP harvests for 30 years under four policy alternatives, the expected value of stock-recruitment steepness parameter (EV), and four discount rates.

	Discount Rate			
	0%	5%	7%	9%
Policy 1	$473	$213	$165	$132
Policy 2	$410	$180	$138	$108
Policy 3	$388	$160	$121	$92
Policy 4	$383	$156	$114	$85

2.4.1.2. Biomass

Biomass as reported here is simply the mature portion of the female POP stock. Over time, policies 2-4 show similar mean rebuilding patterns over alternative hypothesis on the stock-recruitment steepness (the A parameter; Fig. 12). Policy 1 shows an expected doubling of the current spawner biomass in about 30 years whereas policies 2, 3, and 4 indicate doubling in about 20, 15, and 13 years, respectively (Fig. 13). Over this time trajectory, the expected mean spawner biomass increases with stock-recruitment steepness levels and decreases with increasing exploitation (Table 8). In projecting consequences of specific policies, there is a large degree of uncertainty due to the level of recruitment variability. For example, the distribution of possible outcomes of spawning biomass 20 years from now has a range of over 150,000 tons (Fig. 14).

Table 8. --- Mean spawner biomass over the next thirty years.

Probability	A=0.43 0.13	A=0.67 0.71	A=0.90 0.16	EV
Policy 1	103,399	120,771	127,603	119,498
Policy 2	115,362	136,517	142,269	134,566
Policy 3	126,784	146,236	148,155	143,916
Policy 4	129,821	149,754	152,385	147,480

2.4.1.3. Rebuilding rate

Clearly, the fastest rebuilding rate will occur under the policy with the lowest fishing mortality rate. Factors that influence rebuilding include the total mortality rate, individual growth, and, most importantly, recruitment. Because natural mortality for POP is thought to be very low, the population can grow much faster through large recruitment than it can decline through natural mortality, provided fishing mortality is not too high.

At the January 1993 council meeting the Advisory Panel (AP) specifically requested that policy performance be judged in part by: "a 75 percent probability of rebuilding success". In this analysis, rebuilding success was assumed to be the achievement of the target biomass and percent probability was taken as the proportion of simulation runs. The proportion of simulations that had attained a spawner biomass of 150,000 tons or greater over time was highest for the policies with the lowest exploitation rates (Fig. 15). The expected time to reach the target biomass by proportion of simulations are presented in Table 9. The relatively low probability of rebuilding for all policies reflects the large amount of unpredictability in recruitment strengths and subsequent future biomass levels. Also, the distribution of spawner biomass levels over 200 simulations at 20 years in the future shows a wide range of possible stock conditions and is skewed (e.g., Fig. 14).

Table 9. --- Time to attain 150,000 tons of spawner biomass under policies 1-4 as measured by proportions of simulations. For illustration, the highlighted box says that under alternative 2, 50% of the simulations (the *median* value) had attained the target biomass (150,000 tons) in 26 yrs.

	25%	50%	75%
Alternative 1	21 yrs	>30 yrs	>30 yrs
Alternative 2	16 yrs	26 yrs	>30 yrs
Alternative 3	13 yrs	19 yrs	28 yrs
Alternative 4	11 yrs	16 yrs	25 yrs

2.4.1.4. Risk

One type of risk was recorded as the proportion of simulation runs in which the biomass dropped below 75,000 tons of female spawners. This level was selected for two reasons, it is close to the current estimate of female spawner biomass and it represents 50% of the target level. Simulation results using low values for stock-recruitment steepness performed poorly and indicated a higher level of risk for all policies (Fig. 16). The expected value across all hypotheses of stock-recruitment steepness indicates in 10 years, there is about a 15% chance of being below 75,000 tons of spawner biomass under policy 1, while for policy 2 the risk is about 10% (Table 11). For policies 3 and 4, the risk is around 5% (Fig. 17).

For balance, risk can also be framed in terms of lost revenue. This was assessed as the chance that the future, undiscounted revenues drop below the current, expected revenue under the policy alternative 2. With the expected 1993 revenue under policy 2 estimated at $3.8 million, the expected risk of falling below this level was high for policies with the lower exploitation rates (Fig. 18). In 10 years, the expected value of risk was about 70%, 28%, 10%, and 5% for policies 4, 3, 2, and 1, respectively (Table 11).

Table 10. - Proportion of runs which had female spawner biomass levels less than 75,000 tons in the year 2003 (10 years from now).

	A=0.43	A=0.67	A=0.90	EV
Probability	0.13	0.71	0.16	
Policy 1	41.5%	11.0%	0.5%	13.2%
Policy 2	36.5%	7.0%	0.5%	9.7%
Policy 3	15.0%	2.0%	0.0%	3.3%
Policy 4	19.0%	3.5%	0.0%	4.9%

Table 11. - Proportion of runs which yielded less than $3.8 million (gross revenue) in the year 2003 (10 years from now). This risk level was based on the expected gross revenue under policy 2 for 1993.

	A=0.43	A=0.67	A=0.90	EV
Probability	0.13	0.71	0.16	
Policy 1	0.5%	0.0%	0.0%	0.1%
Policy 2	7.0%	0.5%	0.0%	1.2%
Policy 3	23.5%	2.5%	0.0%	4.7%
Policy 4	54.5%	16.0%	1.5%	18.6%

2.5. Marine Mammals

There are many cetacean species that occur in Alaskan waters and have the potential for interaction with groundfish fisheries in the GOA. Four species are listed as endangered under the

Endangered Species Act (ESA) [fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), humpback whale (*Megaptera novaeangliae*), and sperm whale (*Physeter macrocephalus*)] while the others are small- to medium-sized cetaceans that currently are not listed under the ESA [minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*, and the beaked whales (e.g. *Berardius bairdii* and *Mesoplodon* spp.)].

There are also at least three pinniped species as well as the sea otter (*Enhydra lutris*) that occur in the GOA and have the potential for interaction with groundfish fisheries. The three pinniped species [Steller sea lions (*Eumetopias jubatus*), northern fur seals (*Callorhinus ursinus*), Pacific harbor seals (*Phoca vitulina*)] have each experienced declines in their population sizes over the last 30 years. The Steller sea lion was listed as threatened under the ESA in 1990. Additional discussion about marine mammal life history, predator-prey relationships, and interactions with the groundfish fishery can be found in an EA prepared for the 1993 Groundfish Total Allowable Catch Specifications (NMFS 1993).

2.6. Pacific salmon listed under the Endangered Species Act

Five species of Pacific salmon occur off Alaska and might occur as incidental bycatch in groundfish fisheries: chinook salmon, *Oncorhynchus tschawytscha*; coho salmon, *O. kisutch*; sockeye salmon, *O. nerka*; chum salmon *O. keta*; and pink salmon *O. gorbuscha*. Of these species, several populations have been listed or are being considered for listing under the ESA. Snake River sockeye were listed as endangered (November 20, 1991), and Snake River spring/summer and fall chinook are were listed as threatened on June 27, 1991 and April 22, 1992, respectively. A fourth species, winter-run chinook from the Sacramento River, was listed as threatened on November 5, 1990 and has been proposed to be listed as endangered (June 19, 1992), but are almost unknown in Alaskan waters.

Although listed wild fish are not marked or directly identifiable, tagged hatchery fish from nearby locations have been used as indicators of the distribution of listed species. Coded wire tag (CWT) recovery data from observed groundfish fisheries suggests that the ocean distribution of these fish may extend into the GOA. Since 1981, no indicator CWT Sacramento River chinook or Snake River sockeye and only one indicator CWT Snake River chinook salmon has been recovered in the GOA groundfish fisheries.

2.7. Seabirds

Many seabirds occur in Alaskan waters and have the potential for interaction with groundfish fisheries in the GOA. The most numerous seabirds in Alaska are northern fulmars, storm petrels, kittiwakes, murres, auklets, and puffins. These groups, and others, represent 38 species of seabirds that breed in Alaska. Eight species of Alaska seabirds breed only in Alaska and in Siberia. Populations of five other species are concentrated in Alaska but range throughout the North Pacific region. Marine waters off Alaska provide critical feeding grounds for these species as well as others that do not breed in Alaska but migrate to Alaska during summer, and for other species that breed in Canada or Eurasia and overwinter in Alaska. Additional discussion about seabird life history, predator-prey relationships, and interactions with the groundfish fishery can be found in an EA prepared for the 1993 Groundfish Total Allowable Catch Specifications (NMFS 1993).

The following summarizes the status of seabirds currently listed, proposed to be listed, or which are candidates for listing, under the ESA:

Status	Category	Species
Listed	Endangered	Short-tailed albatross (*Diomedea albatrus*)
Proposed (5/92)	Threatened	Spectacled Eider (*Somateria fischeri*)
Candidate	Category 1	Steller's eider (*Polysticta stelleri*)
Candidate	Category 2	Marbeled murrelet (*Brachyramphus marmoratus*)
1993 Candidate	Category 2	Red-legged kittiwake (*Rissa brevirostris*)
1993 Candidate	Category 2	Kittlitz's murrelet (*Brachyramphus brevirostris*)

2.8. Possible Impacts on the Environment

2.8.1. Impacts on the Physical Environment

Under each alternative, physical impacts are those that would be caused by (1) trawl activity disturbing the seabed and associated benthic animals and plants, and (2) deposition of fish wastes from processing activities and discards. Disturbance of the benthos by trawls and fish wastes can alter the abundance and composition of the affected benthic community. The extent of change in the seafloor community and time to recovery will be directly influenced by the frequency and severity of disturbance events. Changes in the benthic community may affect food availability for bottom feeding species and recycling of nutrients. Presently, the actual effects, if any, of trawling and fish waste disposal on the benthic environment of the GOA are unknown. The impact of

trawl fishing on the physical environment in the policies evaluated here do not introduce consequences that have not previously been considered.

2.8.2. Impacts on the Biological Environment

2.8.2.1. Impact on the Pacific Ocean Perch Resource

Under policy alternative 1 (status quo), the stock is expected to rebuild to the target biomass of 150,000 tons in about 26 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is 5%.

Policy alternative 2 results in the expectation that the stock would rebuild to the target biomass of 150,000 tons in about 18 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is 1%.

Under policy alternative 3 the stock is expected to rebuild to the target biomass of 150,000 tons in about 14 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is less than 1%.

The impact of adopting policy alternative 4 is very similar to policy 3. The stock is expected to rebuild to the target biomass of 150,000 tons in about 14 years. The level of risk that the spawning stock in 20 years is less than 75,000 tons is less than 1%.

The mean age of the population increases under all policy alternatives with policies 3 and 4 having the highest expected mean age of the population after 30 years (Fig. 19). The increase in mean age should improve the general biological condition of the stock because a larger number of age groups are available for reproductive contributions. This effect is implicitly taken into account by the type of stock-recruitment relationship that was used in this analysis.

Growth rates appear to be highly variable for POP, as with most other marine fish. Density dependent effects on growth may influence the dynamics investigated here, however, the available data were not sufficient to warrant further consideration.

2.8.2.2. Impacts on Marine Mammals

The interaction between adult POP and marine mammals are thought to be small. POP have occurred rarely in the diet of northern fur seals and northern sea lions (Perez 1990). Yang (1993) indicates that the primary food item for POP in the GOA is the euphausid *Thysanoessa inermis.* This prey species is also important for baleen whales. It is conceivable that if the stocks of POP increases they could compete for the same prey species as some marine mammals. Given the

magnitude of the euphausid abundance and the lack of significant spatial overlap in habitat between POP and baleen whales, this prospect is considered very unlikely.

2.8.2.3. Impact on Bycatch of Prohibited Species, Other Allocated Groundfish and Marine Mammal and Seabird Forage Species

The consequence of the alternatives considered here are not likely to result in direct increases in the bycatch of prohibited species or other allocated groundfish. Restricting the harvestable amounts of POP may result in a re-direction of effort to other fisheries such as flatfish which may experience higher bycatches of prohibited species such as Pacific halibut. The little data available on bycatch of forage species by the POP fishery suggest that the policy alternatives considered here should not significantly impact the availability of forage species.

2.8.3. Impacts on Pacific Salmon Listed under the Endangered Species Act

Sacramento River winter-run chinook salmon and Snake River sockeye salmon, fall chinook and spring/summer chinook salmon are listed as threatened or endangered under the ESA. An informal consultation pursuant to Section 7 of the ESA completed on February 20, 1992 for the FMP concluded that listed and proposed species of salmon are not likely to be adversely affected by groundfish fisheries conducted under the FMP. Consultation for 1993 groundfish TAC's has been initiated.

Proposed Amendment 32 develops a rebuilding plan for POP in the GOA. All alternatives considered involve less fishing effort for POP than the status quo (alternative 1). This proposed action, therefore, is not anticipated to impact listed salmonids in a manner or to an extent not previously considered, and could be beneficial by decreasing the possibility of salmonid mortality in GOA groundfish fisheries.

2.8.4. Impacts on Seabirds

The GOA provides breeding and forage sites for a large number of piscivorous marine birds, including northern fulmars, storm petrels, kittiwakes, terns, murres, murrelets, auklets, puffins, albatrosses, cormorants, jaegers, gulls and guillemots. Fishing interactions include direct effects of entanglements or collisions with fishing gear, or through competition for fish prey; and indirect mortality from encounters with marine debris or pollution, and disruption of the ecosystem from habitat degradation.

An assessment of impacts of groundfish fisheries on colonial and pelagic seabirds and migratory birds was prepared as part of the Final Environmental Assessment for 1993 Groundfish TAC Specifications for the BSAI and the GOA. The EA is incorporated by reference, as is the 1993 informal consultation with the U.S. Fish and Wildlife Service (USFWS) on the 1993 TAC specifications, and a 1989 biological opinion prepared by the USFWS on the effects of the Interim Incidental Take Exemption Program on seabird species listed as endangered or threatened under the ESA. These documents list the endangered, threatened, proposed and candidate species that may be found within the regions of the GOA where the groundfish fisheries operate and the potential impacts of the groundfish fisheries on these species. The informal consultation on the 1993 TAC specifications concludes that (1) groundfish operations are likely to result in an unquantified level of mortality to short-tailed albatrosses, a listed species, (2) an anticipated annual incidental take of up to two individual birds will not jeopardize the existence of this species, and (3) the allowable incidental take does not constitute a "significant impact on the human environment" under NEPA. The USFWS states that this recent opinion does not contradict earlier biological opinions and informal section 7 consultations.

While little is known of the details of the feeding ecology of many marine birds, most of those listed above eat squid and small forage fish (usually less than 20 cm in length), such as sandlance and juvenile capelin, herring, Pacific cod, and pollock. Rockfish (*Sebastes spp.*) have appeared in only incidental quantities of seabird diets (Vermeer et al. 1987; Degange and Sanger 1986). The sizes of fish consumed by marine birds are considerably smaller than fish that are vulnerable to trawl fishing gear. Consequently, the potential for direct competition for prey between the POP fishery and marine birds appears to be low in the GOA.

Since effects on prey availability for marine birds are probably small, the primary risk associated with trawl fishing is likely to be entanglement in gear, through encounters with discarded plastic debris, or from changes in the ecosystem brought about by degradation of habitat. Most entanglement with fishing gear is associated with gillnets and baited hooks on trolled or longline gear. It is estimated that between 96,000 and 250,000 marine birds were killed each year by the Japanese salmon drift gillnet fishery which operated in the vicinity of the western Aleutian Islands between 1952-88 (Byrd et al. 1992). Gillnets and troll gear are rarely used in groundfish fisheries, and trawl gear is much more predominant than is longline gear. Bottom trawls are much less likely to capture marine birds than gillnets, particularly at the depths >100m where POP are commonly caught.

Given these considerations, the rebuilding alternatives are not expected to result in additional impacts on seabirds that have not already been considered in the aforementioned documents. This determination has been submitted to the USFWS for review and concurrence.

3. REGULATORY IMPACT REVIEW - ECONOMIC ANALYSIS OF THE ALTERNATIVES

3.1. Economic History of the Pacific Ocean Perch Fishery in the Gulf of Alaska

3.1.1. LANDINGS AND PRICES

An overview of rockfish landings in the GOA is provided in Table 12. The management reporting category for POP has changed twice since 1986. Originally part of the POP complex, in 1988 POP was included in the slope rockfish category. Subsequently, in 1991, POP was segregated into its own, single species category.

More than 95% of the harvest of POP in the GOA during 1991 and 1992 was conducted by factory trawlers. When fish are processed offshore, they do not receive a price until products have been sold, generally in Asian markets. These prices are not reported on State of Alaska fish-tickets, as fish delivered to shoreside processing facilities would be. NMFS conducts an annual survey of processors as a means of gathering data on the volume and prices of processed products. While this information is not yet required by NMFS or provided by all processors, this survey represents the best available source of prices for fish that are processed at sea. The most recent fishing year for which survey results are available is 1991.

Table 13a shows the average survey prices for 1991 POP products, as well as those of a variety of other species that could be regarded as alternative fishing opportunities for offshore processors, whether as target species or as bycatch, in the GOA and Bering Sea and Aleutian Islands. Since the survey results for the 1992 fishery are not yet available, additional data were informally obtained by the LGL Alaska Research Associates from selected industry participants for 1992. Table 13b shows the results of this modification.

Table 12. - Domestic and joint-venture harvest (mt) of GOA rockfish, by management group, 1986-92.

	1986	1987	1988	1989	1990	1991	1992
POP Complex	2,981	4,981					
Slope Rockfish			13,779	19,002	21,114		
POP						6,137	5,980
Shortraker/Rougheye						1,351	2,148
Other Slope Rockfish						6,506	9,134
Thornyheads	862	1,944	2,786	3,080	1,646	1,200	1,271
Other Rockfish	4,106	5,665	2,352				
Demersal Shelf Rockfish			500	413	324	287	523
Pelagic Shelf Rockfish				1,738	1,647	2,342	3,416

Source: NPFMC GOA Groundfish Plan Team. "Stock Assessment and Fishery Evaluation Report for the 1992 GOA Groundfish Fishery." September 1992. Based primarily on PacFIN estimates of landed weight, 1986-88, and NMFS Weekly Production Reports, 1989-92. NMFS reports include discards

Table 13a. 1991 Prices for Selected Fishery Products Processed Offshore, as reported to NMFS, Trade and Industry Services.

	Bering Sea/Aleutian Islands			GOA		
Species Group	Whole	H & G	Fillet	Whole	H & G	Fillet
Pacific Ocean Perch	$.62	$.69	.	$.63	$.60	.
Sablefish	$2.13	$2.85	.	$2.58	$2.75	.
Atka Mackerel	$.60	$.94	.	$.53	$1.60	.
Pacific Cod	$.49	$.93	$1.72	$.44	$.80	$.96
Pollock	$.21	$.41	$1.07	$.07	$.30	$1.15
Dermersal Shelf Rockfish	.	.	.	$.96	$1.30	.
Shortraker/Rougheye	.	.	.	$.63	$1.41	$1.90
Slope Rockfish	.	.	.	$.70	$.69	.
Pelagic Shelf Rockfish	.	.	.	$.51	$.78	.
Other Rockfish	$.70	$1.93	.	.	.	.
Deep-water Flatfish	$.55	$1.91	.	$.71	$1.08	.
Shallow-water Flatfish	$.33	$1.15	.	$.41	$1.01	.
Arrowtooth Flounder	$.07	$.24	.	$.07	$.18	.

Source: NMFS, Trade and Industry Services, Northwest Region.

Table 13b. Modified prices for 1992, based on 1991 Prices for Selected Fishery Products Processed Offshore, as reported to NMFS, Trade and Industry Services and supplemental information provided by the industry.

	Bering Sea/Aleutians			Gulf of Alaska		
Species Group	Whole	H & G	Fillet	Whole	H & G	Fillet
Pacific Ocean Perch	$.62	$.95	.	.	$.95	.
Sablefish	$2.13	$2.80	.	$2.58	$2.80	$1.85
Atka Mackerel	$.80	$.70	.	$.53	$.70	.
Pacific Cod	$.45	$.80	$1.73	$.41	$.80	$1.41
Pollock	$.21	$.55	$1.13	$.07	$.55	$.82
Dermersal Shelf Rockfish	.	.	.	$.96	$2.50	.
Shortraker/Rougheye	.	.	.	$.63	$2.80	$1.90
Pelagic Shelf Rockfish	.	.	.	$.51	$.90	.
Slope Rockfish	.	.	.	$.70	$.85	.
Other Rockfish	$.70	$1.91	.	.	.	.
Deep-water Flatfish	$.55	$1.52	.	$.80	$1.10	.
Shallow-water Flatfish	$.25	$1.07	.	$.42	$1.23	.
Arrowtooth Flounder	$.07	$.52	.	$.07	$.55	.

Source: NMFS, Trade and Industry Services, Northwest Region, and LGL Alaska Research Associates

3.1.2. The Role of POP in Harvesting Activities of the Offshore Fleet

In order to evaluate the significance of POP harvest in the GOA to the offshore fleet, weekly report data from the 1991 and 1992 fisheries were examined. Using as a criterion, that POP constituted a plurality of catch among the Council-managed groundfish assemblages, a total of 12 factory trawlers had sufficient landings of POP during 1992 to have been considered targeting on POP during some weekly period, within one of the GOA management areas. During 1991, 17 vessels fell into this category. Throughout the following discussion, references to POP-target weeks apply exclusively to fishing in the GOA.

Because these vessels produce products from a variety of species, which may vary considerably in value, the relative importance of this target fishery cannot be assessed meaningfully on the basis of poundage produced. In order to convert amounts of products into dollar values, prices from the processed-products survey, referenced above, were used to calculate estimates of product values. The prices reported for the 1991 fishery are used to evaluate production in both 1991 and 1992. For purposes of comparison, the value of 1992 production was also evaluated using a combination of 1991 data and the informal 1992 data. While the data shown in Tables 13a and 13b are aggregated for the entire GOA, prices from the processed product survey include management area designations, and were applied accordingly in the analysis that follows.

In both years, the fleets which had at least one POP-target week exhibited a wide variety of financial dependence on POP and other species caught during POP-target weeks. A clear

delineation was observed between those vessels which received more than 6% of their total annual revenue from all species caught during POP-target weeks, and those which received less. In each year, 6 vessels fell into the "upper category", with 11 in the "lower group" in 1991 and 6 in 1992. It should be noted, however, that 3 of the upper 6 vessels from 1991 did not have a POP-target week in 1992. In 1991, the upper group accounted for nearly 70% of the POP-target weeks, and 78% of the POP retained during POP-target weeks. In 1992, the upper group recorded 75% of the POP-target weeks, and 85% of the POP retained in those weeks. Therefore only a few of the vessels participating in the POP fishery demonstrated significant financial dependence on that fishery. Additional information pertaining to species composition and revenue shares of factory trawler fishing activity in the GOA is provided in Appendix B.

Tables 14 and 15 provide an overview of the revenue earned by vessels targeting POP, in 1992 and 1991, respectively. Earnings are broken down into categories for POP, caught during POP-target weeks and otherwise, all species caught during POP-target weeks, all species caught in the GOA, and all species caught off Alaska. The percentages which revenue from targeted POP and all species caught during POP-target weeks represent of GOA and total Alaskan earnings are also shown.

In 1992, for the upper group of vessels, the total earnings from POP-target weeks averaged 10.6% of total revenue, using 1991 processed product survey prices, and 14.3% of total revenue using the alternative estimates of 1992 prices. In 1991, the upper group's total revenue from POP-target weeks averaged 9% of overall revenue. None of the vessels, in either year, were estimated to receive more than one-fifth of their income from all species harvested during POP-target weeks, however it must be acknowledged that the prices applied to an individual vessel's reported production were "representative" prices, and may differ from what they actually received. For the lower group, in both years, less than 2% of total revenue, on average, was contributed by earnings from POP-target weeks.

Vessels in the upper group in each year typically caught more than 90% of their POP during weeks in which that species was the target. In the lower group, a higher percentage of POP, occasionally more than 50%, was caught during weeks in which other species were designated as the target.

Table 14.--Estimated earnings of POP vessels (i.e., vessels with at least one target week) in 1992.

	Estimated 1992 revenue (using 1992* prices) for POP-target vessels from:					GOA POP revenue as a % of all revenue from:		Total revenue from POP-target weeks in the GOA as a % of all revenue from:	
	GOA POP POP-target weeks	caught during other target weeks	All GOA species from POP-target weeks	All species caught in the GOA	All species caught off Alaska	GOA[1]	All Alaska[1]	GOA[1]	All Alaska[1]
Vessels with less than 6% of total revenue from POP-target species (6)									
Sum	$ 379,228	$ 345,885	$ 642,611	$ 9,951,157	$62,974,001				
Mean	$ 63,205	$ 57,648	$ 107,102	$ 1,658,526	$10,495,667	4.3%	0.6%	7.2%	1.0%
Vessels with more than 6% of total revenue from POP-target species (6)									
Sum	$ 4,176,090	$ 198,777	$ 6,444,925	$16,272,520	$44,098,489				
Mean	$ 696,015	$ 33,129	$ 1,074,154	$ 2,712,087	$ 7,349,748	34.7%	9.6%	49.2%	14.3%
All POP-target vessels									
Sum	$ 4,555,318	$ 544,662	$ 7,087,535	$26,223,677	$107,072,490				
Mean	$ 379,610	$ 45,388	$ 590,628	$ 2,185,306	$ 8,922,707	19.5%	5.1%	28.2%	7.7%

	Estimated 1992 revenue (using 1991* prices) for POP-target vessels from:					POP revenue as a % of all revenue from:		Total revenue from POP-target weeks as a % of all revenue from:	
	POP caught during POP-target weeks	other target weeks	All species during POP-target weeks	All species caught in the GOA	All species caught off Alaska	GOA[1]	All Alaska[1]	GOA[1]	All Alaska[1]
Vessels with less than 6% of total revenue from POP-target species (6)									
Sum	$ 230,819	$ 204,216	$ 461,670	$10,634,167	$59,121,655				
Mean	$ 38,470	$ 34,036	$ 76,945	$ 1,772,361	$ 9,853,609	2.3%	0.4%	4.3%	0.8%
Vessels with more than 6% of total revenue from POP-target species (6)									
Sum	$ 2,488,540	$ 109,003	$ 4,166,256	$12,503,310	$39,873,416				
Mean	$ 414,757	$ 18,167	$ 694,376	$ 2,083,885	$ 6,645,569	28.9%	6.5%	44.3%	10.6%
All POP-target vessels									
Sum	$ 2,719,358	$ 313,219	$ 4,627,925	$23,137,477	$98,995,071				
Mean	$ 226,613	$ 26,102	$ 385,660	$ 1,928,123	$ 8,249,589	15.6%	3.4%	24.3%	5.7%

* 1991 prices are taken directly from the NMFS Trade and Industry Services Processed Products Survey for 1991. In the "1992" price set, any of the 1991 prices are adjusted based on an informal survey of industry participants by the NMFS Alaska Region. (See Tables 7 and 8)

[1] The percentages reported for each group represent the unweighted averages of the individual percentages for all vessels in the group

Table 15. --Estimated earnings of vessels targeting POP in 1991.

	Estimated 1991 revenue for POP-target vessels from:					GOA POP revenue as a % of all revenue from:		Total revenue from GOA POP-target weeks as a % of all revenue from:	
	GOA POP caught during POP-target weeks	other target weeks	All GOA species from POP-target weeks	All species caught in the GOA	All species caught off Alaska	GOA[1]	All Alaska[1]	GOA[1]	All Alaska[1]
Vessels with less than 6% of total revenue from POP-target species (11)									
Sum	$ 653,803	$ 284,543	$1,563,526	$16,932,386	$109,993,744				
Mean	$ 59,437	$ 25,868	$ 142,139	$ 1,539,308	$ 9,999,431	7.2%	0.7%	14.9%	1.6%
Vessels with more than 6% of total revenue from POP-target species (6)									
Sum	$ 2,339,763	$ 158,088	$4,828,786	$11,182,111	$52,972,983				
Mean	$ 389,960	$ 26,348	$ 804,798	$ 1,863,685	$ 8,828,831	29.8%	4.5%	56.2%	9.0%
All POP-target vessels									
Sum	$ 2,993,566	$ 442,631	$6,392,312	$28,114,497	$162,966,727				
Mean	$ 176,092	$ 26,037	$ 376,018	$ 1,653,794	$ 9,586,278	15.2%	2.0%	29.5%	4.2%

Source: NMFS Trade and Industry Services, Northwest Region.

[1] The percentages reported for each group represent the unweighted averages of the individual percentages for all vessels in the group

3.2. Economic Assessment of the Alternatives

There are many difficulties involved in attempting to estimate the net economic/social effect of a change in the POP harvest policy, in general, and on the groundfish fleet, in particular. One of the most important involves the ability to predict how the fleet will respond to the various management alternatives being considered. Theoretically, a model could be constructed, incorporating accurate cost, production, and price information for all members of the at-sea fleet. Such a model could be used to assess the likely behavioral response to reduced POP opportunities, as well as providing a means for assessing the net economic impact of those changes on members of the POP-target fleet, and on other vessels that would be affected by a shift of effort into other fisheries.

Construction of this kind of model is well beyond the available resources for this analysis. Not only do we lack an accurate picture of the costs and production relationships of most operations, but we have little ability to predict how prices for POP will change, relative to other prices, over a 5 year period, much less 30 years. As a result, the information which is provided on this issue is characterized by two major simplifications: it reflects gross product value, and it reflects only the impacts on the fleet which has previously targeted POP, based on historical patterns of fishing. It is simply not known to what extent POP-target vessels will redirect their fishing effort into particular other fisheries, or how their net earnings will change.

The broader question of how the trawl fleet as a whole will be affected is even more opaque. If POP vessels shift into fisheries that are already fully utilized, the vessels currently in those fisheries would suffer lost earnings, or will they find new opportunities that do not, in turn, displace someone else. As vessels redirect effort to other fisheries, bycatch of prohibited species would be altered. If bycatch rates increase, other trawl fisheries might be closed sooner than if that effort had been directed towards POP. Thus, through the possibility of reaching PSC caps earlier, and through a shifting of effort into non-POP fisheries, a reduction in the TAC for POP could have substantial effects well beyond the vessels who have actually participated in the POP fishery.

Assessment of the impact which the alternatives are likely to have on the POP fleet is addressed in two different ways. The first avenue involves an assessment of the extent to which the historical participants in this fishery are dependent upon that income. Another assessment involves the bio-economic simulation outlined in Section 2.4, in which biomass and yield are projected, under stochastic (random) recruitment conditions over a 30-year period, and a calculation of present gross value of the fish harvested.

3.2.1. Dependence of the Offshore Fleet on POP

Reaching a clear understanding of the effect that reduced POP harvest opportunities will have on these vessels is difficult, because on one hand, POP-target weeks consist predominantly of POP, yet on the other hand, other species represent a considerable portion of the revenue earned during those weeks, and a still larger fraction of annual income. In 1992, for example, POP represented more than 80% of the retained catch in more than half of the POP-target weeks. In only 4 POP-target weeks, out of 40, did POP represent less than 50% of the pounds retained. While sablefish accounted for less than 5% of the poundage retained by the upper group's POP-target weeks, it accounted for an estimated 11-16% of the earnings from those weeks, depending on the prices used. Other species of rockfish accounted for an average of 14% of the POP-target poundage, but 21-23% of the earnings. During 1992, vessels in the upper group averaged more than one third of their income in POP-target weeks from species other than POP, ranging from 16% to 82%.

Regardless of the species composition of their catch during POP-target weeks, it is clear that all of these vessels have earned most of their gross revenue from fish that were caught while targeting species other than POP. However, several other important questions are not as clearly answerable. First, is the contribution of the POP fishery to vessel profits proportional to the percentage of vessel revenue earned? If not, the importance of this target fishery to the annual profitability of the operations may be larger than is suggested by the analysis of revenue shares.

Second, does a reduction in the availability of POP to this fleet imply a reduction in just the income earned from POP, or from all of the species caught during those target weeks? In other words, to what extent can operations alter their fishing strategies and catch composition, given the array of other quotas, so that the reduction in POP is not accompanied by a proportional reduction in the species which have typically been caught during POP-target weeks? In the case of a bycatch-only regime for POP, it is obvious that efforts to maintain recent catches of valuable sablefish could not be done while targeting on POP. Examination of the data suggests that other rockfish assemblages provide the only alternative source of comparable sablefish bycatch. In the eastern Gulf, the 1993 TAC for other slope rockfish is more than 3,000 mt higher than the 1992 harvest. Therefore, it would not be surprising to see increased effort directed towards other available rockfish fisheries by vessels faced with reduced opportunities to target POP, provided opportunities exist for marketing larger quantities of these species.

Third, although other fishing opportunities may exist for these vessels, as long as they fish in U.S. waters, they are almost certain to end up harvesting some fish that would otherwise have been caught by someone else. Even in the flatfish fishery, where sizable portions of the TACs have gone unharvested, landings have been constrained by halibut PSC caps. Reducing the amount of POP harvested will free some PSC to be used for other species that are not currently fully utilized, such as flatfish and other slope rockfish. However, if some of the POP fleet redirects effort

toward flatfish, the caps will be reached at a lower level of groundfish catch, due to the higher halibut bycatch rate in those fisheries. Additionally, since flatfish are of lesser value, there is very little chance that opportunities in those fisheries will offset reductions in POP harvest. Perhaps most importantly, increased fishing for flatfish may reduce the amount of higher-valued species, such as Pacific cod, that can be taken by all trawl vessels, given the PSC caps.

3.2.2. Economic Findings of the Bio-economic Simulation Model

The development of the simulation model is presented in Section 2.4. The model is used to predict the biomass and yield of POP in the GOA over the next 30 years, and to estimate the value of the allowable harvest under four different harvest policy regimes. These policies range from an adjusted F35% harvest strategy, representing a fishing mortality of 0.11 when biomass is not less than the target level, to one allowing POP to be caught only as bycatch with other species, with a fishing mortality of 0.023, until the biomass reaches the target level. For each policy, several hundred simulations were run, reflecting not only the stochastic nature of recruitment success, but also different underlying assumptions regarding recruitment strength. For each year, within each simulation, a portion of the biomass was "harvested", and that portion distributed among three fish-size categories. This allowed the simulation to incorporate size-dependent prices, and capture at least some of the effects that changes in the level of biomass may have on catch size-composition and, in turn, on the value of the harvest. The size categories and associated prices used in the simulation are shown in Table 2.

The prices used in the model are intended to represent gross ex-processor prices for headed-and-gutted product. Thus, the results of the model overstate the net economic change to producers that is directly attributable to the change in POP harvest. Since no cost data were available specifically for this fishery, an effort was made to estimate what portion of this fleet's earnings would be used to cover variable costs, by employing the formula used to represent factory trawler costs in a Pacific cod allocation analysis. This ad hoc approach suggests that, on average, variable costs represent about 30-40% of the gross value of the fishery. If one is willing to assume that costs will represent a fixed proportion of revenue over the time period of the analysis, then a net value for the change in POP harvest could be obtained by reducing the model results by that percentage. It should be remembered, however, that if vessels lose the ability to land other valuable bycatch, then the modified model result would understate the overall net loss to these vessels from the change in policy.

The four policies are compared by calculating present values over time of gross earnings. For comparative purposes, the results obtained using four alternative discounting assumptions are presented in Table 7. The discounting alternatives range from a 9% rate to a 0% rate, which represents the simple summation of the predicted annual earnings. As depicted in Fig. 8, it is significant that only in the last two years of the 30-year simulation do any of the alternatives

produce more POP revenue than Policy 1, the modified F35% option. This means that whether future values are discounted or not, Policy 1 easily produces the greatest cumulative earnings from the fishery over the time period analyzed. Without discounting, the difference between Policy 1 and Policy 4 is about $90 million, which represents roughly 19% of the Policy 1 value. Using a 7% discount rate, the difference between the two policy extremes is about $51 million, or 31% of the Policy 1 amount.

Although it is not the only objective of accelerating the rebuilding schedule, the simulations suggest that the more restrictive harvest policies are not likely to provide an increase in catch and earnings over the next 30 years that will more than offset the economic sacrifices made in the short term. Another comparison, which may be useful in evaluating the strengths and weaknesses of each policy option, is afforded by Figures 17 and 18. These show, respectively, the proportion of simulations, for each year, where the projected spawning biomass is below 75,000 mt, and where the harvest revenue is lower than the mean value for Policy 2 in the simulated results for 1993. For the more biologically conservative options 3 and 4, by 1997, fewer than 25% of runs result in a biomass of less than 75,000 mt. For Policy 1, this stock condition does not occur until the year 2000. In contrast, the likelihood of POP fishery income falling below the level using Policy 2 (F=0.8) is reduced to less than 25% by 1995 with Policy 2, while a comparable reduction in earnings risk is not achieved with Policy 4 until 2001. In fact, 5 years into the simulation, roughly half of the Policy 4 runs produced a lower amount of income (undiscounted) from the fishery than the 1993 mean with Policy 2. In all years there was no risk of dropping below the Policy 2 1993 mean under Policy 1.

Two important qualifications should be kept in mind when weighing the economic results of this exercise. First, even if the biological predictions of the model accurately reflect the true probabilities of occurrences 30 years into the future, the economic values that have been attached to them are extremely speculative. Aside from the above mentioned limitations on distinguishing net from gross returns, it is important to recognize that the dynamics of fishery markets have not been taken into account. In the short run, if quantities of POP available to the market are reduced, the price may rise, depending on the location of markets and their access to substitute products. If other substitutes are not readily available and demand for POP is strong, then a resulting rise in price may offset some of the loss associated with reduced quotas. Correspondingly, in the long run, as increases in harvest are made available, price would tend to fall creating some ambiguity over the net effect that such a price effect would have on the discounted present value of a reduction. On the other hand, if substitutes are available, price may not change dramatically. This is the relationship assumed in this analysis. However, even though price may not be affected much by a reduction in quantity, a dramatically reduced supply of fish, in the short run, could potentially lead to a loss of access to some markets. Thus, POP might be replaced by other fish that can be delivered more reliably in desired quantities. Once markets are lost for this reason, they may prove difficult to recapture as the harvest level rebounds.

Another factor, which could have a substantial impact on the eventual desirability of various levels of rebuilding efforts, is changes in demand for POP and for seafood, in general, that may occur over the planning horizon reflected in this analysis. From 1960 to 1990, U.S. per capita consumption of seafood increased from 10.3 lb. to 15.5, with most of the increase attributable to fresh and frozen products. In the 9 years from 1976 to 1985, Japanese annual per capita consumption of seafood increased from 148.6 lb. to 152.8 lb. If health consciousness and other factors continue to raise consumer preferences for seafood, particularly in wealthy countries, real prices for fishery products could rise considerably over the next thirty years. The price effects of such an increase in demand would be accentuated if global seafood production were to decline over that period. On the other hand, advances in aquaculture might produce a glut of more highly desired species, lowering future seafood prices. At one extreme, POP might become revered as a delicacy in an important world market, or it might become viewed as an inferior product, or a poor value for the price. A significant change in demand occurring at some point in the course of rebuilding could produce a considerable change the magnitude of the economic results predicted in the simulations. Future price increases would decrease the cost of the more conservative policies. On the other hand, price increases in the future would increase the cost of foregoing current harvests. Currently, we do not have a quantifiable understanding of markets for POP and its substitutes, nor are we able to reliably predict how the supply of and demands for these substitutes will change over the next 30 years.

As noted above, this simulation does not address the magnitude of economic impacts that reductions in the harvestable amounts of POP will have on overall vessel profits, both within the POP fleet and outside it. Although a measure of the direct change in POP profits might be approximated by removing 30-40% of the earnings, in the form of costs, the model makes no attempt to address any of the indirect effects that will result from redirecting fishing effort to non-POP fisheries.

Finally, there are several other potential economic impacts that are not addressed by either the simulation modeling or the analysis of historical fleet utilization of POP. There is uncertainty over the role which POP plays in the ecosystem. As a result, it is difficult to say what effect achieving various levels of biomass may have on the productivity of other valuable species. Also, some of society's members may feel that their well-being is increased simply by having a larger stock of POP, whether that larger stock results in a greater harvest of POP or not. Non-use values for other natural resources are commonly discussed in the economics literature, even if they are, in practice, often difficult to estimate. Furthermore, there is always the possibility, as with many plant species in the world's rainforests, that POP could be found at some future time to have a currently unknown valuable property, which would tend to increase our concern over the possible risk of placing the stock in jeopardy. But, it should be emphasized, with regard to this point, that even under Option 1, the mean size of the biomass at the end of 30-year simulation is roughly twice the size of the current population.

4. CONCLUSIONS

4.1. Biological Conclusions

This study represents an analysis based on the current stock assessment. In 1993, there will be another NMFS survey which will provide a new biomass estimate of the POP population and an estimate of age structure. Subsequent data will add more information and will improve these types of analyses. In developing a rebuilding strategy, the Council should establish a goal and allow for flexibility in the policy selected as new information becomes available.

The ability to predict future stock levels with a high degree of certainty is poor. This is partly due to observation errors, however, a large component of uncertainty in future stock sizes can be tied to the high level of variability in recruitment. Evaluation of alternative policies should emphasize the distribution of particular outcomes in addition to their expected values.

The question of whether a faster rebuilding strategy is *better*, from a biological standpoint, depends on how one defines a healthy population. At one extreme a healthy population could be defined as one that is unperturbed by human activity. At the other extreme, of course, would be extinction brought on by anthropogenic causes. Wide fluctuations in abundance are common for many fish populations (e.g. Caddy and Gulland 1983) and changing environmental conditions undoubtedly regulate populations to some degree. Whether the decision is made to allow a target fishery for POP or just have a bycatch, the resource utilization choice has already been made and pristine conditions are now not achievable.

Analysis of policy alternative 1 indicated that the expectation of spawner biomass would increase, but that the fishing mortality rate equivalent to $F_{35\%}$ was higher than optimal as determined from analyses of stock-recruitment data. Repeating the analysis of Clark (1991) with specific consideration of recruitment variability, POP life history parameters, and the available recruitment data indicate that the optimum fishing rate is closer to the value giving $F_{45\%}$. This refined rate was used to identify policy alternative 2.

Under policy alternative 2, spawner biomass is expected to rebuild to double the current estimate in about 18 years. This compares with about 26 years for policy 1, and about 14 years for policies 3 and 4. The mean age of the population increases under all policies but reaches a higher level for the lower exploitation rates. The biological advantage of the different mean ages between policies could not be objectively evaluated except as in previous considerations of increased spawner biomass.

The expected yield for the implementation of the policies and the exploitation rates for the policies presented here is less than the recommended ABC from Ianelli and Heifetz (1992) assessment

(Table 16). The analyses presented in this document suggest that the optimal fishing mortality rate for POP in the GOA should be lower than previously considered. As new information becomes available, in particular, recruitment generated from the current relatively low level of spawner biomass, then these rates may change in future analyses. For example, if several strong year classes appear then our hypotheses on higher productivity in the stock-recruitment relationship will be favored. In other words, as assessments improve with more information, our ability to assign probabilities to alternative hypotheses on stock productivity should also improve.

Table 16. - Expected yield in 1993 by policy and alternative recruitment assumptions. The SAFE ABC represents the F35% fishing mortality rate adjusted by the 1960 estimate of female spawner biomass (118,000 tons) as a target instead of the refined target of 150,000 tons as in Policy 1. The exploitation rate is the ratio of yield over the estimated biomass of age 6 yrs and older Pacific ocean perch.

Probability	A=0.43 0.13	A=0.67 0.71	A=0.90 0.16	EV	Exploitation Rate
SAFE ABC	-	-	-	5,560	0.036
Policy 1	4,244	4,580	5,855	4,734	0.031
Policy 2	2,985	3,309	4,029	3,378	0.022
Policy 3	1,895	2,079	2,420	2,107	0.014
Policy 4	1,962	2,086	2,284	2,100	0.014

The model used in this analysis assumes that the Gulf-wide stock of POP is harvested uniformly throughout it's geographic range. This is probably not true. There may be areas within the GOA where harvests are significantly out of proportion to the distribution of biomass. That is, fishing mortality may be distributed unevenly with respect to the distribution of the population. The effect this may have on the stock is not known. In the past, the ABC recommendation has been divided among three subareas (the eastern, central and western GOA) in proportion to the biomass estimated from NMFS surveys.

Gunderson (1978) presented a rebuilding schedule for POP for the west coast of the continental U.S. In this study he used a constant recruitment based on the average observed from an age-structured cohort analysis. This strategy was adopted in 1981 and catches were restricted by implementing trip limit quotas for each vessel. The trip limit system was chosen because in 1978, the state of Oregon and later Washington set a precedent by using this method to discourage directed fishing for POP.

According to Gunderson's (op. cit.) analysis, the average landings (not counting discarded catch) since 1982 of 1,171 tons (Ianelli et al. 1992) indicates that it should take from 16 to 18 years to rebuild the west coast POP stocks to levels producing MSY. In Ianelli et al.'s (op. cit.) assessment conducted in 1992, they were unable to detect any strong evidence of rebuilding,

although there was some indication of one or more good year classes from the mid-1980's entering the fishery. The lack of rebuilding signs after a decade of rebuilding may be explained by several phenomena. First, the power to detect the type of expected increase is low. The probability of detecting a change of 10% per year of a population when our observation errors have CV's on the order of 30% (optimistically), is about 35% over three survey observations. POP, at stable recruitment rates, are expected to increase in the absence of fishing at about 5-8% per year. Another problem is that Gunderson provided the expected rate of rebuilding, and did not present the distribution about that expectation. As shown in this document, the recruitment variability and the uncertainty in the assessment contributes substantially to uncertainties in future stock biomasses. Finally, on the west coast there is little or no observer coverage to monitor actual catches and discards, consequently, the estimated landings as presented here are lower than the actual removals.

Archibald et al. (1983) analyzed the rebuilding rates for POP for a stock found in Queen Charlotte Sound, Canada. In that study they accounted for recruitment variability and presented the effect of different fishing rates in terms of risk probabilities. They used a single Ricker stock-recruitment relationship in their simulations and, as such, did not evaluate alternative hypotheses on the stock productivity. Their results are similar to ours, however, and shows that the expected rebuilding trajectory of biomass is slow. At moderate fishing levels (about equal to Policy 1 in this document) the stock doubles from the low 1977 level in about 30 years.

Balsiger et al. (1985) examined rebuilding rates and economic effects for a range of fishing rates for POP in the GOA. Their study was based on stock reduction analysis (Kimura et al. 1984) assuming a range of possible Beverton-Holt stock recruitment relationships and did not account for recruitment variability. They concluded that exploitation rates of less than 2% were needed to provide adequate rebuilding. The effect of ignoring recruitment variability, however, is that this rate would be conservative.

POP stock-recruitment patterns from stocks other than that analyzed for the GOA show similar levels of variability. Also, assessments from the Aleutian Islands and the west coast of the continental U.S. indicate that these stocks have been reduced by nearly an order of magnitude (Fig. 20). The west coast stock-recruitment pattern is similar to that for the GOA in that year-class strength at low levels of spawner biomass has been low. In the Aleutian Islands, however, year-class strength in the past decade has been relatively high and the stock appears to be increasing steadily (Ianelli and Ito 1992). The reason the Aleutian Islands stock appears to have rebounded successfully from low levels may be attributed to several factors. Taking the assessments at face value, the environmental conditions that affect year-class success may be different in these areas. The Aleutian Islands region is influenced by conditions in the Bering Sea more so than for the GOA and the west coast. Biological factors may also play a role. In the GOA the dominant species has shifted from POP in the 1960's to walleye pollock since the mid 1970's. In the Aleutian Islands region, walleye pollock are not as dominant as in the GOA.

Further investigations into these types of factors should improve our understanding of the recruitment processes that affect POP.

This analysis has focused on POP in the GOA, a stock which has a relatively large amount of information available for assessment purposes. The ability to extend these results to other rockfish species will obviously depend on the similarities in the life history patterns between species. Whereas previously, an $F_{35\%}$ fishing mortality would have been applied to stocks based the plan team recommendations when information is otherwise lacking, we propose that a more appropriate rate for rockfish is on the order of $F_{45\%}$. That is, the amount of fishing that reduces the spawner biomass per recruit to 45% of the unfished ratio near the optimal yield. This rate compares favorably with Clark's (1991) max-min yield if his Ricker stock-recruitment curves are excluded. For POP, we found that the optimum fishing rate corresponded to an $F_{43.8\%}$ rate. Comparisons to other species should take into account differences in individual growth rate, and natural mortality and variability in recruitment.

4.2. Economic Conclusions

The fleet of offshore vessels that harvests POP in the GOA is a relatively small one. Although 17 vessels are categorized as having targeted POP in 1991, during either of the past two years, only 6 vessels received more than 3.5% of their overall income from the catch of all species in POP-target weeks. These vessels received between 6% and 17% of their earnings from all species caught while fishing POP. POP accounted for more than 80% of the poundage caught during most of these target weeks, although it was not uncommon for 30-40% of the revenue earned to come from other species. Given available information, it is difficult to assess how the overall amount and composition of catch will change for these vessels, given a reduction in POP.

According to the bio-economic simulation model developed for this analysis, adopting more restrictive harvest policies for the GOA POP fishery is expected to reduce the income generated by the fishery in nearly every year of the next thirty years. The difference between the present value of income under the status quo and the most restrictive policy amounts to roughly $90 million if future values are not discounted, and $51 million if they are discounted at a rate of 7% per year. This estimate reflects changes in gross earnings and is based on the assumption that prices remain constant over the 30-year period. Subtracting variable costs would likely reduce the difference between the alternatives by an estimated 30-40%, based on cost formulas developed for other offshore fisheries. The simulation does not address any changes in earnings except for those derived from POP directly. Without considerable additional information and model building, little can be reliably concluded about the net effect on income from other species harvested by POP vessels, or the remainder of the trawl fleet. The economic results projected by the simulation model also do not include any economic benefits that might result from ecosystem enhancement, or any non-market benefits from achieving relatively larger stock sizes.

Although all of the policy alternatives result in mean projected biomass levels that are at least twice the current biomass, the options with higher exploitation rates require more years, on average, to reach the target biomass and possess a greater risk of the biomass falling below 75,000 mt. For example, after 7 years the chance of having a biomass less than 75,000 mt is estimated to be just under 25% for policy 1, and about 10% for policies 3 and 4. On the other hand, the more conservative strategies have a much higher likelihood that income from POP will be less than the 1993 fishery under the status quo. By 2000, the likelihood of smaller levels of income is reduced to less than 5% for policy 1, but remains at nearly 50% for policy 3 and more than 80% for alternative policy 4.

The interpretation of the this analysis should consider the range of projected outcomes as much as the mean values. The results of this study on the GOA POP reflect many sources of uncertainty, both in terms of how well the model represents the true stock-recruitment relationships, and also with regard to which set of currently unpredictable environmental conditions happens to occur in the future. The principal economic conclusion that can be drawn from this is that under the recruitment scenarios examined, reductions in the POP harvest rate will result in reductions of gross earnings from the POP fishery, which would not likely be made up for by increased gross earnings anytime during the next 30 years. Other economic considerations omitted in this analysis would have required extensive research and market analysis with predictably uncertain outcomes. These ommissions are unlikely to change the conclusion substantively, however.

5. STATEMENT OF FINDINGS

5.1. Effects On Endangered and Threatened Species and on the Alaska Coastal Zone

The status quo or other alternative are not expected to adversely affect endangered or threatened species, or their habitat in a manner or to an extent not already considered. Thus, formal consultation under Section 7 of the Endangered Species Act is not required.

Each of the alternatives discussed above would be conducted in a manner consistent, to the maximum extent practicable, with the Alaska Coastal Zone Management Program within the meaning of Section 307(c)(1) of the Coastal Zone Management Act of 1972 and its implementing regulations.

5.2. Executive Order 12291 Requirements

Executive Order 12291 requires that the following three issues be considered:

1. Will the amendment have an annual effect on the economy of $100 million or more?
2. 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?
3. Will the amendment have significant adverse effects on competition, employment, investment, productivity, or on the ability of U.S. based enterprises to compete with foreign enterprises in domestic or export markets?

This amendment will not have an annual effect of $100 million on the United States' economy.

The amendment would 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 because the amendment simply provides a management mechanism by which the Council may evaluate policy alternatives. It presents alternative harvest strategies, but contains no other regulatory change.

5.3. Impact of the Amendment 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.

Adoption of the proposed amendment would establish a management mechanism for rebuilding POP stocks. The POP fishery is prosecuted by factory trawlers, which under the EPA gross >$2 million and are not considered to be small entities. No concomitant effects are anticipated for a substantial number of small entities.

5.4. Finding of No Significant Impacts

For the reasons discussed above, implementation of either of the alternatives to the status quo would not significantly affect the quality of the human environment, and the preparation of an environmental impact statement on the final action is not required under Section 102(2)(c) of the National Environmental Policy Act or its implementing regulations.

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8. APPENDIX A. MODEL DETAILS

8.1. The Population Dynamics Model

The population dynamics model used in the stock projections is age structured and is the same as the underlying stock synthesis model (Methot 1990). The model begins with the current estimate of age structure and biomass for the population as assessed by Heifetz and Ianelli (1992). These include estimates of the stock and recruitment data from 1960 to 1984 (Table 12), and the estimated age composition of the population in 1986 as well as demographic information on mean weight at age, proportion mature at age, selectivity to the fishery, and the mean ex-vessel value per fish (Table 13). Natural mortality was set at 0.05.

The stock-recruitment relationship is the most critical aspect in a projection analysis. Several alternative treatments were investigated. Initially, an empirical approach was taken where observed recruitment were resampled–independently of stock size–in making projections. This approach was rejected on the basis that this would assume that all observed magnitudes of recruitment would be equally likely to occur, even though spawning biomass had been reduced by an order of magnitude. To acknowledge the change in spawner biomass and retain empiricism, the method proposed by Evans and Rice (1988) was investigated. This "fixed interval" method splits observed recruitment ranked by observed spawner biomass so that, for a chosen number of intervals, there are equal numbers of observations in each interval. In our data there are only 28 observations and splitting these into equal size units (bins) results in too few observations at intermediate spawner biomass levels. Additionally, the transition from a high biomass situation in the mid-1960's to near the current level occurred over a short period, consequently, there are relatively few observations of recruitment strengths at intermediate spawner biomass levels.

Mayo (1987) employed a probability-transition matrix approach to model the stock-recruitment relationship for the Atlantic redfish, *Sebastes fasciatus*. This species has life history traits, recruitment patterns, and an exploitation history that is very similar to Pacific ocean perch in the Gulf of Alaska. The transition approach he used is appealing because the stock-recruitment relationship does not rely on an underlying functional form. The problem with this approach is that the number of elements in the matrix is arbitrary (but obviously less than the number of data points), and the number of effective parameters is often high. For example, Mayo's (op. cit.) recruitment matrix required estimating 6 parameters to complete the matrix. Standard stock recruitment curves typically have only 2 or 3 parameters. As the number of parameters increase relative to the observations, the variances of the parameters increase such that they become poorly defined.

Re-sampling and probability-transition methods are commonly selected in favor of parametric functions because of concern that the distribution of recruitment about the stock-recruitment

function does not follow a statistical (usually exponential family) distribution. Hennemuth et al. (1982) showed that of the 18 sets of stock-recruitment data they analyzed, 17 were adequately modeled using a lognormal error distribution. This suggests that a lognormal model structure is appropriate in many stock-recruitment situations.

Some studies have shown that recruitment history can be modeled well using time series analyses. This approach is typically applied independent of stock sizes and is used to show if trends can be explained as a function of time. The problem with this type of analysis is that a long time series is usually required before potential serial correlations become significant. In this case, with 28 years of data, examined for lags up to 14 years, there is no apparent serial correlation in the pattern of recruitment (Fig. 21.). These results may be attributed to the lack of data on the scale needed. For example, several recent studies have indicated that environmental conditions that affect productivity in the north Pacific may be changing on a decadal scale (Hollowed and Wooster 1992).

These preliminary investigations led to the selection of a functional stock-recruitment relationship as estimated from the observed data. A Beverton-Holt stock-recruitment relationship using the parameterization of Kimura (1988) was selected where:

1) $$R_{t+2} = \frac{S_t R_0 e^{\varepsilon_t}}{AS_t + B_0(1-A)} \qquad \varepsilon_t \sim N(0, \sigma_R^2)$$

where S_t is the mature female biomass during year t:

$$S_t = \sum_{a=1}^{25} w_a \phi_a N_{t,a}$$

ϕ_a is the fraction of animals of age a which are mature,

w_a is the mean weight at age a;

$N_{t,a}$ is the beginning of the year numbers at age:

$$N_{t+1,a} = N_{t,a-1}\left(1 - e^{-F_t s_a - M}\right)$$

F_t is the full selection fishing mortality rate in year t;

s_a is the selectivity at age (see below);

M is the natural mortality rate; and

A, R_0 are parameters of the stock-recruitment curve.

The parameter A determines the shape of the curve while R_0, the average pre-exploitation recruitment level, simply scales the curve and can be thought of as a nuisance parameter. The parameter for average pre-exploitation spawner biomass, B_0, is determined by R_0 and the life history characteristics for the species. The error term, ε_t, represents the deviations from the predicted curve. A lognormal error distribution was assumed with σ_R set to the estimate of 1.08.

The A parameter essentially governs the level of density dependent mortality on pre-recruit fish. That is, for high values of A, the level of spawner biomass does not affect recruitment until the stock is severely depleted. Low A values result in mean recruitment levels that change directly as a function of spawning stock size. Fig. 22 shows the effect of different A values relative to the estimated stock-recruitment data.

For the stock projections, the stochastic recruitment levels were generated following equation 1). Thirty simulated recruitment levels at fifty different levels of spawner biomass for the best fit stock-recruit relationship are shown in Fig. 23. This represents the general pattern of recruitment used throughout the stock projection analysis. Note that the frequency of extremely high recruitment is relatively low. In all projections, the recruitment variability parameter, σ_R, was fixed at 1.08. This estimate was based on the residuals of the maximum likelihood fit.

The simulation model began with the estimated age structure of the population in 1986 from Heifetz and Ianelli (1992). The ages considered were from age 2 to 25 years with the numbers at age older than 24 accumulating in the last age group. The observed catch from 1986 to 1992 was modeled exactly. The recruitment of age 2 individuals during this interval followed the stock-recruitment model presented in 1). The basic population dynamics equations that describe the catch in numbers at age C_a and total catch biomass Y in a given year are

$$C_a = \frac{N_a F s_a}{F s_a + M}\left(1 - e^{-F s_a - M}\right)$$

$$Y = \sum_{a=1}^{25} w_a C_a$$

where s_a is selectivity at age a, F is the fishing mortality rate for fully selected age groups (i.e. s_a = 1.0), and w_a is weight at age. A double logistic function was used to model fishery and survey selectivities (Methot 1990). This four parameter selectivity function is described by:

$$S1_a = \frac{1}{1+e^{-P2(a-P1)}}$$

$$S2_a = 1 - \frac{1}{1+e^{-P4(a-P3)}}$$

$$s_a = \frac{S1_a S2_a}{max}$$

where, $P1$ and $P3$ are inflection ages for the individual curves, $P2$ and $P4$ are the slopes, s_a is the selectivity at age a, and max is the maximum of the product of $S1$ and $S2$. This parameterization provides great flexibility enabling both domed and asymptotic selectivity patterns to be modeled. The parameter values and shape used throughout this analysis are from the recent fishery selectivity patterns estimated in Heifetz and Ianelli and are shown in Fig. 24.

Table 17. - Stock recruitment estimates used in this analysis.

Year	Spawner Biomass	Recruitment
60	360,528	95,754
61	415,464	640,796
62	450,982	9,466
63	457,048	114,312
64	419,985	44,041
65	321,340	200,041
66	232,974	41,291
67	194,701	147,835
68	181,663	44,538
69	163,922	59,492
70	148,623	82,263
71	132,751	25,417
72	112,329	16,235
73	94,580	5,599
74	79,521	5,965
75	63,825	7,447
76	49,532	65,873
77	43,077	13,147
78	42,483	9,744
79	42,150	8,154
80	39,358	67,566
81	35,362	12,291
82	33,749	29,719
83	36,699	47,183
84	40,256	54,984

Table 18.--Estimated numbers (thousands) of POP at age in 1986 and schedule of age specific mean weight, value, fishery selectivity and maturity used in the stock projections model

Age	Weight (grams)	Round wt. value/fish	Numbers in 1986	Percent Selected	Percent Mature
2	53	$0.02	61,470	4%	0%
3	116	$0.05	41,404	6%	0%
4	194	$0.08	27,790	9%	5%
5	279	$0.11	7,686	12%	12%
6	363	$0.15	58,344	16%	27%
7	442	$0.18	4,630	21%	50%
8	515	$0.24	7,471	28%	73%
9	579	$0.27	8,200	37%	88%
10	635	$0.30	42,338	47%	95%
11	683	$0.32	3,313	59%	98%
12	724	$0.34	2,795	71%	99%
13	759	$0.35	1,534	82%	100%
14	788	$0.37	5,348	91%	100%
15	812	$0.47	5,156	97%	100%
16	832	$0.48	13,855	100%	100%
17	848	$0.49	5,845	100%	100%
18	861	$0.50	2,183	98%	100%
19	872	$0.50	3,206	94%	100%
20	881	$0.51	346	89%	100%
21	889	$0.51	1,238	83%	100%
22	895	$0.52	196	77%	100%
23	900	$0.52	547	71%	100%
24	904	$0.52	23	65%	100%
25+	907	$0.52	23,745	60%	100%

8.2. Assigning Probabilities to Stock Productivity

The approach taken in this analysis was to incorporate the uncertainty in the A parameter in stock projections. This was accomplished by constructing a likelihood profile and applying Bayes theorem to arrive at estimates of probabilities for each A parameter. In this case we have assumed a uniform prior distribution over a range of possible A values.

8.2.1. THE LIKELIHOOD MODEL

The likelihood function which was maximized in this analysis consists of two parts. The first component simply reflects the deviations of estimated recruitment presented in Heifetz and Ianelli (1992) from the stock-recruitment relationship given in 1)

$$2) \qquad \frac{1}{\left(\sqrt{2\pi\sigma_R^2}\right)^n}\exp\left(-\frac{\Sigma\left[\ln(R_t)-\ln\left(\hat{R}_t\right)\right]^2}{2\sigma_R^2}\right)$$

The second component of the likelihood takes into account the fact that the initial population size, here taken to be the estimate of the 1960 mature female biomass, is allowed to vary from the expected pristine female spawning biomass (B_0). Because the fishing mortality prior to this time is considered slight, then it is unreasonable that the B_{1960} level should deviate to extremes from the estimated B_0. This gives rise to a second likelihood component to the stock-recruitment objective function as

$$3) \qquad \frac{1}{\sqrt{2\pi\sigma_B^2}}\exp\left(-\frac{\left[\ln(B_{1960})-\ln(B_0)\right]^2}{2\sigma_{B_0}^2}\right)$$

where σ_B is the CV of the ratio of the 1960 biomass and the average pristine level (B_0). The value for σ_B was estimated to be 0.21 based on 100 simulations of 75 years into the future with no fishing. The estimated value of σ_R^2, and the mortality and growth assumptions presented in Heifetz and Ianelli (1992).

8.2.2. BAYESIAN POSTERIOR DISTRIBUTION

The total likelihood for the stock recruitment model can be expressed as a function of the data, X (consisting of stock and recruitment estimates), and two free parameters, A and R_0. As the goal of this exercise is to assign probabilities to hypotheses on the A parameter, Bayes theorem is used. The probability of a single A parameter value is thus attained by the marginal distribution of the joint Bayesian posterior distribution:

$$4) \qquad P\{A,R_0|X\} = \frac{P\{X|A,R_0\}P\{A,R_0\}}{\sum_{R_0}\sum_{A} P\{X|A,R_0\}P\{A,R_0\}}$$

$$5) \qquad P\{A|X,R_0\} = \sum_{R_0} P\{A,R_0|X\}$$

where $P\{X|A,R_0\}$ is the probability based on the joint likelihood function of A and R_0, and $P\{A,R_0\}$ represents the prior probability of the hypothesis, here taken to be uniform on the interval A=*(0.3, 1.0)* and R_0=*(30 000, 100 000)*.

The joint density of R_0 and A is shown in Fig. 25. The marginal of the posterior distribution showing the relative probabilities of different A values is given in Fig. 26. These values are used to calculate the expected values. For example, to determine the level of F_{msy}, yield curves were calculated for each value of the A parameter and the results weighted by the probability of each A parameter, to compute the expected yield curve.

8.3. Sensitivity Analysis

8.3.1. AGE AT MATURITY

Heifetz and Ianelli (1992) examined the effect of uncertainty on age at maturity for Pacific ocean perch in the Gulf of Alaska. They showed that the $F_{35\%}$ rate is sensitive to the maturity schedule. If the fish mature, on average, at older ages than the schedule that was used in the assessment then the fishing mortality rate will be too high. To illustrate this effect on the proposed fishing mortality rate, stock projection simulations using an older age at maturity schedule were run. The alternative maturity schedule is shown compared to the assumed schedule in Fig. 27.

Results from this analysis indicate that mis-specification of the maturity schedule under Policy 2 does not affect the rate of increase in spawner biomass drastically (Fig. 28). This indicates that the refined fishing mortality rate is relatively robust to errors in maturity-at-age specifications. It should be noted that the estimate of spawner biomass in the early 1960's is affected by the maturity schedule. That is, if an older maturity-at-age schedule is applied then the magnitude of the female spawner biomass that generated the strong year classes during this period will be less. Also, the estimated level of average unfished spawning biomass and the biomass which maximizes yield will be less for older maturity-at-age schedules.

8.3.2. ALTERNATIVE ASSESSMENT MODELS

The Council SSC addressed concern that the estimated stock recruitment parameters may be sensitive to alternative assumptions about the assessment model. Heifetz and Ianelli (1992) presented three alternative assessment models by changing the statistical weighting on the triennial biomass surveys. They chose a range of models that had roughly equal trade-offs in overall fit to all available data. These models ranged from a pessimistic scenario about current biomass, the base-case scenario used in this analysis, and an optimistic scenario of current biomass. The estimates of spawning stock and recruitment between these alternatives vary slightly (Fig. 29).

8.3.3. THE EFFECT OF PERFECT INFORMATION

In this analysis we have based our projections on perfect knowledge of the stock condition (i.e. current biomass) to set ABC's for a given policy. In reality, future stock levels will continue to be uncertain. To incorporate this uncertainty in our projections, we added an observation error to the current true biomass in each year which is a function of the estimated biomass in previous years and new information. This can be modeled as:

$$\hat{B}_{t+1} = \hat{B}_t\alpha + (1-\alpha)(B_{t+1} + \varepsilon_t), \quad \text{for } \hat{B}_{t+1} > \hat{B}_t e^{-(F_t+M)}$$

$$\hat{B}_{t+1} = \hat{B}_t e^{-(F_t+M)}, \quad \text{for } \hat{B}_{t+1} < \hat{B}_t e^{-(F_t+M)}$$

$$\varepsilon_t \sim N(0, \sigma_B^2)$$

Where B_{t+1} is the true biomass in the next year, $\hat{B}_t$ is the observed (through a stock assessment model) biomass in the current year, σ_B^2 is the variance of typical survey information, and α is the weight given to past stock assessment estimates relative to new

survey information. Note that the observed biomass is not allowed to decrease at a rate greater than that indicated by the forces of natural and fishing mortality. This feature essentially truncates the amount of decline possible. The goal of this exercise is to have a simple method of mimicking future assessment processes used to set quotas. For preliminary investigations α was given a value of 0.5; the value for σ_B^2 was set to give a coefficient of variation in $\hat{B}_t$ of 0.3.

Results from this analysis indicate that for the policies with the lower exploitation rate, the number of years required to rebuild in 50% of the simulations increases and that at the end of thirty years, the proportion of runs that have actually rebuilt is much less (Fig. 30). The outcomes for Policies 1 and 2, however, are only slightly different than the case when perfect information was assumed. This indicates that policies 3 and 4 would be more difficult to implement given the goals as defined. This analysis does not take into account the effect of learning over time under the different policies. Assuming that information on the stock is related to the amount of observer coverage, and that observer coverage is related to the level of fishing, then one could conclude that more information and hence, understanding of the stock condition would be available under policies with higher quotas.

9. APPENDIX B. CATCH/REVENUE TABLES FOR VESSELS WHICH TARGETED ON POP

Table B-1. --Catch composition of vessels which targeted on POP during 1992.

Total metric tons of groundfish retained, in 1992, from each species group in GOA fisheries

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
POP	4,101	178	125	485	34	58	77
Rockfish	163	609	90	5,472	11	209	44
Pacific cod	0	0	305	21	0	44	0
Flatfish	3	39	77	57	3	875	0
Pollock	1	0	1	1	2	2	1
Other species	306	2	197	109	22	29	6,010

Average metric tons of groundfish retained, per vessel, from each species group in GOA fisheries

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
Vessels with less than 6% of total revenue from POP-target species (6)							
POP	58	2	6	6	2	2	6
Rockfish	20	37	2	322	1	4	6
Pacific cod	0	0	104	9	0	11	0
Flatfish	1	17	27	25	1	389	0
Other species	62	0	58	28	4	7	1,197
Vessels with more than 6% of total revenue from POP-target species (6)							
POP	626	28	15	74	4	8	7
Rockfish	9	77	16	707	1	37	2
Pacific cod	0	0	33	1	0	7	0
Flatfish	0	2	8	2	0	32	0
Pollock	1	0	1	1	2	2	1
Other species	40	0	8	8	3	3	807

	1992 percentage of total revenue from POP-target weeks using:		Species composition of retained catch during 1992 POP-target weeks in the GOA				
Vessel group	1991 prices	1992* prices	POP	Sable-fish	Pacific cod	Rock-fish	Other species
Vessels with less than 6% of total revenue from POP-target species (6)							
Minimum	0.2%	0.3%	57.7%	0.0%	0.0%	1.8%	0.0%
Mean	0.8%	1.0%	73.1%	2.4%	6.9%	8.1%	9.5%
Maximum	1.6%	2.3%	82.5%	12.0%	13.3%	25.3%	17.5%
Vessels with more than 6% of total revenue from POP-target species (6)							
Minimum	6.3%	7.7%	42.4%	2.0%	0.0%	1.3%	0.0%
Mean	10.6%	14.3%	77.1%	4.4%	2.1%	14.1%	2.3%
Maximum	13.2%	16.9%	88.9%	10.3%	4.0%	43.6%	6.5%
All POP-target vessels							
Mean	5.7%	7.7%	75.1%	3.4%	4.5%	11.1%	5.9%

Source: NMFS Trade and Industry Services, Northwest Region.

Table B-2. --Estimated revenue earned from various species groups in 1992 by vessels which targeted POP, based on informal 1992 price estimates.

Total 1992 groundfish revenue earned from each species group (using 1992* prices)

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
POP	$ 4,555,318	$ 705,019	$ 112,084	$1,510,684	$ 66,507	$ 77,987	$ 59,936
Rockfish	$ 173,037	$2,386,686	$ 77,287	$7,642,168	$ 6,605	$ 211,354	$ 34,742
Pacific cod	$ 314	$ 247	$ 302,794	$ 21,816	0	$ 112,765	0
Flatfish	$ 3,037	$ 153,432	$ 76,357	$ 192,729	$ 2,058	$1,537,664	0
Pollock	$ 1,550	$ 247	$ 1,447	$ 4,357	$ 4,717	$ 1,870	$ 191
Other species	$ 366,724	$ 8,457	$ 186,382	$ 198,606	$ 22,732	$ 27,528	$5,376,241

Average 1992 groundfish revenue, per vessel, from each species group (using 1992* prices)

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
Vessels with less than 6% of total revenue from POP							
POP	$ 63,205	$ 6,379	$ 5,161	$ 19,451	$ 4,998	$ 3,055	$ 4,853
Rockfish	$ 21,244	$ 145,641	$ 1,853	$ 421,143	$ 633	$ 5,118	$ 4,915
Pacific cod	$ 63	0	$ 109,667	$ 8,107	0	$ 21,704	0
Flatfish	$ 1,518	$ 67,840	$ 28,752	$ 84,248	$ 1,029	$ 686,008	0
Other species	$ 71,753	$ 1,955	$ 55,395	$ 55,786	$ 4,891	$ 6,160	$1,033,189
Vessels with more than 6% of total revenue from POP							
POP	$ 696,015	$ 111,125	$ 13,519	$ 232,330	$ 6,087	$ 9,943	$ 5,136
Rockfish	$ 9,115	$ 302,568	$ 13,233	$1,023,061	$ 562	$ 36,129	$ 1,050
Pacific cod	$ 63	$ 82	$ 27,820	$ 1,867	0	$ 23,119	0
Flatfish	0	$ 5,917	$ 6,285	$ 8,078	0	$ 55,216	0
Pollock	$ 1,550	$ 247	$ 1,447	$ 4,357	$ 4,717	$ 1,870	$ 191
Other species	$ 50,488	$ 864	$ 6,732	$ 10,416	$ 2,686	$ 3,016	$ 758,892

* 1991 prices are take directly from the NMFS Trade and Industry Services Processed Products Survey for 1991. In the "1992" price set, any of the 1991 prices are adjusted based on an informal survey of industry participants by the NMFS Alaska Region.

Table B-3. --Estimated revenue earned from various species groups in 1992 by vessels which targeted POP, based on 1991 survey prices.

Total 1992 groundfish revenue earned from each species group (using 1991* prices)

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
POP	$ 2,719,358	$ 689,261	$ 117,948	$ 908,287	$ 32,594	$ 63,759	$ 96,718
Rockfish	$ 108,598	$2,344,589	$ 81,893	$5,746,082	$ 4,472	$ 156,333	$ 62,155
Pacific cod	$ 200	$ 243	$ 316,026	$ 16,917	0	$ 93,341	0
Flatfish	$ 1,933	$ 150,728	$ 78,916	$ 103,510	$ 2,058	$1,364,894	0
Pollock	$ 987	$ 243	$ 1,529	$ 2,401	$ 2,173	$ 1,012	$ 191
Other species	$ 201,501	$ 8,182	$ 190,812	$ 135,567	$ 17,440	$ 16,999	$7,297,626

Average 1992 groundfish revenue, per vessel, from each species group (using 1991* prices)

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
Vessels with less than 6% of total revenue from POP-target species (6)							
POP	$ 38,470	$ 6,261	$ 5,337	$ 10,919	$ 2,597	$ 2,591	$ 10,770
Rockfish	$ 13,286	$ 143,059	$ 1,890	$ 346,627	$ 468	$ 4,251	$ 8,710
Pacific cod	$ 40	0	$ 113,688	$ 6,628	0	$ 18,865	0
Flatfish	$ 967	$ 66,643	$ 29,405	$ 45,205	$ 1,029	$ 605,169	0
Other species	$ 40,830	$ 1,895	$ 56,445	$ 36,764	$ 3,505	$ 3,496	$1,619,556
Vessels with more than 6% of total revenue from POP-target species (6)							
POP	$ 414,757	$ 108,616	$ 14,321	$ 140,462	$ 2,836	$ 8,035	$ 5,349
Rockfish	$ 5,777	$ 297,247	$ 14,110	$ 733,264	$ 333	$ 26,165	$ 1,979
Pacific cod	$ 40	$ 81	$ 29,550	$ 1,220	0	$ 18,537	0
Flatfish	0	$ 5,814	$ 6,702	$ 4,366	0	$ 51,519	0
Pollock	$ 987	$ 243	$ 1,529	$ 2,401	$ 2,173	$ 1,012	$ 191
Other species	26,337	832	7,159	8,425	2,308	2,170	812,986

* 1991 prices are take directly from the NMFS Trade and Industry Services Processed Products Survey for 1991. In the "1992" price set, any of the 1991 prices are adjusted based on an informal survey of industry participants by the NMFS Alaska Region.

Table B-4.--Estimated shares of revenue for 1992 POP-target weeks from various species groups.

Vessel group	1992 % of total revenue from POP-target weeks using: 1992* prices	Percentage of 1992 revenue (using 1992* prices) from various species/groups caught during POP-target weeks: POP	Sable-fish	Pacific cod	Rock-fish	Other species	Revenue from all species during POP target weeks
Vessels with less than 6% of total revenue from POP-target species (6)							
Minimum	0.3%	34.0%	0.0%	0.0%	6.1%	0.0%	$ 36,931
Mean	1.0%	60.7%	6.7%	4.9%	17.4%	10.2%	$ 107,102
Maximum	2.3%	77.8%	33.1%	10.9%	53.0%	20.5%	$ 317,832
Vessels with more than 6% of total revenue from POP-target species (6)							
Minimum	7.7%	19.0%	6.1%	0.0%	2.0%	0.0%	$ 160,289
Mean	14.3%	63.2%	11.0%	1.3%	22.5%	2.1%	$ 1,074,154
Maximum	16.9%	79.6%	17.3%	2.5%	61.9%	5.8%	$ 2,074,477
All POP-target vessels							
Mean	7.7%	62.0%	8.9%	3.1%	20.0%	6.1%	$ 590,628

Vessel group	1992 percentage of total revenue from POP using: 1991 prices	Percentage of 1992 revenue (using 1991* prices) from various species/groups caught during POP target weeks: POP	Sable-fish	Pacific cod	Rock-fish	Other species	Revenue from all species during POP target weeks
Vessels with less than 6% of total revenue from POP-target species (6)							
Minimum	0.2%	31.8%	0.0%	0.0%	4.8%	0.0%	$ 25,137
Mean	0.8%	53.4%	8.9%	7.8%	15.6%	14.3%	$ 76,945
Maximum	1.6%	67.8%	42.7%	17.8%	50.5%	29.6%	$ 245,169
Vessels with more than 6% of total revenue from POP-target species (6)							
Minimum	6.3%	18.5%	9.3%	0.0%	1.9%	0.0%	$ 110,185
Mean	10.6%	58.5%	16.2%	2.0%	20.9%	2.4%	$ 694,376
Maximum	13.2%	73.7%	26.1%	3.9%	52.6%	6.8%	$ 1,348,945
All POP target vessels							
Mean	5.7%	56.0%	12.5%	4.9%	18.2%	8.4%	$ 385,660

* 1991 prices are take directly from the NMFS Trade and Industry Services Processed Products Survey for 1991. In the "1992" price set, any of the 1991 prices are adjusted based on an informal survey of industry participants by the NMFS Alaska Region.

Table B-5. --Catch composition of vessels which targeted on POP during 1991.

Total metric tons of groundfish retained, in 1991, from each species group in GOA fisheries

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
POP	4,452	400	142	903	26	213	26
Rockfish	205	456	128	4,577	76	221	7
Sablefish	110	153	7	118	0	37	0
Pacific cod	27	22	809	38	12	142	1
Flatfish	154	322	390	379	204	3,036	15
Pollock	89	67	53	66	2,962	207	2
Other species	28	0	64	13	0	3	1,702

Average metric tons of groundfish retained, per vessel, from each species group in GOA fisheries

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
Vessels with less than 6% of total revenue from POP-target species (11)							
POP	88	8	11	15	2	7	2
Rockfish	16	55	18	581	11	26	1
Sablefish	0	31	6	18	0	9	0
Pacific cod	4	3	115	5	2	20	0
Flatfish	18	35	46	30	25	282	1
Pollock	15	11	9	11	494	35	0
Other species	5	0	0	0	0	0	14
Vessels with more than 6% of total revenue from POP-target species (6)							
POP	581	51	3	123	0	23	1
Rockfish	23	17	1	128	0	10	1
Sablefish	37	41	0	33	0	9	0
Pacific cod	0	0	2	0	0	0	0
Flatfish	3	8	5	28	0	156	2
Other species	11	0	32	6	0	2	844

Source: NMFS Trade and Industry Services, Northwest Region.

Table B-6. --Estimated revenue earned from various species groups in 1991 by vessels which targeted POP.

Target for week/area	POP	Sablefish	Pacific cod	Rockfish	Pollock	Flatfish	Other
Total 1991 groundfish revenue earned from each species group in GOA fisheries							
POP	$2,993,566	$1,530,828	$ 159,652	$1,495,325	$ 9,785	$ 166,852	$ 36,305
Rockfish	$ 149,779	$1,749,599	$ 137,405	$5,530,331	$ 21,517	$ 195,310	$ 8,944
Sablefish	$ 73,478	$ 603,295	$ 8,079	$ 229,003	0	$ 21,320	0
Pacific cod	$ 17,773	$ 85,502	$ 860,274	$ 53,387	$ 4,334	$ 180,705	$ 2,016
Flatfish	$ 123,858	$1,233,191	$ 422,331	$ 675,297	$ 81,676	$3,926,298	$ 4,343
Pollock	$ 59,332	$ 255,516	$ 57,627	$ 118,169	$1,520,419	$ 203,573	$ 446
Other species	$ 18,413	0	$ 70,097	$ 10,467	$ 131	$ 2,186	$3,006,766
Average 1991 groundfish revenue, per vessel, from each species group in the GOA							
Vessels with less than 6% of total revenue from POP-target species (11)							
POP	$ 59,437	$ 32,352	$ 12,697	$ 26,011	$ 890	$ 7,607	$ 3,146
Rockfish	$ 12,662	$ 211,962	$ 19,213	$ 683,729	$ 3,074	$ 23,362	$ 1,194
Sablefish	0	$ 118,463	$ 7,929	$ 16,042	0	$ 11,116	0
Pacific cod	$ 2,539	$ 12,180	$ 122,383	$ 7,534	$ 619	$ 25,773	$ 237
Flatfish	$ 14,421	$ 133,938	$ 49,629	$ 54,687	$ 10,210	$ 373,023	$ 165
Pollock	$ 9,889	$ 42,586	$ 9,605	$ 19,695	$ 253,403	$ 33,929	$ 74
Other species	$ 3,440	0	$ 470	0	0	0	$ 22,512
Vessels with more than 6% of total revenue from POP target species (6)							
POP	$ 389,960	$ 195,826	$ 3,332	$ 201,533	0	$ 13,863	$ 283
Rockfish	$ 15,286	$ 66,466	$ 729	$ 186,058	0	$ 7,944	$ 146
Sablefish	$ 24,493	$ 161,611	$ 50	$ 70,987	0	$ 3,402	0
Pacific cod	0	$ 121	$ 1,796	$ 323	0	$ 148	$ 177
Flatfish	$ 1,699	$ 32,338	$ 5,059	$ 47,560	0	$ 188,423	$ 605
Other species	$ 7,486	0	$ 34,813	$ 5,233	$ 66	$ 1,093	$1,492,127

Source: NMFS Trade and Industry Services, Northwest Region.

Table B-7. --Estimated shares of revenue for 1991 POP-target weeks from various species groups.

Vessel group	1991 % of total revenue from POP-target weeks	Percentage of 1991 revenue from various species/groups caught during POP-target weeks: POP	Sable-fish	Pacific cod	Rock-fish	Other species	Revenue from all species during POP target weeks
Vessels with less than 6% of total revenue from POP-target species (11)							
Minimum	0.1%	9.3%	0.0%	0.0%	0.0%	0.0%	$ 9,318
Mean	1.6%	47.0%	21.4%	9.4%	14.4%	7.9%	$ 142,139
Maximum	3.2%	81.4%	77.2%	35.0%	36.0%	24.3%	$ 367,588
Vessels with more than 6% of total revenue from POP-target species (6)							
Minimum	6.1%	33.0%	2.9%	0.0%	15.0%	0.0%	$ 125,012
Mean	9.0%	52.5%	21.3%	0.3%	24.0%	1.9%	$ 804,798
Maximum	13.1%	77.5%	40.2%	1.4%	39.6%	4.4%	$ 1,383,856
All POP-target vessels							
Mean	4.2%	48.9%	21.4%	6.2%	17.8%	5.8%	$ 376,018

Vessel group	1991 % of total revenue from POP-target weeks	1991 species composition (in percent) of retained catch during POP-target weeks: POP	Sable-fish	Pacific cod	Rock-fish	Other species
Vessels with less than 6% of total revenue from POP-target species (11)						
Minimum	0.1%	18.6%	0.0%	0.0%	0.0%	0.0%
Mean	1.6%	64.4%	8.2%	7.9%	8.6%	10.9%
Maximum	3.2%	92.2%	41.8%	25.0%	25.1%	47.8%
Vessels with less than 6% of total revenue from POP-target species (6)						
Minimum	6.1%	59.5%	0.5%	0.0%	7.6%	0.0%
Mean	9.0%	74.6%	6.2%	0.3%	15.7%	3.3%
Maximum	13.1%	88.6%	12.8%	1.0%	28.8%	8.2%
All POP-target vessels						
Mean	4.2%	68.0%	7.5%	5.2%	11.1%	8.2%

Source: NMFS Trade and Industry Services, Northwest Region.

10. APPENDIX C. GLOSSARY

B_0	The average virgin or "pristine" female spawner biomass: the average female spawner biomass that would occur in the absence of fishing.
$B_{current}$	The current total biomass of mature females.
B_{msy}	The total biomass of mature females that would produce the maximum sustainable yield, on average.
B_{target}	The desired total biomass of mature females.
CV	The coefficient of variation: a measure of variability expressed as the ratio of the standard deviation over the mean.
EV	The expected value: the weighted mean of an outcome over plausible hypotheses on stock productivity.
F	The full selection instantaneous fishing mortality rate, i.e., the fishing rate applied when the fish are fully selected by the fishing gear.
$F_{35\%}$	The fishing mortality rate that will reduce the spawning biomass per recruit to 35% of the unfished level.
F_{mmy}	The fishing mortality rate that minimizes the maximum loss of sustainable yield over different plausible stock productivity relationships.
F_{msy}	The fishing mortality rate that would, on average, produce the maximum sustainable yield.
M	The instantaneous natural mortality rate.
Stock-recruitment steepness (the *A* parameter)	A parameter of the stock-recruitment relationship which controls the shape of the stock-recruitment curve. For low steepness values incremental changes in spawning stock result affect the mean recruitment level in the same direction, for high values mean recruitment levels are less sensitive to changes in the spawning stock size.

11. LIST OF FIGURES.

Figure 1. Historical estimated age composition of the catch from 1961-1992 in relative proportion.

Figure 2. Example yield curves with different levels of recruitment variability (CV).

Figure 3. Relative dollar yield (upper panel) and relative yield in weight (lower panel) under alternative values for stock recruitment parameters *A*. Clark's (1991) F_{mmy} value is represented where the lines representing high and low values for *A* cross. The optimum full-selection fishing mortality rate selected was 0.08, indicated by the vertical line.

Figure 4. Expected value of yield curves for POP showing the difference in optimum fishing mortality in terms of value and weight.

Figure 5. Expected value of relative yield vs. female spawner biomass. The previous target biomass (118,000 tons) was set to be 35% of the 1960 spawner biomass estimate; the refined target was selected as the biomass which gives the maximum yield (B_{msy}).

Figure 6. Relative yield of POP as a function of spawner biomass for different values of the *A* parameter.

Figure 7. Trajectory of expected value of yield (in tons) of POP under the four policy alternatives.

Figure 8. Trajectory of expected value of yield (in $) of POP under the four policy alternatives.

Figure 9. Present value of future expected annual yields of POP. A 7% discount rate was used.

Figure 10. Cumulative present value of future expected annual yields of POP. A 7% discount rate was used.

Figure 11. Frequency distribution of simulation runs showing the cumulative present value of the fishery (in millions) over 30 year projections for each policy alternative with no discounting (left) and with a 7% discount rate (right).

Figure 12. Trajectories of female spawner biomass relative to the 1993 estimate by policy and different hypotheses of stock-recruitment steepness (the *A* parameter).

Figure 13. Expected values of trajectories of female spawner biomass of POP relative to the 1993 estimate by policy.

Figure 14. Percent frequency distribution from 200 simulation runs of spawner biomass in the year 2013. The different shadings represent weighted contributions of alternative hypotheses on stock-recruitment steepness (the A parameter).

Figure 15. The expected value of the proportion of simulations achieving a rebuilt spawner biomass of 150,000 tons or more over time.

Figure 16. Proportion of simulations dropping below 75,000 tons of female spawner biomass over alternative hypotheses on the stock-recruitment relationship and policies.

Figure 17. The expected value of the proportion of simulations dropping below 75,000 tons of female spawner biomass for each policy.

Figure 18. The expected value of the proportion of simulations dropping below the value of $3.8 million of undiscounted revenue for each policy.

Figure 19. Expected mean age of the exploitable population under the different policy alternatives.

Figure 20. Stock-recruitment data for three north Pacific stocks of Pacific ocean perch. The units for spawner biomass and recruitment are scaled to represent the distance from the means in standard deviations.

Figure 21. Diagnostic plots testing for serial correlation and normality of the time series of recruitment (log scale). The two right-hand panels represent plots of the autocorrelation function (top), and the partial autocorrelation function (bottom). The dotted lines indicated significance levels at each lag.

Figure 22. Stock recruitment data and Beverton-Holt curves for different values of the A parameter. Note that the vertical axis is scaled logaritmically.

Figure 23. An example of simulated stock recruitment data used in the stock projections model. In this case $A = 0.671$, with a CV of recruitment set to 1.08.

Figure 24. Selectivity at age pattern for the recent fishery estimated by Heifetz and Ianelli (1992). Parameter values for P1-P4 are 13.22, 0.39, 0.04, and 0.10, respectively.

Figure 25. Joint likelihood surface for the stock recruitment parameters R_0 and A.

Figure 26. Posterior probability distribution of the density dependence parameter A, integrated over the range of R_0 values.

Figure 27. Alternative maturity schedule used to evaluate the effect on stock projections.

Figure 28. The effect of an alternative maturation schedule on relative spawner biomass increase under policy alternative 2.

Figure 29. Stock-recruitment estimates under the 3 alternative assessment models presented in Heifetz and Ianelli (1992).

Figure 30. Proportion of simulations achieving a rebuilt spawner biomass of 150,000 tons or more by year and policy when uncertainty in future biomass levels is incorporated.

12. ADDENDUM I.

At the April Council meeting the AP requested an additional presentation showing the actual catches in recent history with the ABC's that would have resulted by applying each of the 4 policy options to both the perceived biomass in the year the ABC was established and the current (1992) estimate of what the biomass was for this period. To carry out this task the estimated biomass in either case was simply multiplied by the exploitation rate for each policy in 1993. In reality, The exploitation rates can change within a single policy because of age-specific fishing mortality rates, however, for the purpose of this presentation the exploitation rate was assumed to be constant and fixed at the 1993 exploitation rate. The results for each policy based on the perceived biomass in the years 1986-1993 are presented in table A1. The ABC's by policy for the *current* estimate of what the biomass had been is given in table A2. It should be noted that the ABC's and biomass estimates for some of the years in table A1 were calculated based on different survey information and assessment models.

Table A1. ---ABC's by policy based on perceived (in each year) biomass for the years 1986-1993. Biomass units are tons of POP aged 6 years and older, exploitation rates are based on the 1992 estimates for each policy.

			Actual	ABC's by Policy			
Year	Perceived Biomass	ABC*	Estimated Catch**	Policy 1 0.031	Policy 2 0.022	Policy 3 0.014	Policy 4 0.014
1986	335,000	6,500	2,200	10,385	7,370	4,690	4,690
1987	335,000	6,500	4,500	10,385	7,370	4,690	4,690
1988	352,800	7,500	8,540	10,937	7,762	4,939	4,939
1989	328,500	9,360	11,780	10,184	7,227	4,599	4,599
1990	328,500	8,213	13,090	10,184	7,227	4,599	4,599
1991	229,139	5,800	6,100	7,103	5,041	3,208	3,208
1992	229,139	5,730	6,000	7,103	5,041	3,208	3,208
1993	153,500	3,378		4,734	3,378	2,107	2,100

*For 1986-1990 POP was managed within the POP complex or slope assemblage. Thus the ABC's for 1986-90 period are what would have been if POP had been managed separately.

**Catches during 1985-90 are based on catch estimates obtained from species compositions obtained from the observer programs.

Table A2. ---ABC's by policy based on the current model estimate (presented in the 1992 SAFE document) of biomass for the years 1986-1993. Biomass units are tons of POP aged 6 years and older, exploitation rates are based on the 1992 estimates for each policy.

Year	1992 Model Estimate of Biomass	ABC*	Actual Estimated Catch**	ABC's by Policy			
				Policy 1 0.031	Policy 2 0.022	Policy 3 0.014	Policy 4 0.014
1986	117,329	6,500	2,200	3,637	2,581	1,643	1,643
1987	120,455	6,500	4,500	3,734	2,650	1,686	1,686
1988	126,703	7,500	8,540	3,928	2,787	1,774	1,774
1989	132,760	9,360	11,780	4,116	2,921	1,859	1,859
1990	141,275	8,213	13,090	4,380	3,108	1,978	1,978
1991	137,822	5,800	6,100	4,272	3,032	1,930	1,930
1992	140,698	5,730	6,000	4,362	3,095	1,970	1,970
1993	153,500	3,378		4,734	3,378	2,107	2,100

*For 1986-1990 POP was managed within the POP complex or slope assemblage. Thus the ABC's for 1986-90 period are what would have been if POP had been managed separately.

**Catches during 1985-90 are based on catch estimates obtained from species compositions obtained from the observer programs.

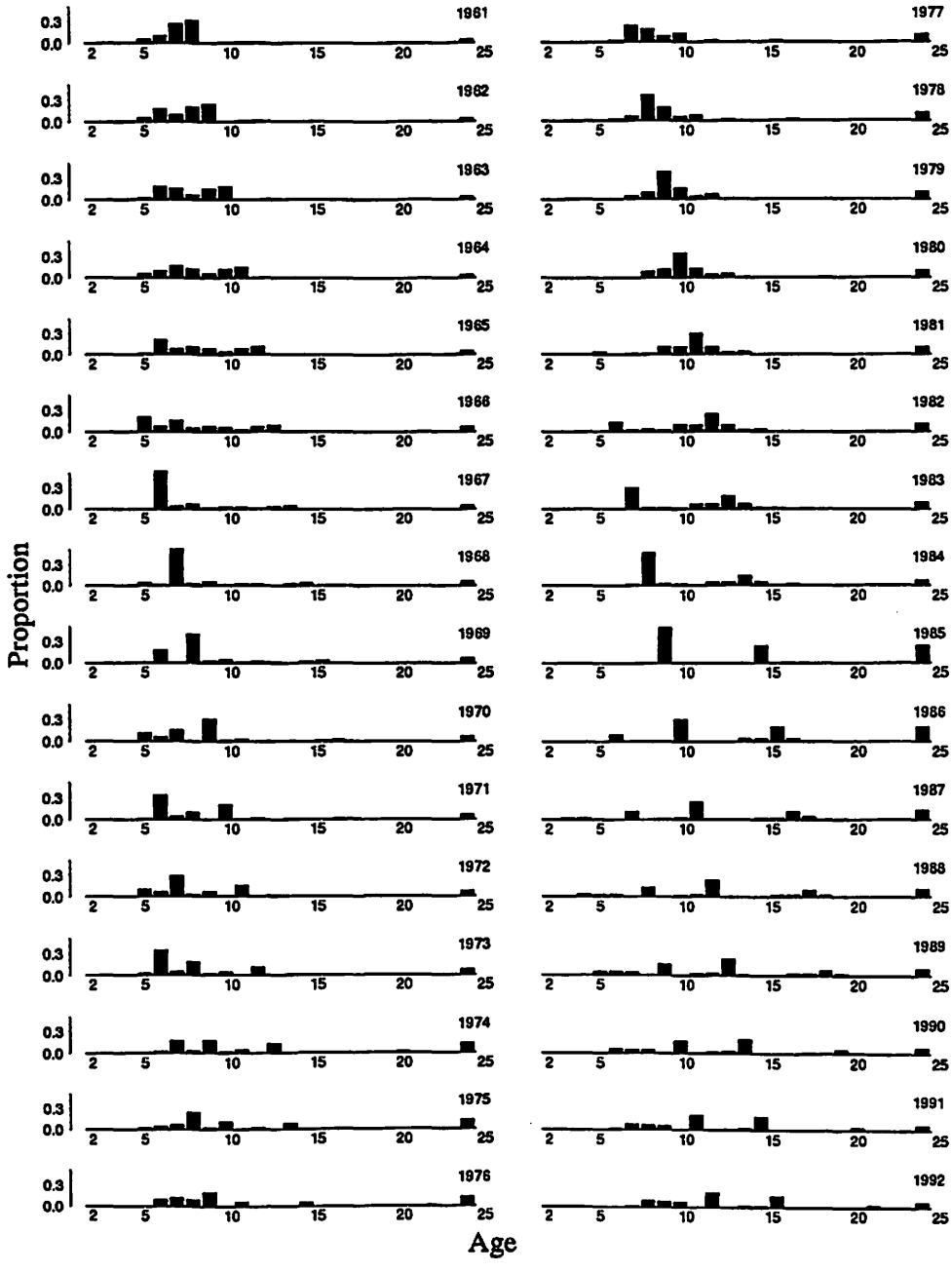

Figure 1. Historical estimated age composition of the catch from 1961-1992 in relative proportion.

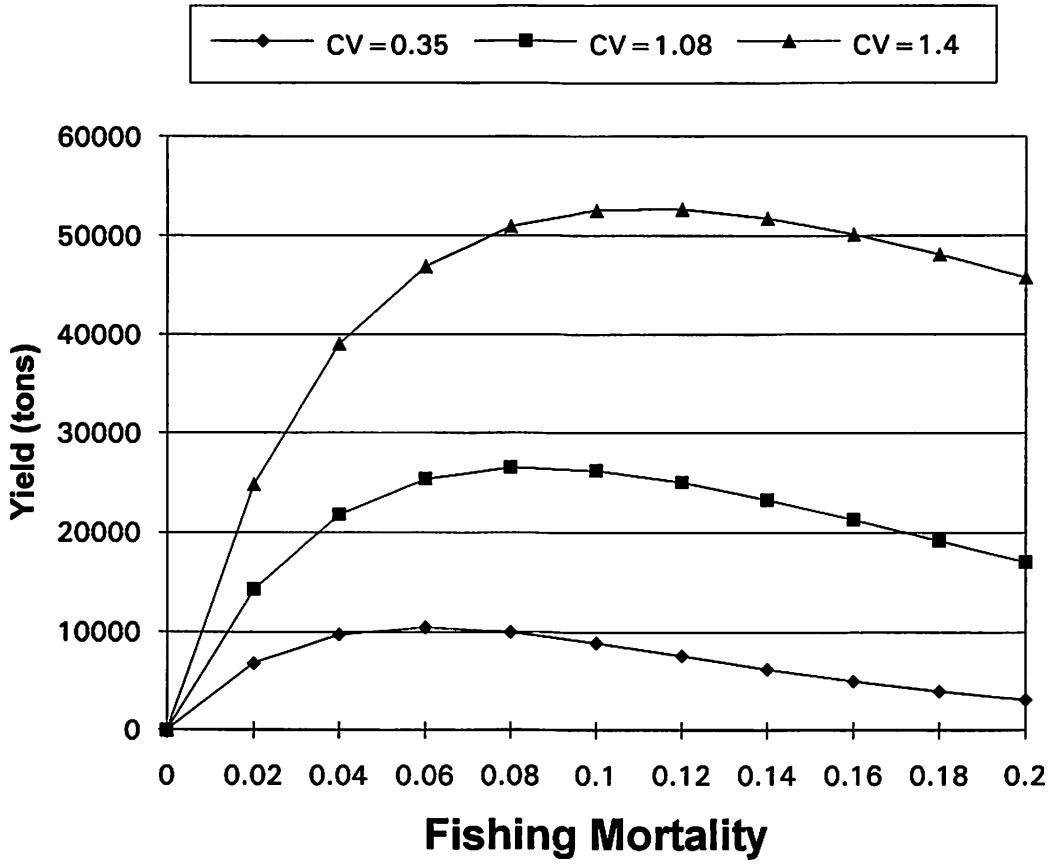

Figure 2. Example yield curves with different levels of recruitment variability (CV).

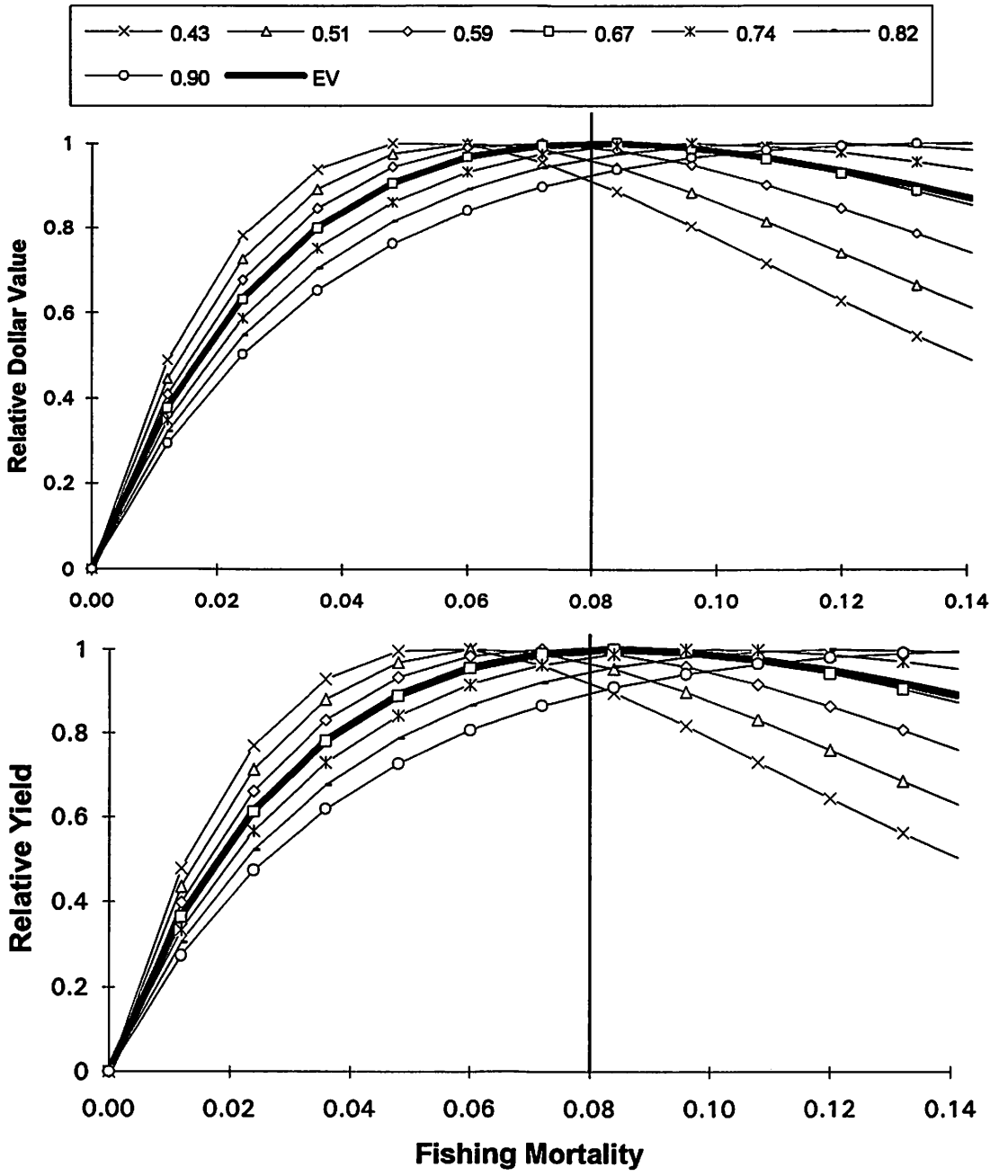

Figure 3. Relative dollar yield (upper panel) and relative yield in weight (lower panel) under alternative values for stock recruitment parameters *A*. Clark's (1991) F_{mmy} value is represented where the lines representing high and low values for *A* cross. The optimum full-selection fishing mortality rate selected was 0.08, indicated by the vertical line.

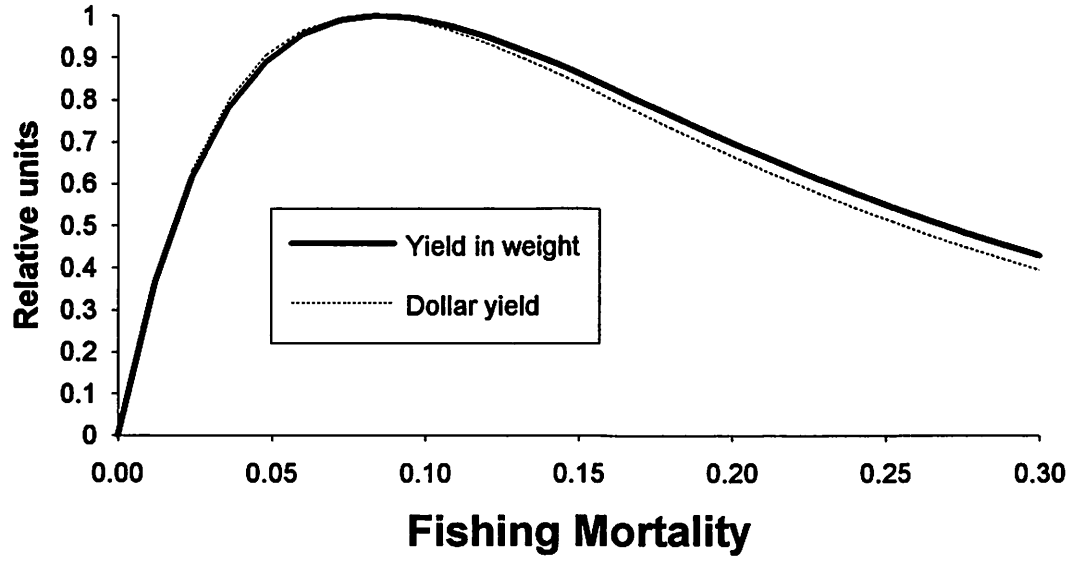

Figure 4. Expected value of yield curves for POP showing the difference in optimum fishing mortality in terms of value and weight.

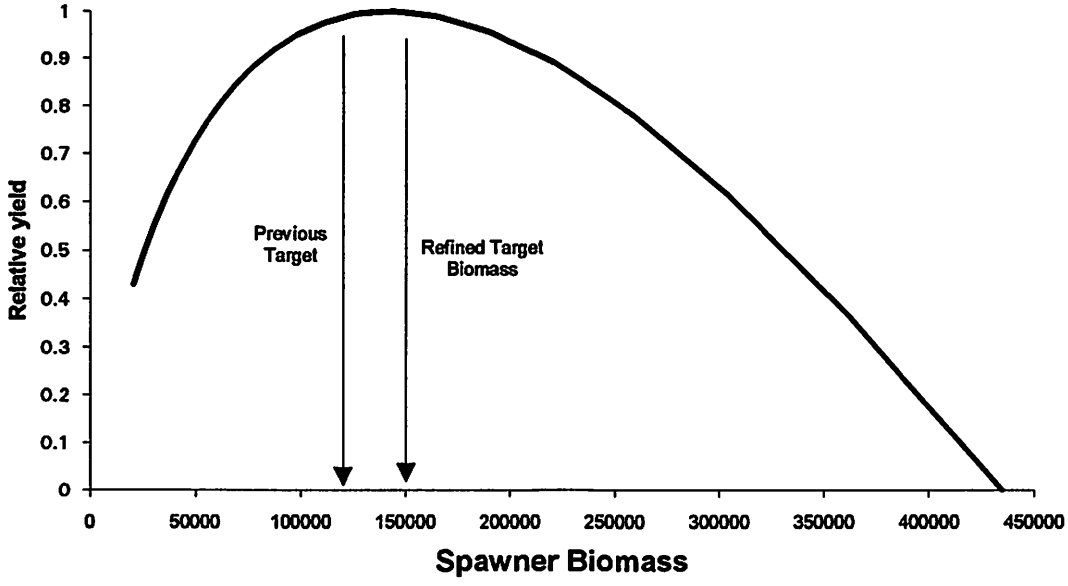

Figure 5. Expected value of relative yield vs female spawner biomass. The previous target biomass (118,000 tons) was set to be 35% of the 1960 spawner biomass estimate; the refined target was selected as the biomass which gives the maximum yield (B_{msy}).

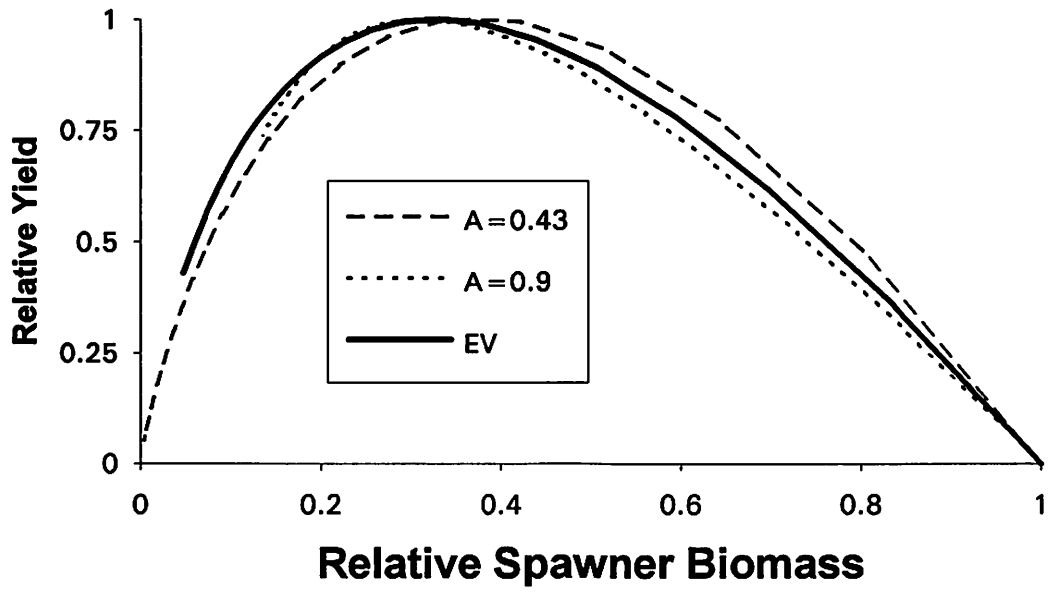

Figure 6. Relative yield of POP as a function of spawner biomass for different values of the *A* parameter.

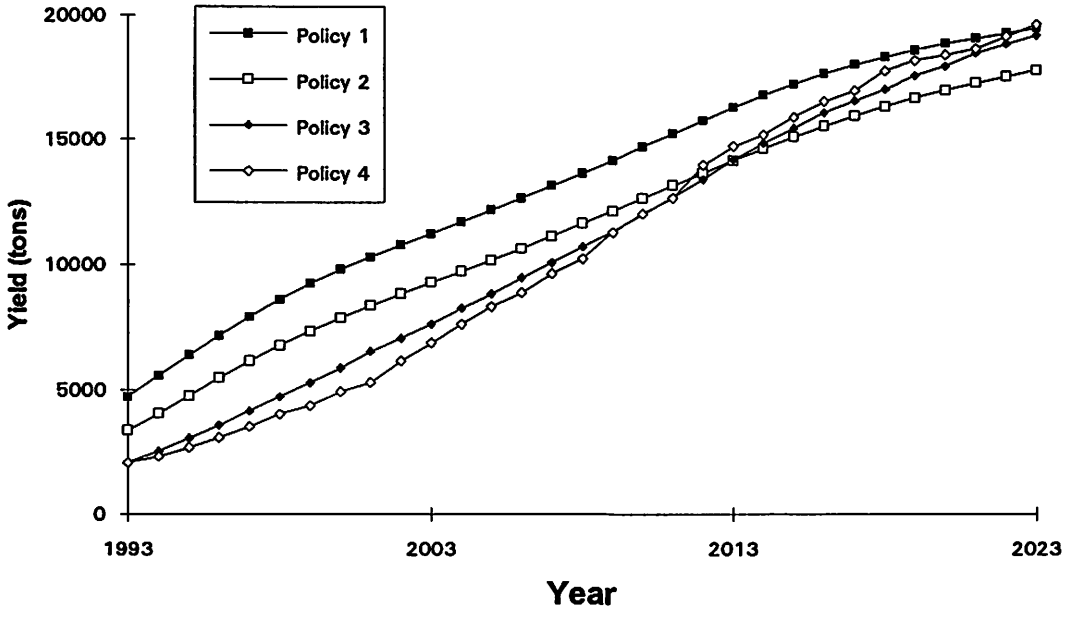

Figure 7. Trajectory of expected value of yield (in tons) of POP under the four policy alternatives.

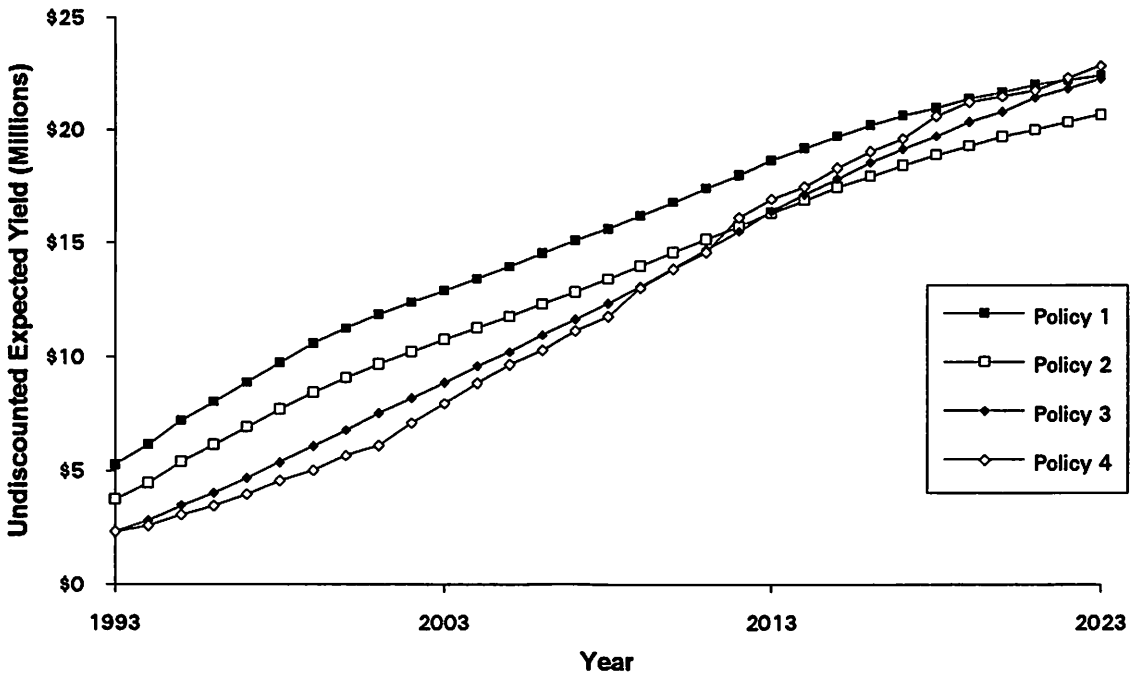

Figure 8. Trajectory of expected value of yield (in $) of POP under the four policy alternatives.

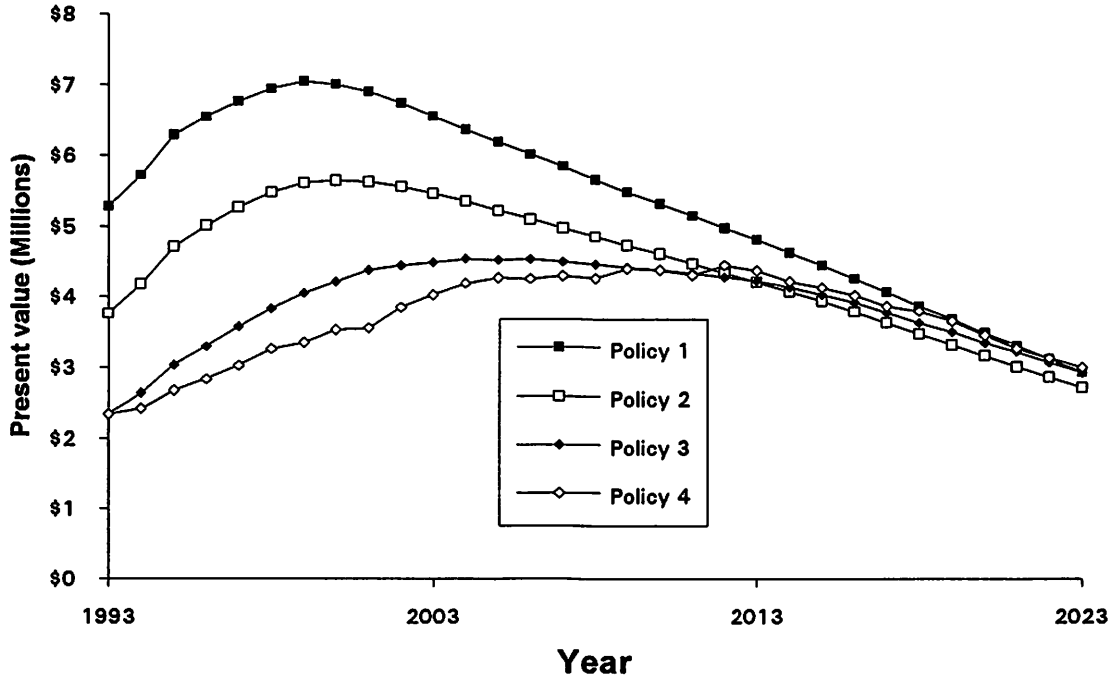

Figure 9. Present value of future expected annual yields of POP. A 7% discount rate was used.

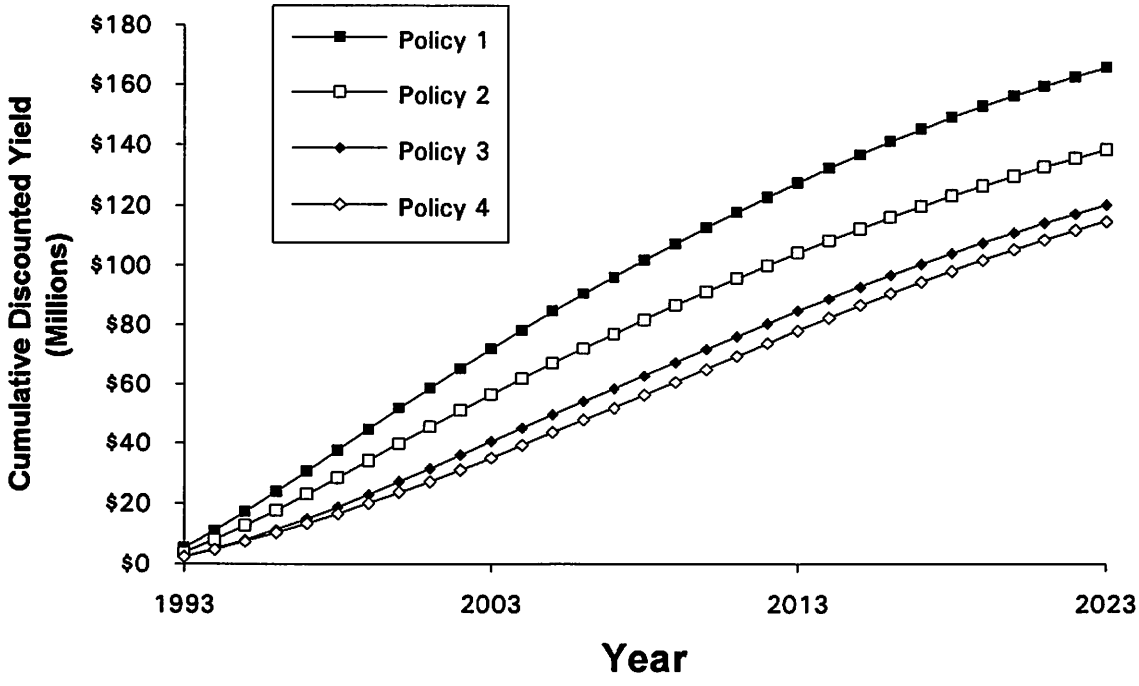

Figure 10. Cumulative present value of future expected annual yields of POP. A 7% discount rate was used.

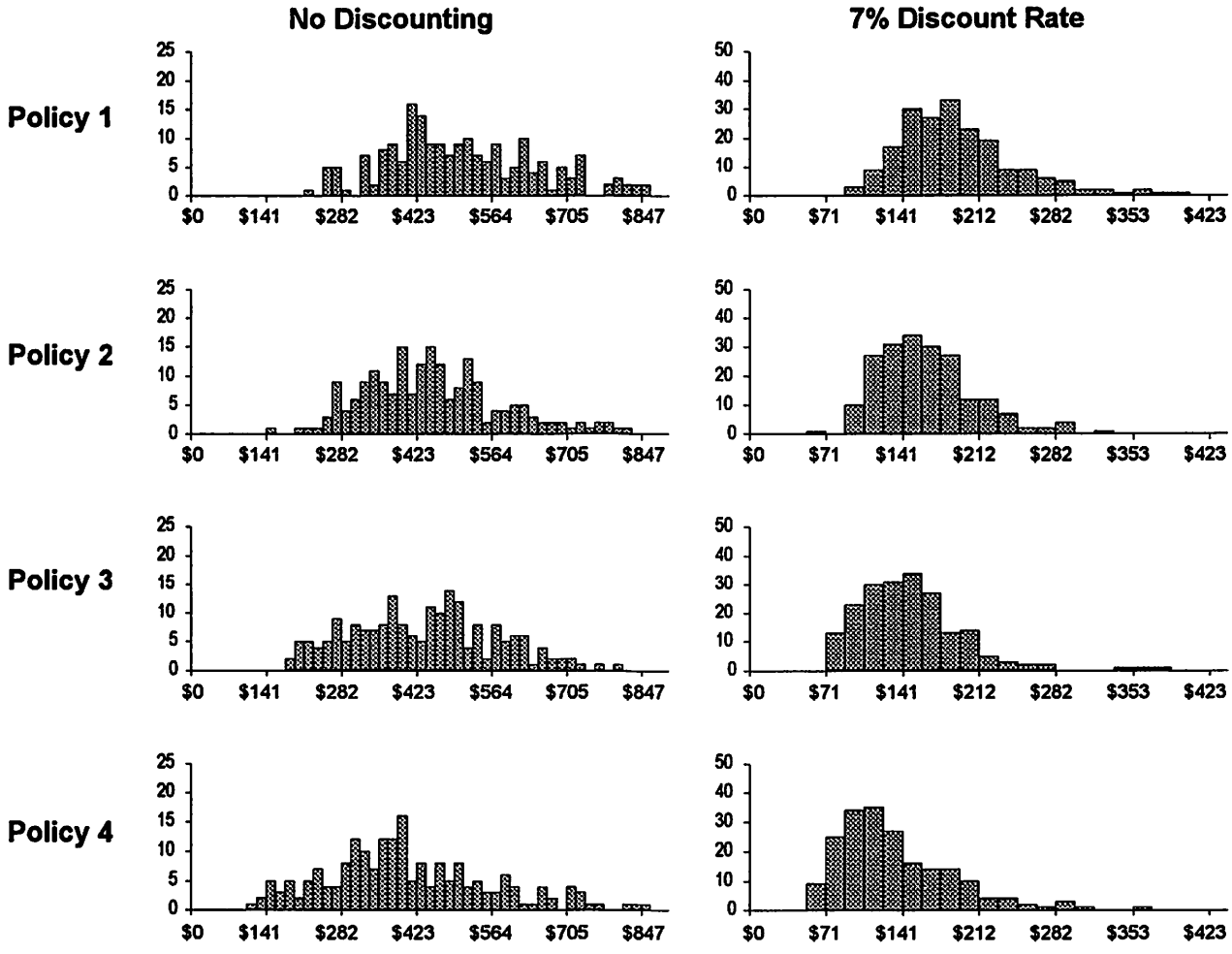

Figure 11. Frequency distribution of simulation runs showing the cumulative present value of the fishery (in millions) over 30 year projections for each policy alternative with no discounting (left) and with a 7% discount rate (right).

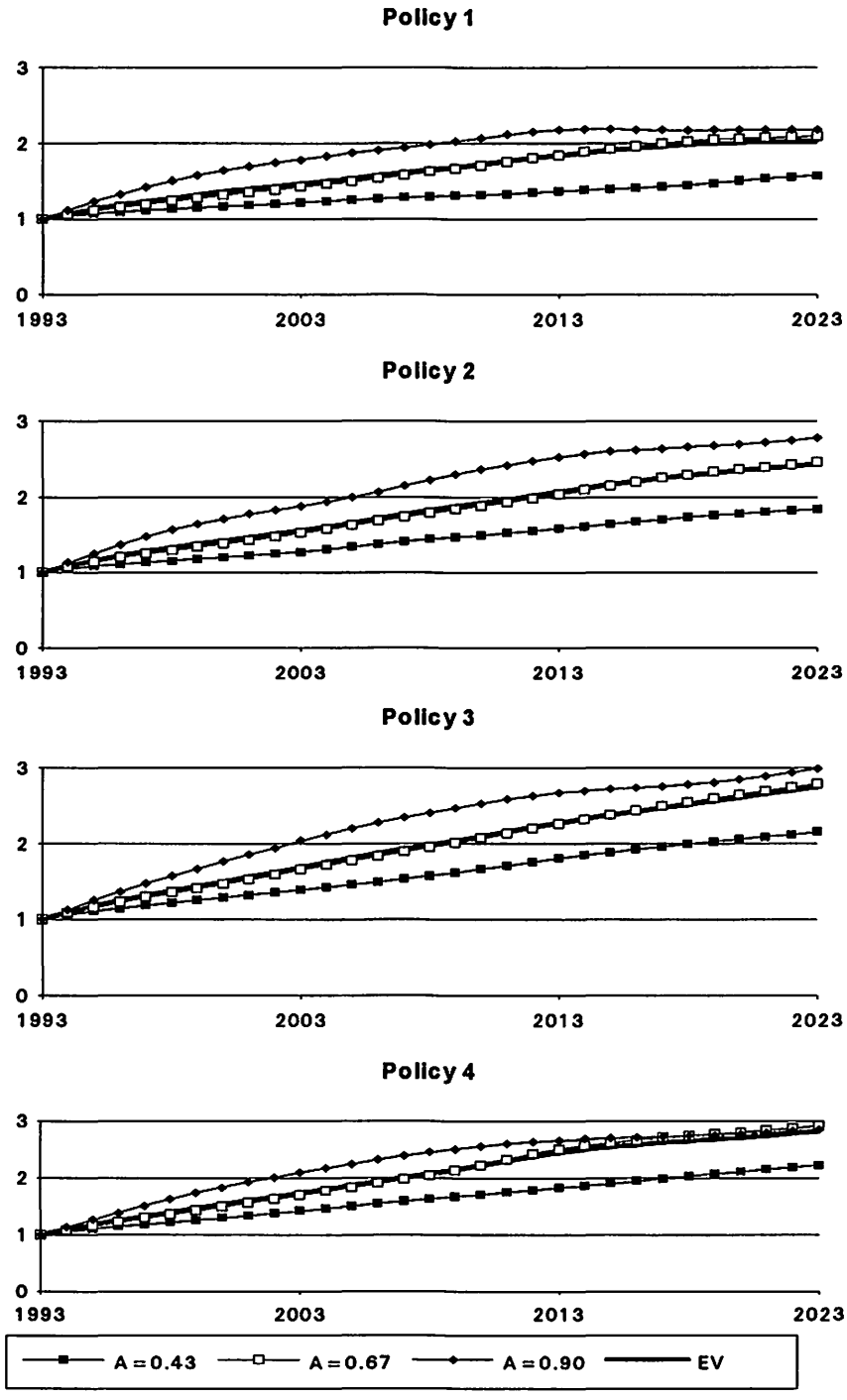

Figure 12. Trajectories of female spawner biomass relative to the 1993 estimate by policy and different hypotheses of stock-recruitment steepness (the *A* parameter).

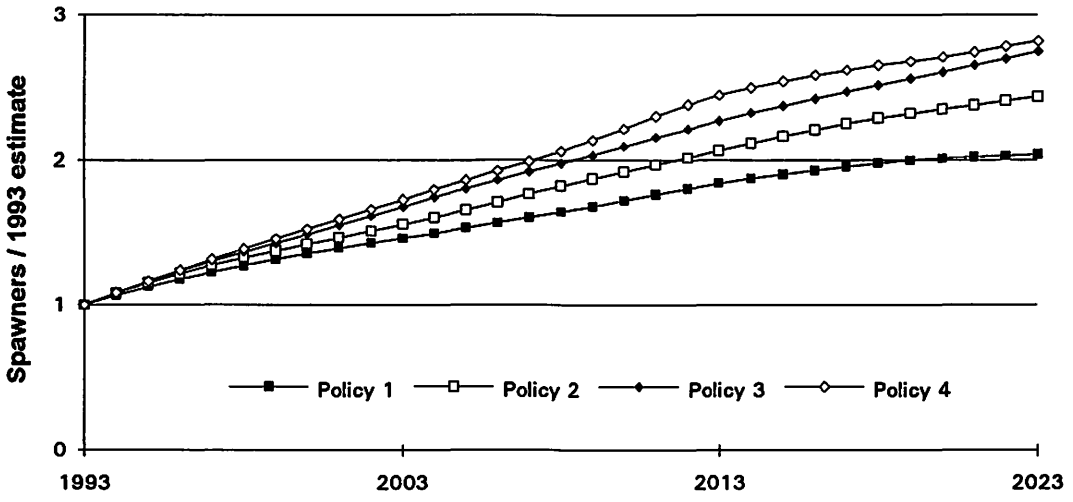

Figure 13. Expected values of trajectories of female spawner biomass of POP relative to the 1993 estimate by policy.

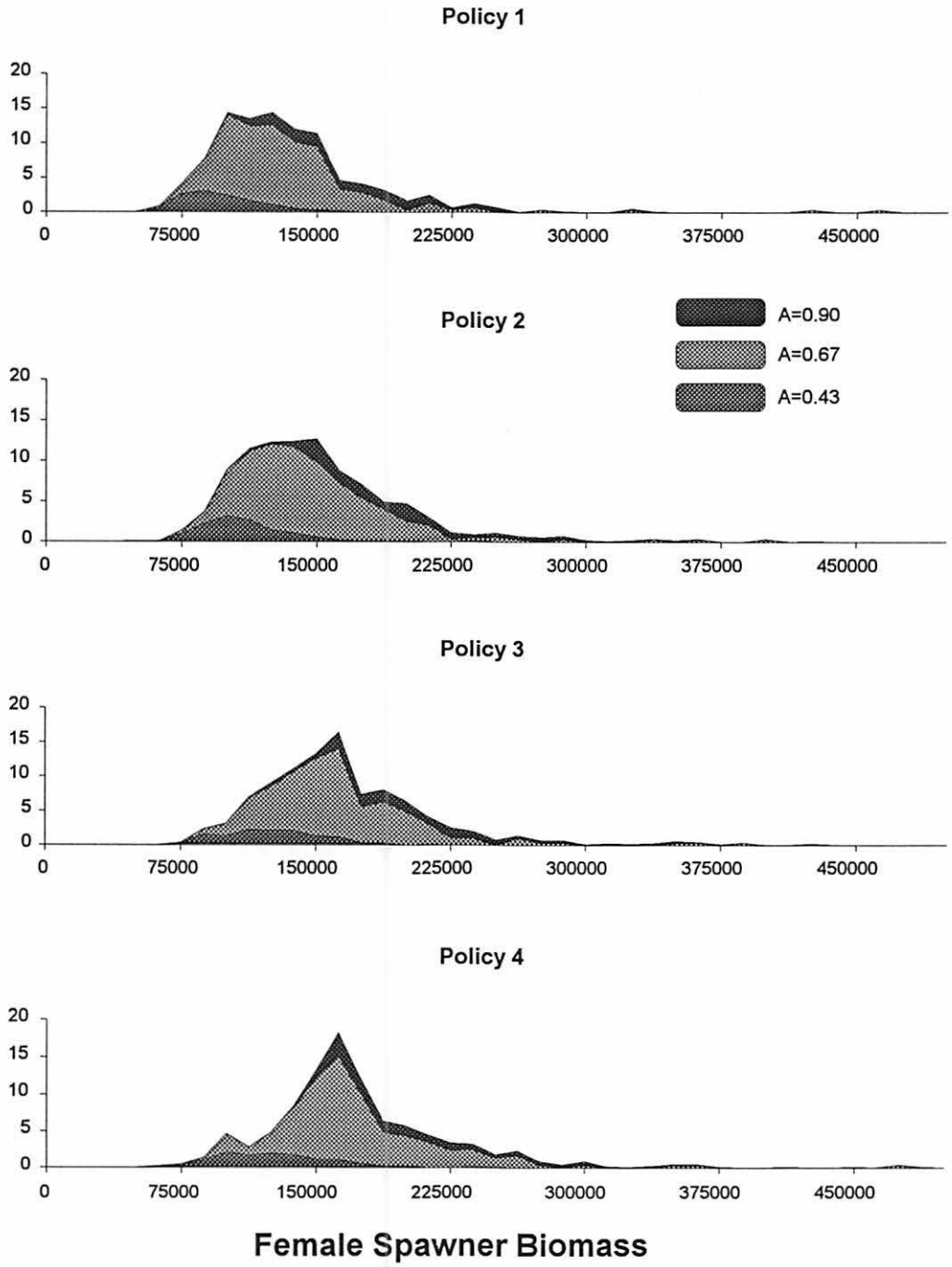

Figure 14. Percent frequency distribution from 200 simulation runs of spawner biomass in the year 2013. The different shadings represent weighted contributions of alternative hypotheses on stock-recruitment steepness (the *A* parameter).

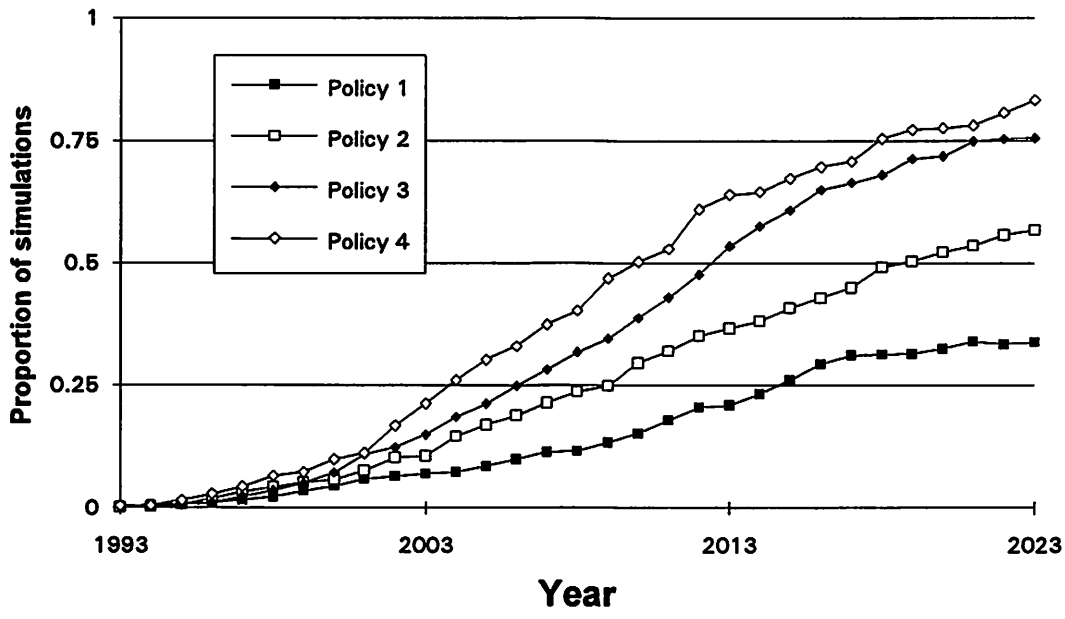

Figure 15. The expected value of the proportion of simulations achieving a rebuilt spawner biomass of 150,000 tons or more over time.

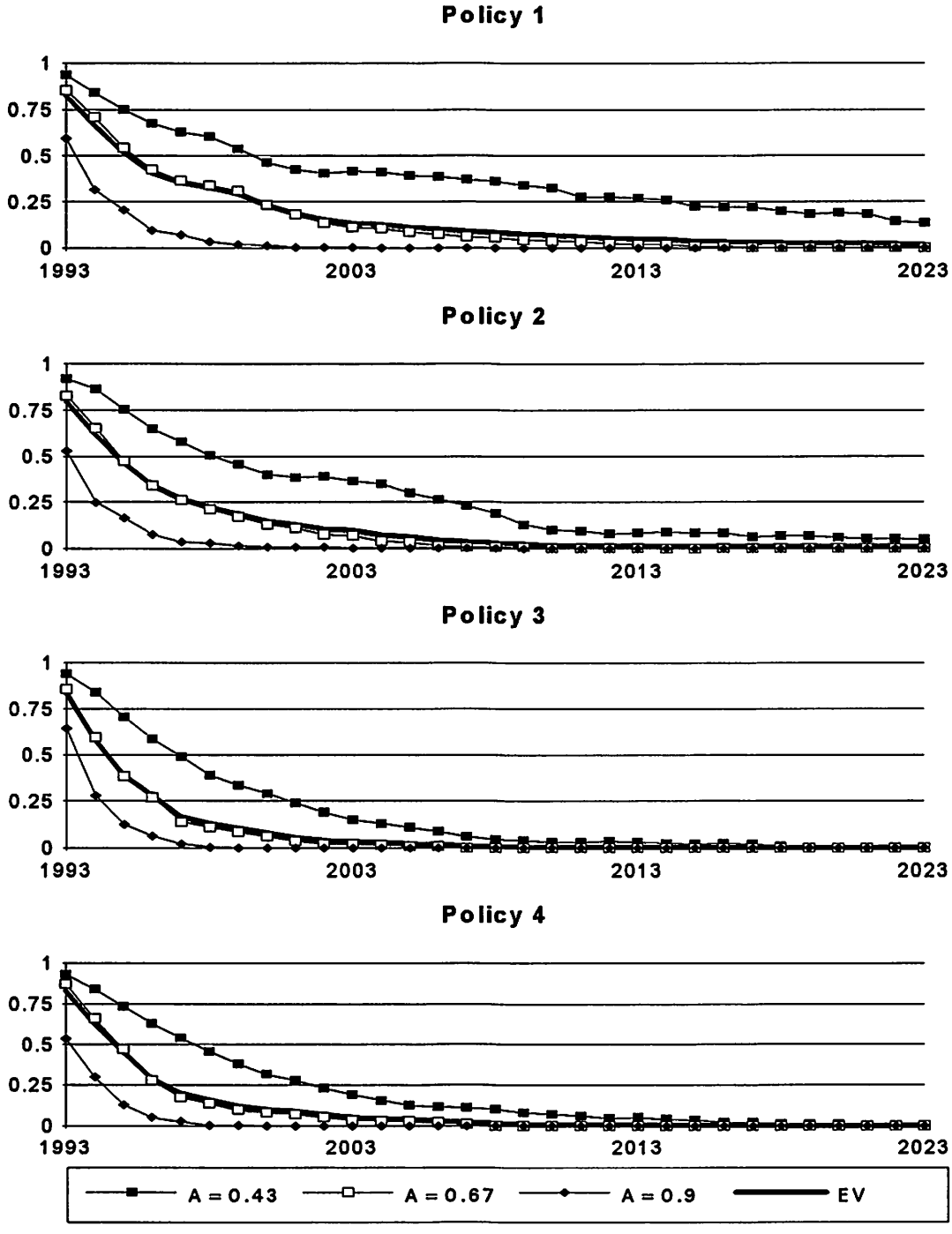

Figure 16. Proportion of simulations dropping below 75,000 tons of female spawner biomass over alternative hypotheses on the stock-recruitment relationship and policies.

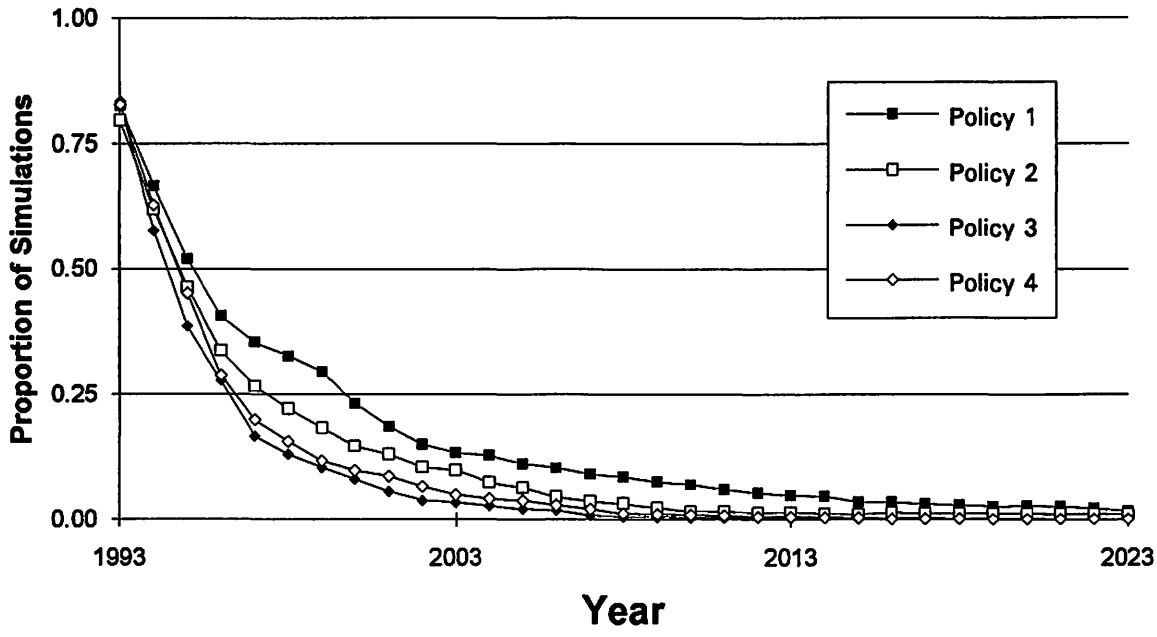

Figure 17. The expected value of the proportion of simulations dropping below 75,000 tons of female spawner biomass for each policy.

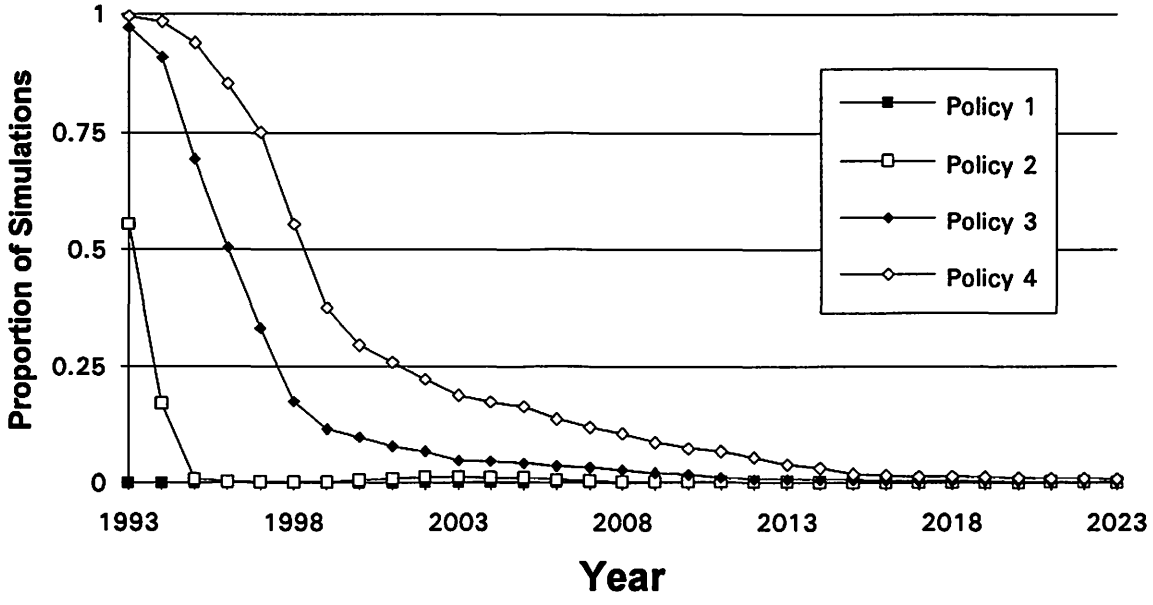

Figure 18. The expected value of the proportion of simulations dropping below 3.8 million dollars of undiscounted revenue for each policy.

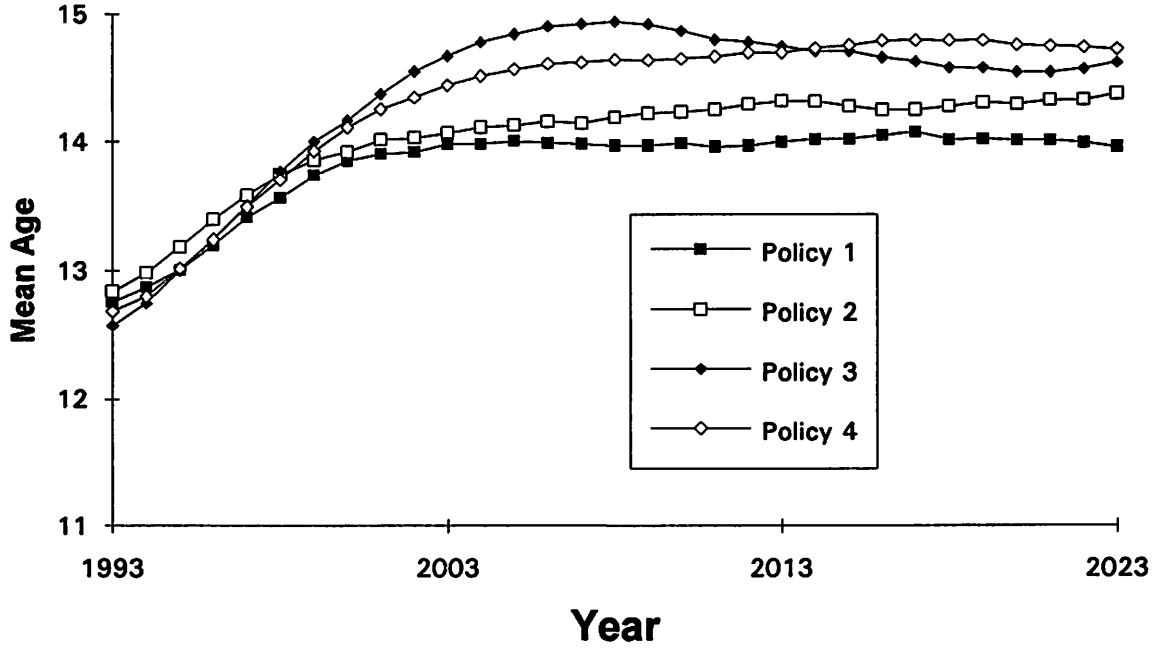

Figure 19. Expected mean age of the exploitable population under the different policy alternatives.

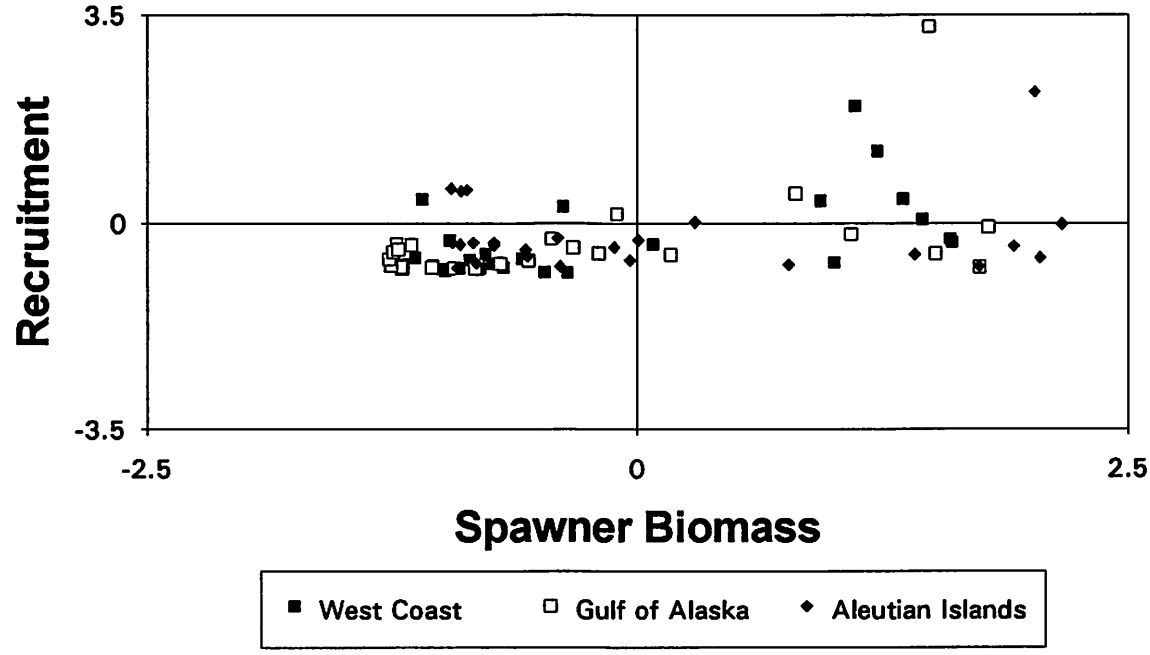

Figure 20. Stock-recruitment data for three north Pacific stocks of Pacific ocean perch. The units for spawner biomass and recruitment are scaled to represent the distance from the means in standard deviations.

Gulf of Alaska Recruitment

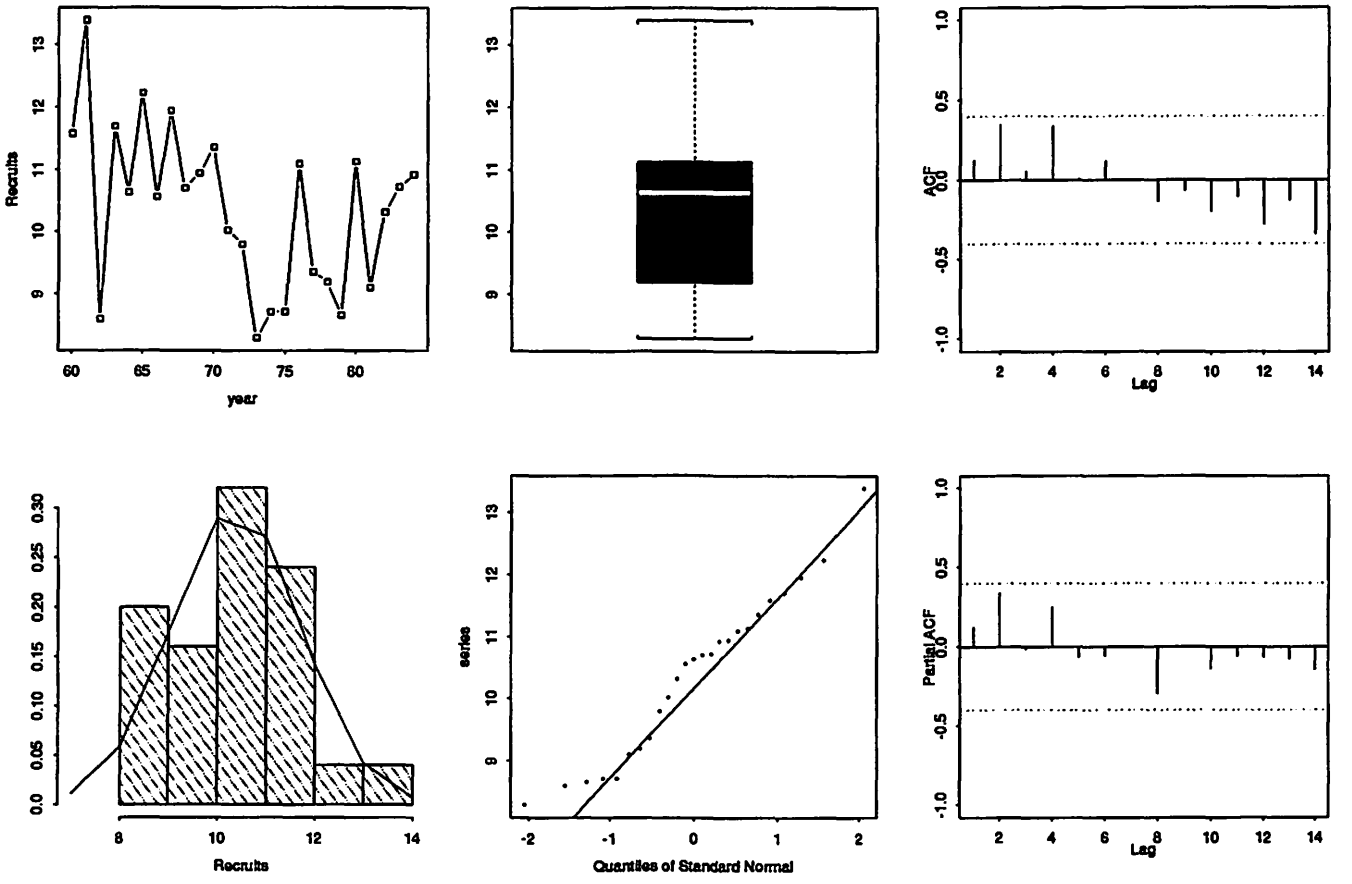

Figure 21. Diagnostic plots testing for serial correlation and normality of the time series of recruitment (log scale). The two right-hand panels represent plots of the autocorrelation function (top), and the partial autocorrelation function (bottom). The dotted lines indicated significance levels at each lag.

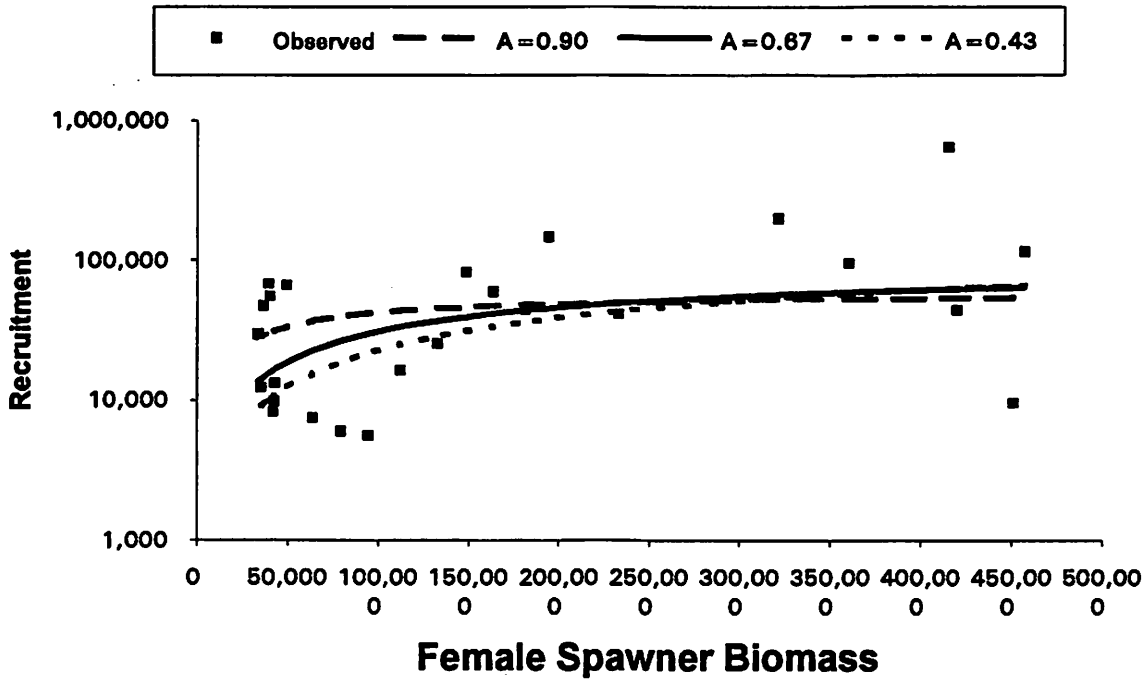

Figure 22. Stock recruitment data and Beverton-Holt curves with different values of the A parameter. Note that the vertical axis is scaled logarithmically.

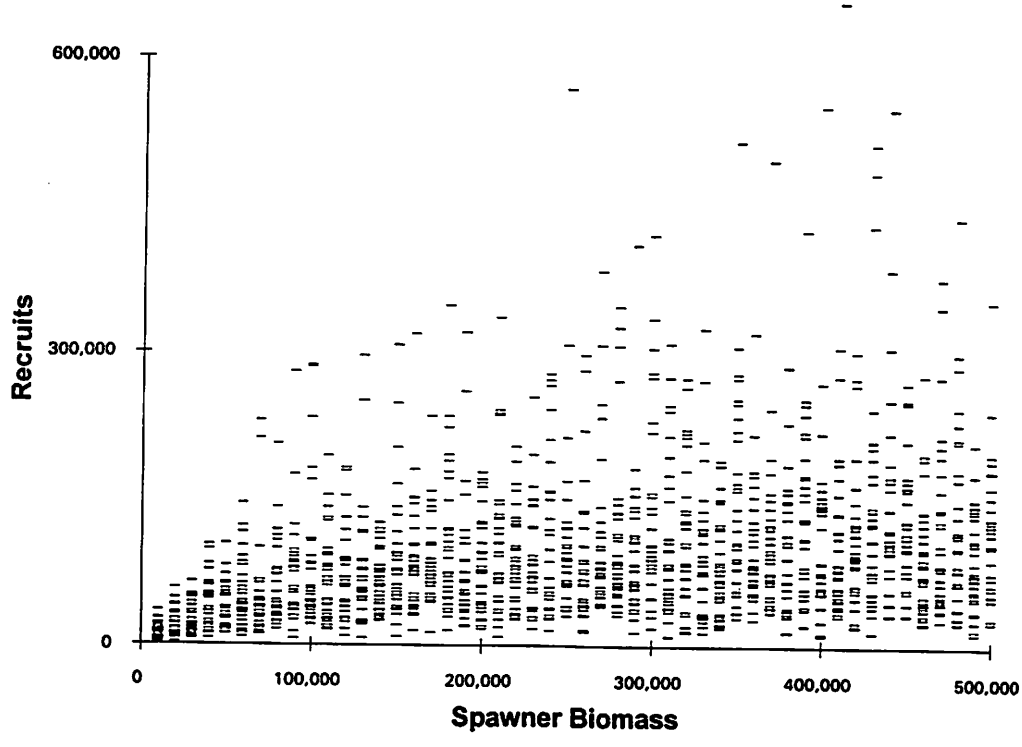

Figure 23. An example of simulated stock recruitment data used in the stock projections model. In this case $A = 0.671$, with a CV of recruitment set to 1.08.

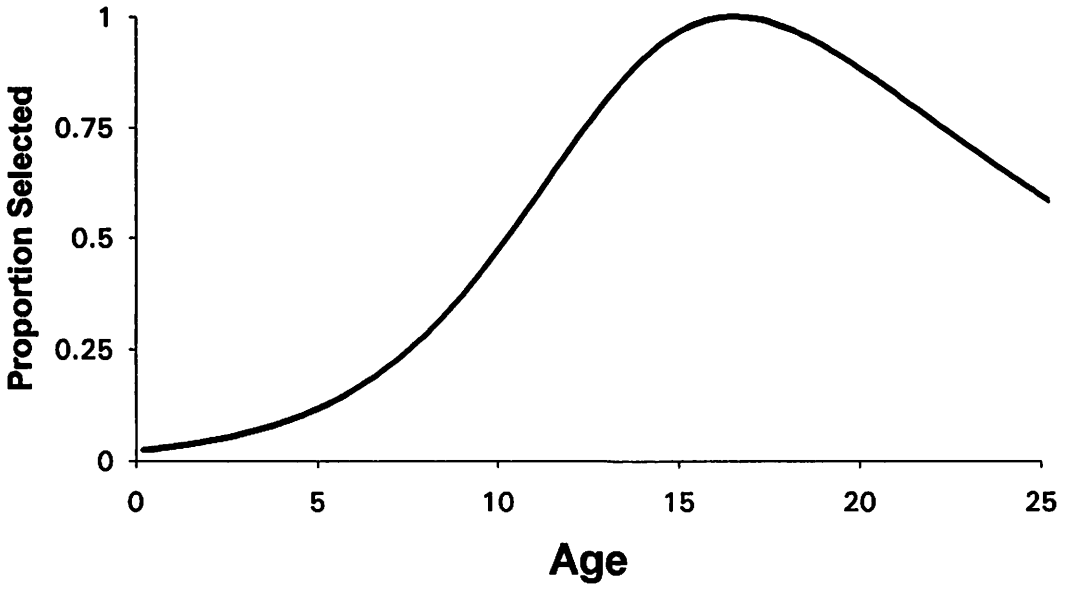

Figure 24. Selectivity at age pattern for the recent fishery estimated by Heifetz and Ianelli (1992). Parameter values for P1-P4 are 13.22, 0.39, 0.04, and 0.10, respectively.

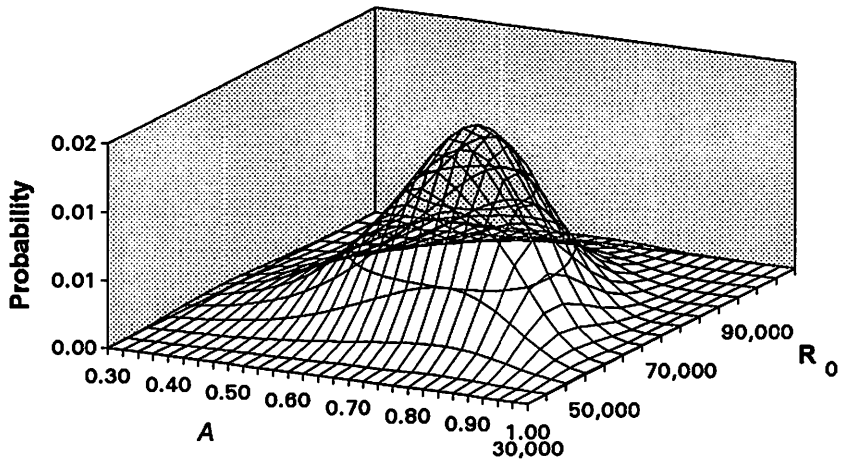

Figure 25. Joint likelihood surface for the stock recruitment parameters R_0 and A.

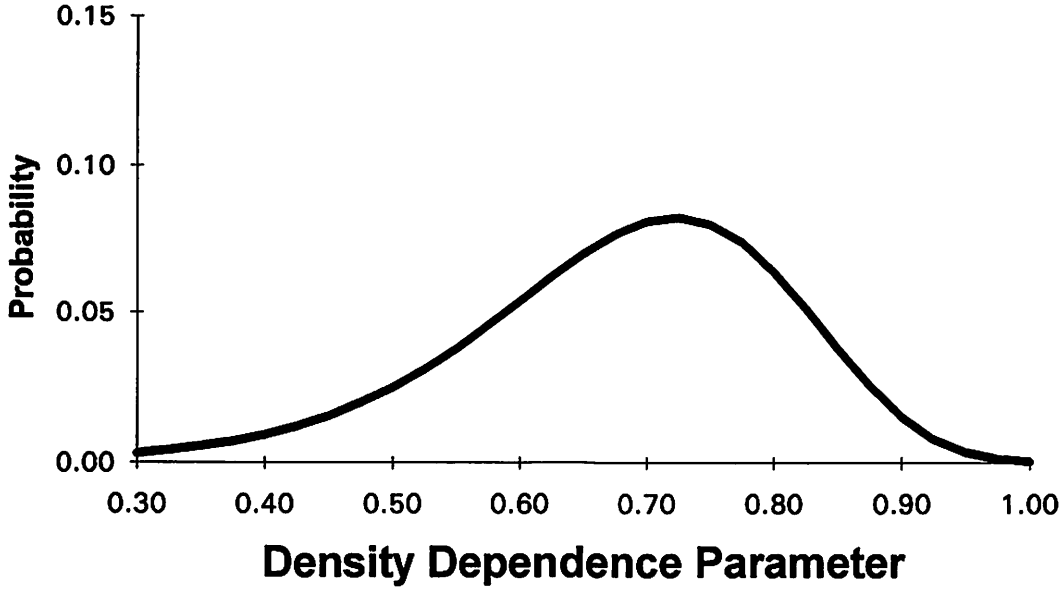

Figure 26. Posterior probability distribution of the density dependence parameter A, integrated over the range of R_0 values.

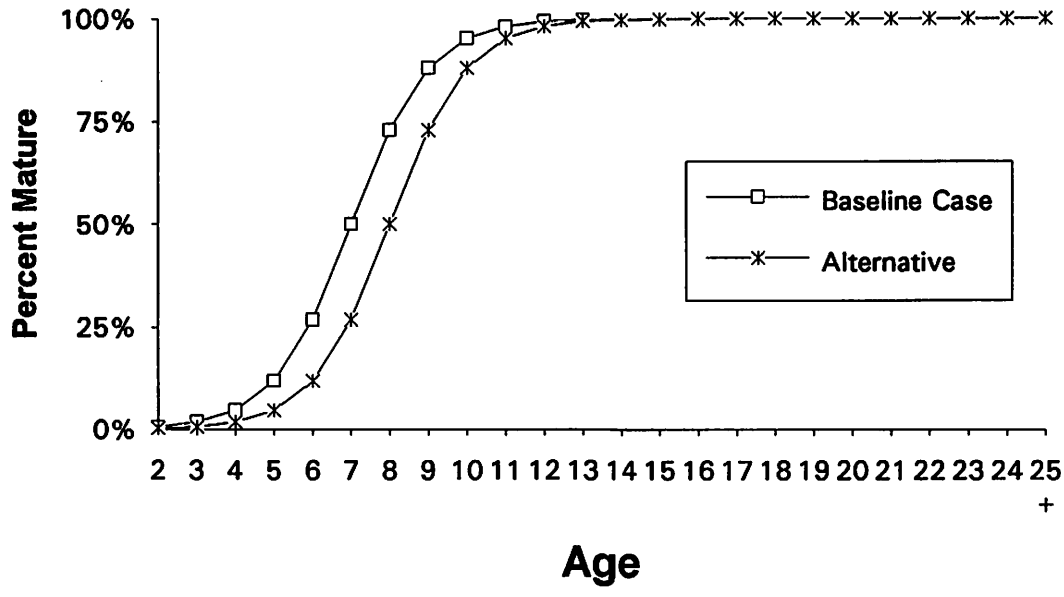

Figure 27. Alternative maturity schedule used to evaluate the effect on stock projections.

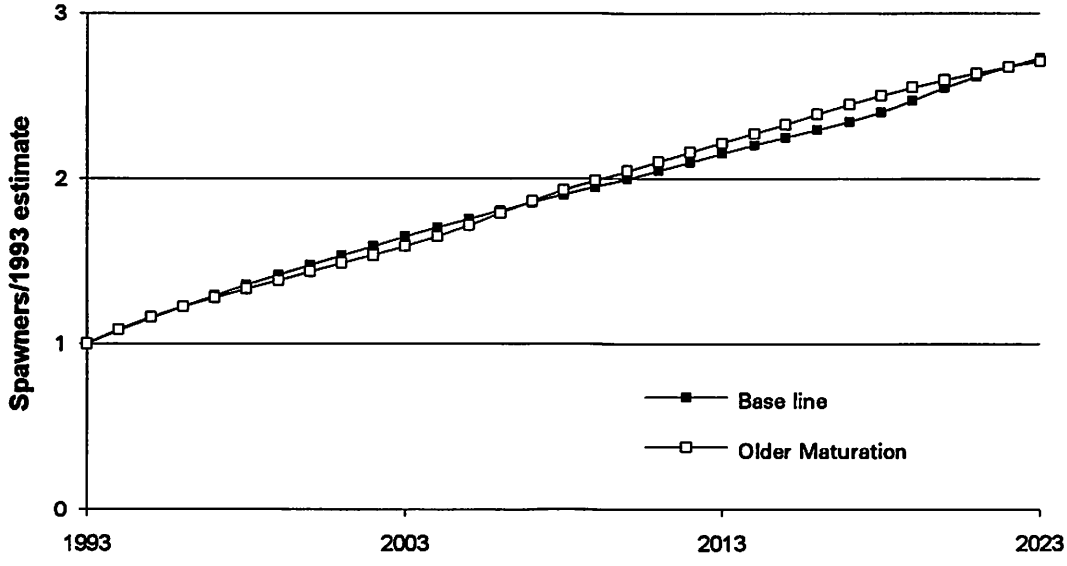

Figure 28. The effect of an alternative maturation schedule on relative spawner biomass increase under policy alternative 2.

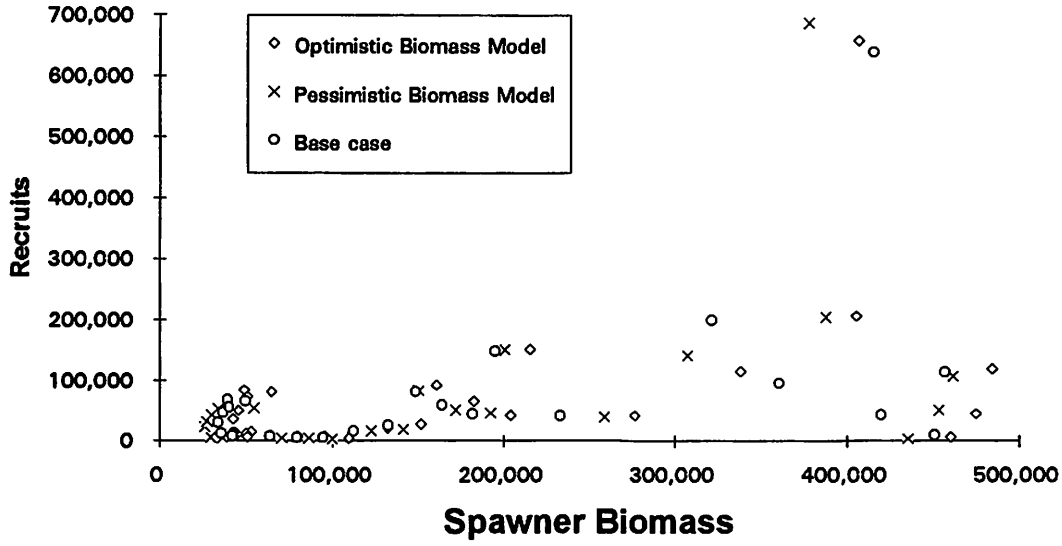

Figure 29. Stock-recruitment estimates under the 3 alternative assessment models presented in Heifetz and Ianelli (1992).

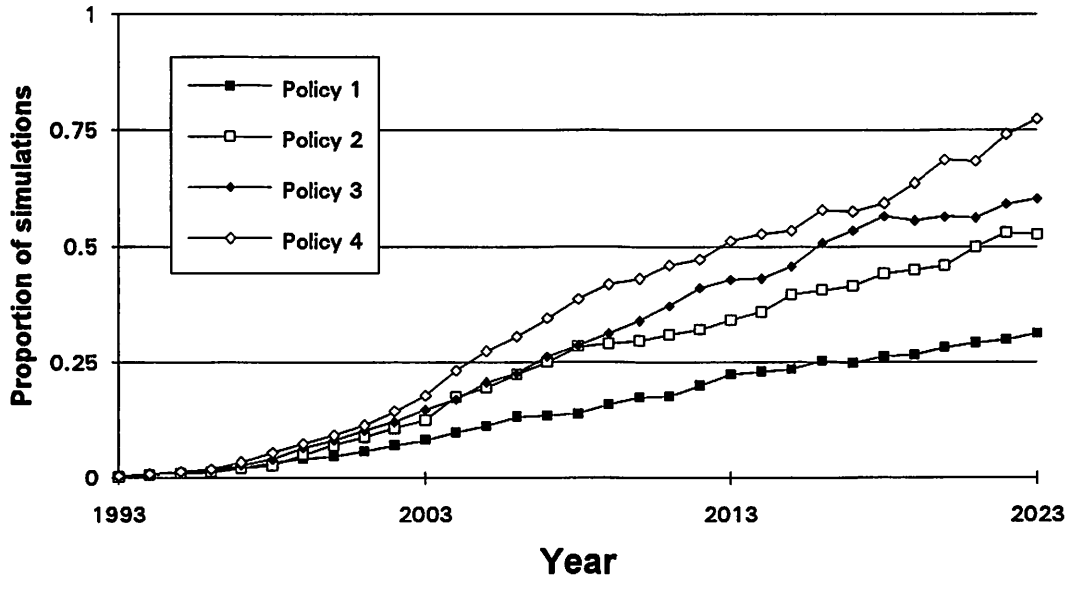

Figure 30. Proportion of simulations achieving a rebuilt spawner biomass of 150,000 tons or more by year and policy when uncertainty in future biomass levels is incorporated.