Chapter 4

Chapter 4 Environmental and Economic Consequences

This Programmatic Supplemental Environmental Impact Statement (SEIS) has so far presented the preliminary information necessary to analyze the potential impacts resulting from implementation of any of the five policy alternatives (Alternatives 1-4, plus the North Pacific Fishing Management Council's [NPFMC] Preferred Alternative). We have explained the purpose and need for federal action (Chapter 1) and reviewed both the legal context of federal fisheries management in Alaska and the tools managers use to satisfy those legal requirements (Chapter 2); also in Chapter 2, we defined the alternatives presented in this document and the Fishery Management Plan (FMP) bookends created to illustrate the range of management measures that might be used to implement a given policy alternative; and, in Chapter 3, we defined the environmental and economic baseline conditions against which the impacts of the alternatives can be measured.

We now turn to the work of analyzing the possible impacts of the alternatives. Chapter 4 presents our analysis of the FMP bookends and the environmental and economic impacts that might reasonably be expected to follow from implementation of the suite of management measures contained in each FMP bookend. The analyses contained in this chapter will thus allow readers to evaluate the relative effectiveness of the policy alternatives in meeting the legal, environmental, and economic demands of the federal groundfish fisheries off Alaska.

Analysis of the impacts of management policies requires knowledge of potential actions that could be taken to implement the policy. Policies are, by definition, a high-level, overall statement or plan embracing the general goals and procedures of a government body. In the United States (U.S.), policies usually reflect the values and wisdom of the citizens, as expressed by laws and agencies of the nation. Policy goals and objectives are often used to frame the policy and make the statement clearer and easier to understand. Still, determination of the effects of a policy on the human environment is difficult to comprehend and analyze without some indication of how the policy might be implemented.

This chapter evaluates a number of example FMPs intended to illustrate a particular policy as defined by the alternatives described in Section 2.6. In evaluating example FMPS, we will be able to better understand the current management policy governing federal management of the groundfish fisheries off Alaska, as well as the trade-offs of changing existing policy to reflect a new management approach. Since we had no proposed alternative management policies or alternative FMPs to consider at the outset of the Programmatic SEIS process, National Marine Fisheries Service (NMFS or national Oceanic and Atmospheric Administration [NOAA] Fisheries) has relied heavily on comments received during the public scoping process and on the 2001 Draft Alaska Groundfish Fisheries Programmatic SEIS in crafting the alternatives. Additionally, NOAA Fisheries consulted frequently with the NPFMC in developing the alternatives by relying on their expertise and judgement.

Significant changes to the structure and organization of this chapter have been made in response to public comments on the 2001 Draft Programmatic SEIS. As we explained in Chapter 2, we have restructured the policy alternatives to better reflect a multi-species, ecosystem management approach. Each of the policy alternatives (Alternatives 1 through 4) now represents a different management approach, ranging from a more aggressive harvest strategy (Alternative 2) to a very restricted harvest strategy where fishing is only authorized with proof that no adverse impacts will occur (Alternative 4). Two intermediate policy alternatives are presented: Alternative 1, which would continue the current risk-averse policy, and Alternative 3, which would adopt a more precautionary policy. Each policy alternative contains a suite of policy goals and objectives, each addressing to various degrees the important components of the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) marine ecosystems.

To help both the decision-maker and the public understand what a policy means and what environmental consequences may occur, we have defined example FMPs to illustrate each policy. These example FMPs contain a number of FMP components that were identified by the public as important features of any fishery management program. The best example of the current management policy are the current BSAI and GOA groundfish FMPs. For Alternatives 2 through 4, we define two example FMPs, each comprised of a different combination of management tools and tool applications. Each of these example FMPs contain concepts or specific suggestions obtained from NPFMC and the public. From an overall programmatic perspective, the actual characterization of the example FMPs and their effects is not as important as what is learned about the environmental trade-offs one can expect when considering alternative management policies governing the Alaska groundfish fisheries. Understanding these general environmental trade-offs will enable NPFMC, NOAA Fisheries, and the public to collectively shape future management policy and identify potential alterations to the existing management program.

The example FMPs also satisfy another purpose. NOAA Fisheries has determined that providing a management framework can help guide and communicate the direction of future actions. This is accomplished by including, as an element of the preferred alternative, two example FMPs that serve as “bookends” to a range of management actions, recognizing their inherent environmental consequences. Each example FMP will be analyzed separately and will proxy a range of future management actions. The bookend framework, comprised of two example FMPs, will indicate the range of environmental effects of that policy. The FMP bookends are not intended to be stand-alone alternatives. The FMP bookends are examples of management plans that are driven wholly by the policy statements. They illustrate different ways the groundfish fisheries can be managed and the range of environmental effects that can be expected from the implementation of a policy alternative. An FMP framework will be included in NPFMC’s and NOAA Fisheries’ final decision, and will be used to define a range of management actions that will be pursued following completion of the Programmatic SEIS. This alternative structure recognizes that the resource being managed, as well as the marine ecosystem, is quite dynamic in nature and only partially understood. Providing a range of management tools and their potential effects for each policy alternative is an attempt to take into account the dynamic nature of the fisheries as a whole and to provide enough management program flexibility in each alternative to allow decisions based on the best available science.

Analyzing such a complex set of alternatives is difficult. Presenting our analysis in a single chapter of the Programmatic SEIS also has its challenges. This is first provided in Section 4.1, which describes the methods used to evaluate the alternatives and their associated FMP bookends. This section defines the term significance; describes how data gaps and incomplete information are treated; defines what is meant by direct, indirect, and cumulative effects; and provides a technical description of the multi-species model and its assumptions. Section 4.2 describes the concept of the FMP bookends and provides a detailed summary of each of the example FMP components used as proxies for a policy alternative. Section 4.3 provides the public with a qualitative examination of each FMP component and discusses the range of management measures that could later serve as plan amendments. In this qualitative assessment section, the public is provided with a general review of the likely environmental effects that could be expected from each of the measures, across example FMPs (Figure 4.0-1; illustrating the “row look”). Section 4.3 is intended to provide the public with information on what could be expected from each management tool (in relative isolation from other plan components), across a range of environmental effects categories, as well as an indication on how well these management tools may meet a particular set of policy objectives.

The Programmatic SEIS continues in Section 4.4 by reviewing the statements defining the current environmental baseline to which all the alternatives and their associated example FMPs will be compared. These baseline statements, developed in Chapter 3, provide an important reference point for this Programmatic SEIS. Sections 4.5 through 4.8 analyze Alternatives 1 through 4 by examining their associated example FMPs as proxies. Each FMP is analyzed as a whole (Figure 4.0-2; illustrating the “column look”) so as to represent the entire FMP and all of its components. This is a marked departure from the 2001 Draft Programmatic SEIS document and is included as a result of considerable public input. Another difference between this and the 2001 Draft Programmatic SEIS is that this chapter is organized around alternatives, rather than by resource categories. Many members of the public recommended this organization as an improvement over the earlier draft.

Section 4.9 presents a policy analysis of each of the alternatives using the potential impacts of the example FMPs as a guide. Evaluation of each alternative is provided in terms of satisfying the Magnuson-Stevens Fishery Conservation and Management Act (MSA), Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and other applicable federal laws. Section 4.10 concludes this chapter by providing the public with an overall comparison of the alternatives at the policy level.

At this point, we feel obliged to beg the reader’s continuing patience. The following analyses are unavoidably lengthy. We have tried to err on the side of inclusiveness, rather than run the risk of omitting any information or analysis that might aid decision-makers and the public in evaluating the relative merits of the alternatives. Also, the description of modeling methods in Section 4.1.5 contains highly technical information and mathematical equations that we have seen fit to include in the text rather than consign to an appendix. Although we do not expect that all readers will want to follow these equations variable by variable, we have placed the methods description prominently to allow public scrutiny of the scientific rigor with which the analyses have been conducted. Yet, however lengthy, detailed, and technical the analyses, we have tried our best where possible to keep the information accessible to the reader.

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4.1 Methodology

Alternatives are analyzed in the Programmatic SEIS to determine their environmental impacts. As previously described at the beginning of this chapter, each alternative is analyzed first at the FMP level, and later at the policy level. The FMP-level analysis examined both individual components as well as all of the components together, using the example FMPs, to determine the significance and intensity of impacts. A number of analytical models were used to conduct this analysis.

Section 4.1.1 discusses the significance thresholds used to analyze the impacts of the alternative, and Section 4.1.2 explains how data gaps and incomplete information were treated in this document. Section 4.1.3 describes the methodology for the direct and indirect effect analysis, and Section 4.1.4 describes methodology for the cumulative impact assessment. Section 4.1.5 describes the multi-species model, Section 4.1.6 describes the habitat model, and Section 4.1.7 describes the sector model used to estimate socioeconomic effects.

4.1.1 Determining Significance of Potential Consequences

The National Environmental Policy Act (NEPA) requires that an Environmental Impact Statement (EIS) include

> *... the environmental impacts of the alternatives including the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented (40 Code of Federal Regulations [CFR] 1502.16).*

The EIS analysis must also identify whether or not an adverse environmental effect is significant. Significance is determined by considering the contexts (geographic, temporal, societal) in which the action will occur, and the intensity of the action. The evaluation of intensity should include consideration of the magnitude of the impact, the degree of certainty in the evaluation, the cumulative impact of the action as related to other actions, the degree of controversy over the action, and violations with other laws.

In this Programmatic SEIS, significance thresholds have been determined for each resource category (target species, socioeconomic effects, ecosystem, etc.). In some instances, although the significance threshold remains the same, the qualifier "conditional" is assigned. This indicates that a significant impact is assumed, based on credible scientific information and professional judgement, but that more complete information is needed for certainty. The following impact ratings may be used for each resource category:

Significantly adverse (S-): Significant adverse effect in relation to the reference point, based on ample information and data and the professional judgement of the analysts who addressed the topic.

Conditionally significant adverse (CS-): Conditionally significant adverse effect in relation to the reference point. This determination is lacking in quantitative data or information; however, the professional judgement of the analysts is that the alternative will cause a decline in the reference point condition.

Insignificant impact (I): Insignificant effect in relation to the reference point; this determination is based on information and data, along with the professional judgement of the analysts, that suggest that the effects will not cause a significant change to the reference point condition.

Conditionally significant beneficial (CS+): Conditionally significant beneficial effect in relation to the reference point. This determination is lacking in quantitative data and information; however, the professional judgement of the analysts is that the alternative will cause an improvement in the reference point condition.

Significantly beneficial (S+): Significant beneficial effect in relation to the reference point, based on ample information and data and the professional judgement of the analysts who addressed the topic.

Unknown (U): Unknown effect in relation to the reference point; this determination is characterized by the absence of information or data sufficient to adequately assess the significance of the impacts, either because the impact is impossible to predict, or because insufficient information is available to determine a reference point for the resource, species, or issue.

These ratings are applied to resource-specific impact indicators in the following resource categories: target species, prohibited species, other species, forage fish species, non-specified species, habitat, seabirds, marine mammals, socioeconomic effects, and ecosystem effects. The specific application for each is described below.

4.1.1.1 Target Species, Prohibited Species, Other Species, Forage Fish Species, Non-Specified Species

The significance of the impacts on target species, prohibited species, forage fish species, other species, and non-specified species was evaluated with respect to five effects: 1) fishing mortality, 2) change in biomass level, 3) spatial/temporal concentration of the catch, 4) prey availability, and 5) habitat suitability. The significance of these effects was evaluated as to whether the impacts, within the current fishery management regime, may be reasonably expected to jeopardize the sustainability of each target species or species group.

Target species are unique in that thresholds for overfishing and stock size have been developed (Amendment 56/56 to the BSAI and GOA FMPs) that relate to sustainability of the stock. As such, these thresholds are used to evaluate the significance of the effects of the example FMPs relative to their impacts on the sustainability of the target species. Fishing mortality rates that exceed the overfishing mortality rate are considered to jeopardize the capacity of the stock to produce maximum sustainable yield (MSY) on a continuing basis and adversely impact the sustainability of the stock. A related measure of this potential is indicated by change in biomass levels. The significance of effects of the current spatial/temporal concentration of the catch, and the level of prey availability and habitat suitability for target species is evaluated with respect to each stock's current size relative to its maximum stock size threshold (MSST). An action that jeopardizes the stock's ability to sustain itself at or above its MSST is considered to adversely affect the sustainability of the stock.

The significance of the five selected effects is evaluated according to the specific criteria for the impact ratings (Tables 4.1-1, 4.1-2, and 4.1-3). Species or species complexes that fall within Tiers 1 though 5 have estimates of the current fishing mortality rates and are evaluated with respect to exceeding the overfishing mortality rate (fishing mortality effect). Species or species complexes that fall within Tiers 1, 2, or 3 have reliable estimates of MSST and are evaluated for the effects of spatial/temporal concentration of the catch, prey availability, and habitat suitability. Species or species complexes that fall within Tiers 4, 5, or 6 do not have reliable estimates of MSST and therefore cannot be evaluated for the significance of these effects. This inability to evaluate the significance of the effects also occurs for the forage, prohibited, and non-specified species. Since several species or species complexes do not have estimates of abundances-at-age, in this version of the model their abundance levels simply reflect the most recent estimate. For these groups, analysis of the effects of the example FMPs was limited to catch projections and likely consequences given patterns in related fauna.

4.1.1.2 Habitat

The potential effects of the groundfish fisheries on habitat that were used to compare the alternatives include mortality of, and damage to, living habitat, changes to benthic community diversity, and changes to the geographic diversity of impacts and protection. Specific impacts of groundfish fisheries on habitat are very difficult to predict. Evaluation of effects requires detailed information on the distribution and abundance of habitat types, the life history of living habitat, habitat recovery rates, and the natural disturbance regime. This information is generally incomplete.

Qualitative judgments as to the significance of effects were made after considering information on 1) bycatch of living habitat derived from the multi-species projection model; 2) the results of a habitat impacts model for estimates of the equilibrium levels of living habitat in fishable and currently fished areas; 3) estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species; and 4) evaluation of the spatial distribution of bottom trawl closures relative to fishing intensity and habitat types. The evaluation criteria are described in Table 4.1-4. Significance determination in this analysis differs from the more commonly used approach in scientific research. Typically, the null hypothesis of no effect is tested rigorously and only rejected if there is a very low probability of it being true (Type I error). Scientists are trained to minimize the chance of a Type I error. In this Programmatic SEIS analysis, however, rigorous tests of available data to reject the hypothesis of no fishing effects were not relied upon to determine significance. This was done for two reasons. First, there was little information available to detect fishing effects, so rigorous statistical testing for a Type I error could not be performed. Second, it was believed that a more appropriate approach for this Programmatic SEIS was to decrease making a Type II error (accepting a hypothesis of no effect to habitat when an effect to habitat does actually exist. Reducing the probability of making a Type II error is more precautionary and is more responsive to both essential fish habitat (EFH) mandates and public comments received on the 2001 Draft Programmatic SEIS.

During the course of preparing the revised draft Alaska Groundfish Fisheries Programmatic SEIS, comments and questions were raised about the purpose and scope of the Programmatic SEIS and the agency's EFH EIS that is currently being prepared on a separate schedule. In response to these questions and to clarify the purpose and need, the following summary compares the two analyses.

<u>The Alaska Groundfish Programmatic SEIS and its Relationship to the Ongoing EFH EIS</u>

The EFH EIS and Groundfish Programmatic SEIS have different scopes and areas of focus.

EFH EIS. The analyses within the EFH EIS consider adverse effects of fishing on benthic marine habitat from the perspective of managed fish species that are dependent on certain qualities and features of that habitat. As such, the scope of this work is more narrow than a consideration of these changes at the scale of entire marine ecosystems (as pursued in the Programmatic SEIS.)

Programmatic SEIS. The analyses within the Programmatic SEIS consider adverse effects of fishing on benthic marine habitat from the perspective of ecosystem structure and function, as well as managed fish species. As such, the scope of this work is broader than a consideration of these changes on commercially important and functionally dependent fish species.

These differences are reflected in the issues, criteria, and assessments made in each EIS. To a lesser extent, the information available for analysis in each EIS is different because the Draft Programmatic SEIS was written and released prior to the EFH EIS. The principal differences between the scope, alternatives, and purpose and need of the two documents are summarized in Table 4.1-1.

Table 4.1-1 Major differences between the Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement and the Essential Fish Habitat Environmental Impact Statement.

	Programmatic Supplemental Environmental Impact Statement (SEIS)	**Essential Fish Habitat (EFH) Environmental Impact Statement (EIS)**
Purpose and need	Programmatic review of Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish Fishery Management Plans (FMPs) and their effects on the marine ecosystem.	Review of alternatives for identifying EFH, identifying habitat areas of particular concern (HAPCs), and minimizing adverse effects of fishing on EFH for groundfish, crabs, salmon, and scallops.
Action	Broad scope: Reauthorization of all groundfish fisheries under Magnuson-Stevens Act (MSA), Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and other applicable law; set policy.	Narrower scope: Consider revising EFH designations and adopting mitigation measures to reduce the effects of fishing on EFH.
Alternatives	Broad multi-objective policies.	Alternative EFH designations, approaches to identifying HAPCs and mitigation measures.
Source of closed areas used in analysis	Based on public comments on 2001 draft Programmatic SEIS, EFH Committee (Fall 2002) concepts, internal analysis.	EFH Committee (finalized by North Pacific Fisheries Management Council in April 2003).
Legal authority	Under MSA, agency can take action to protect habitat even if not specified as EFH.	Under MSA, agency must minimize to the extent practicable adverse effects of fishing on EFH.

The different analyses used to assess the effects of fishing on habitat in the Programmatic SEIS and the EFH EIS are outlined in Table 4.1-2. While the Programmatic SEIS looks only at bottom trawl impact, the EFH EIS examines trawl, dredge, pot, and longline gear. Another difference is that the Programmatic SEIS usually cited results using the upper recovery value for soft bottom habitats (15 years, higher effects), while the EFH analysis uses a central value (5.5 years). However, both EISs acknowledge that impacts to benthic habitat occur in areas of high fishing intensity regardless of the recovery rate assumed in the analysis. The same quantitative model relating fishing effort to habitat impact is used in both EISs and the results are highly comparable with only subtle differences, which have little effect on the ratings or discussion in the two EISs.

Table 4.1-2 Differences in data and methods for habitat effect analysis and evaluation issues.

	Programmatic supplemental Environmental Impact statement (SEIS)	**Essential Fish Habitat (EFH) Environmental Impact Statement (EIS)**
Input data source	Bottom trawl only.	Trawl, dredge, pot, longline.
Years	1997-2001.	1998-2002.
Fishery class	Trawl.	By target species and gear.
Living substrate recovery time (soft bottom)	2 and 15 years, 200 years for coral.	3.8, 5.5, and 10 years.
Habitat issues	Living habitat mortality/damage, including coral benthic community and geographic impact diversity.	Prey availability, epibenthic structure, coral.
Managed fish habitat issues	Habitat suitability.	Spawning/breeding, feeding, growth to maturity.

The Programmatic SEIS baseline evaluation identifies areas of high impact on living substrates and noted the estimated high potential impact level to living benthic structure and the size of affected areas. The analysis also considers the likelihood that those areas represent a unique habitat for managed fish species as determined by geography and oceanography, and is not equivalent to all other habitat in the same classification. The analysis concludes that, coupled with historical impacts, impacts to long-lived, slow-growing species (i.e., coral) could cause long-term damage and possibly irreversible loss of living habitat, especially in the Aleutian Islands. The baseline condition of benthic habitat is, therefore, rated as conditionally significant adverse. For purposes of making policy decisions, it is important that any potential significant adverse effects, even if conditional, be presented to decision-makers and the public so that consideration can be given to these effects when developing management measures in the future.

The EFH EIS describes the same areas of high impact to habitat features identified in the Programmatic SEIS, but goes on to evaluate the expected effects of such reductions in habitat quality on the welfare of each managed species. Those evaluations include areas occupied by each species, available information on their use of the habitat, and the stock history of each species. The Programmatic SEIS analysis evaluates impacts to the habitat itself, focusing on habitat features that might provide functions to managed species and speculating that linkages to productivity exist. Considering the paucity of information on habitat function for species life history stages and the broader scope of the Programmatic SEIS, the Programmatic SEIS does not depend on finding proof of such linkages. The EFH EIS examines the likelihood of significant linkages between habitat effects and the welfare of each managed species to determine whether the effects of fishing on EFH of managed species are more than minimal and not temporary. The purposes and methods of analysis used in the EFH EIS are discussed in more detail in Appendix B of the EFH EIS.

While the Programmatic SEIS baseline evaluation identifies areas of concern regarding of the current state of habitat effects from fishing, the EFH EIS was designed to specifically address criteria set forth in the EFH final rule. While identifying areas of concern was one step in the EFH EIS, the ultimate purpose of the EFH EIS is to evaluate whether the effects of fishing has had negative effects on the EFH of managed species that was more than minimal and not temporary. Specific meaning of these terms are discussed in Appendix B of the EFH EIS.

The approach and methodology employed to assess the impacts on target groundfish species in the Programmatic SEIS and EFH EIS are similar. For each species in each EIS, a knowledgeable scientist was designated to perform an evaluation of whether the alternatives affected the welfare of each species in question relative to a number of key issues. In the Programmatic SEIS, the key issues are 1) fishing mortality; 2) change in biomass level; 3) spatial/temporal concentration of the catch; 4) prey availability; and 5) habitat suitability. The key issues analyzed in the EFH EIS are 1) stock biomass; 2) spatial/temporal concentration of the catch; 3) spawning/breeding; 4) feeding; and 5) growth to maturity. These issues are evaluated relative to the status quo fishery, or baseline condition, as well as to the alternatives developed under each EIS. Criteria are established for each issue to assist the analysts in making conclusions. The primary consideration in these evaluations revolve around the ability of the stock to maintain its health and support a sustainable fishery.

In the National Standard Guidelines to the MSA, sustainability is defined relative to a MSST, where stocks below the MSST are considered sufficiently small as to require an appropriate rate of rebuilding. This concept of sustainability is used in the Programmatic SEIS and EFH EIS to maintain consistency with the National Standard Guidelines. For Tier 3 fish stocks, estimated recruitments from the late 1970s to the present are used in defining MSST proxies. These estimated recruitments thus cover a range of recent history when impacts to the stock from fishing practices would be expected. Additionally, 10 year projections are made to assess whether the stock would be likely to fall below their MSST level under the status quo harvesting policy. In the EFH EIS, these projections are not available for the remaining mitigation alternatives. However, because each of the mitigation alternatives represents a more conservative harvest policy than the status quo alternative, a finding of stock status above the MSST under the status quo alternative could reasonably be expected to hold under the remaining alternatives.

It should be noted that the MSST criterion is not the only metric used for the evaluation. For some stocks, information is known about habitat associations and how these may be impacted under various harvesting regimes, from both previous studies and from the results of the Fujioka-Rose model. This information is presented in the narrative of the EFH EIS as part of the more focused look at the linkages between habitat impacts and sustainability. Additionally, for stocks in Tiers 4 through 6, MSST is not available, and an evaluation is based on professional judgment using the best available scientific information and evidence.

4.1.1.3 Seabirds

Significance criteria for seabirds are based on whether the proposed action would be likely to result in population level effects, defined as changes in the population trend outside the range of natural fluctuations. The projection model was used for predictions of fishing effort under the different FMP bookends, especially with respect to different gear types. The analysis also includes other factors such as spatial/temporal restrictions and potential gear modifications for seabird avoidance. However, because there are a large number of unpredictable variables and gaps in our knowledge about particular species and ecosystem effects, it is impossible to ascertain significance on a strictly quantitative basis. Conclusions are based on professional judgement of pertinent data and literature review.

Except for the supplemental food provided by the fisheries in the form of offal, the effects of the fisheries are all considered adverse to individual birds. Low levels of incidental take of seabirds are better for conservation purposes than high levels of take, but no amount of incidental take can be considered beneficial to a seabird population. The significance ratings for incidental take are, therefore, either insignificant or adverse. Although the number of seabirds that would be expected to be taken under the alternative FMPs varies considerably, this difference is not discernible by looking at a shared insignificant rating. The same type of situation applies to fishery-induced changes in benthic habitat important to benthic-feeding seabirds, so there is no beneficial rating for this effect. Effects of the fishery on food availability could be adverse, insignificant, or beneficial. If there is a plausible mechanism and a reasonable set of conditions under which an effect may occur under a given FMP, the significance rating may be labeled conditional. If there is a plausible mechanism for an effect, but not enough data to assess whether it occurs or whether the FMP would create the conditions under which it would occur, the significance rating may be unknown. The evaluation criteria are described in Table 4.1-5.

Species were grouped according to the similarity of their response to the groundfish fishery and/or similarity in their management status. Two species were analyzed on their own and the rest were discussed in five groups. The species categories and the main reason for their distinctions are listed below:

- Short-tailed albatross (listed as “endangered” under the ESA and have played a central role in the development of seabird protection measures).

- Laysan and black-footed albatross (do not breed in Alaska, conservation concerns regarding incidental take in fisheries).

- Shearwaters (do not breed in Alaska, most abundant seabird in Alaska in summer).

- Northern fulmars (the most frequently taken species in every groundfish gear type).

- Species of Management Concern (a U.S. Fish and Wildlife Service [USFWS] designation for species that may be susceptible to listing under the ESA, including red-legged kittiwakes, marbled murrelets, and Kittlitz’s murrelets).

- Other piscivorous (fish-eating) species (most alcids, gulls, and cormorants).

- Other planktivorous species (storm-petrels and auklets).

- Spectacled and Steller’s eiders (benthic feeding sea ducks listed as threatened under the ESA).

4.1.1.4 Marine Mammals

The standard for determining significance for effects on marine mammals is whether the impact would be expected to be detectable at the population level. Individual effects categories do not have to cause a measurable population decline or increase to be labeled significant, but data and/or plausible arguments must exist to determine that the action would have more than a negligible impact on the reproduction and/or survival of a species group in a way that could affect the population.

For each category of effects, it was determined wether the alternative fishing regime would result in significant adverse, insignificant, significant beneficial, or unknown effects on marine mammals. In addition, effects may be classified as conditionally significant, if significant effects could be expected under a plausible set of conditions. The intent of the conditional label is to imply uncertainty about whether an alternative FMP would actually result in conditions that led to a significant impact. When the conditional label is applied, a plausible mechanism for the impact and the conditions under which a significant impact would be realized is stated. In cases where data are lacking to rank an effect according to the significance criteria, the effect was determined to be unknown.

The expected effects of each alternative were compared to the baseline conditions to determine the relative significance of the impacts of the alternatives on marine mammals. The significant criteria are described in Table 4.1-6.

4.1.1.5 Socioeconomic Effects

In the socioeconomic impact analysis, the term significant for an expected change in a quantitative indicator means a 20 percent or more change (either plus or minus) relative to the comparative baseline. If the expected change is less than 20 percent, the change is not considered to be significant. The same threshold is roughly used to roughly assess changes in qualitative indicators (e.g., fishing vessel safety). However, whereas changes in quantitative indicators are based on model projections, predicted changes in qualitative indicators are based on the judgement of the socioeconomic analysts.

4.1.1.6 Ecosystem

Significance thresholds for determining the ecosystem-level impacts of fishing would involve both population-level thresholds that have already been established for species in the system (MSST for target species, fishing-induced population impacts sufficient to lead to listing under the ESA, and fishing-induced impacts that prevent recovery of a species already listed under ESA, for nontarget species) and community- or ecosystem-level attributes that are outside of the range of natural variability for the system (Table 4.1-7). These community or ecosystem-level attributes are more difficult to measure directly, and the range of natural variability of those attributes is not well known. We may also lack sufficient data on population status of target or non-target species to determine whether they are above or below MSST or ESA-related thresholds. Thus, indicators of the strength of fishing impacts on the system will also be used to evaluate the degree to which any of the alternatives may be having a significant ecosystem impact.

For each of the alternatives, the possible impacts on 1) predator/prey relationships, including introduction of non-native species; 2) energy flow and redirection (through fishing removals and return of discards to the sea); and 3) diversity will be addressed.

4.1.2 Data Gaps and Incomplete Information

The Council on Environmental Quality (CEQ) guidelines require that

> *When an agency is evaluating reasonably foreseeable significant adverse effects on the human environment in an environmental impact statement and there is incomplete or*

> *unavailable information, the agency shall always make clear that such information is lacking (40 CFR 1502.22).*

The regulations instruct that where the information is relevant, but "the overall costs of obtaining it are exorbitant or the means to obtain it are not known" (40 CFR 1502.22), the following should be included in the EIS:

- A statement that such information is unavailable.
- A statement of the relevance of the information to evaluate reasonably foreseeable significant adverse impacts.
- A summary of existing information that is relevant to evaluating the adverse impacts.
- The agency's evaluation of adverse impacts based on generally-accepted scientific methods.

In the analysis, this Programmatic SEIS identifies those areas where information is unavailable to support a thorough evaluation of the environmental consequences of the alternatives. Efforts have been made to obtain all relevant information; however, some data gaps still exist at this time due to several reasons, such as the costs of obtaining the missing data are exorbitant, the data will take several years to obtain, or the means to obtain the data are unknown. Limited resources to collect and analyze baseline information due to limited funding is problematic. NOAA Fisheries receives a certain level of funding, of which a certain amount is set aside for research on Alaska fisheries issues. The amount set aside for research (including data collection) is fully committed, and NOAA Fisheries cannot expend funds it does not have. Therefore, the cost of research needed to fill in current data gaps in addition to currently funded research is exorbitant. Examples of existing data gaps include the uncertainty of survey biomass estimates for many species, which in some cases would require the initiation of species-specific surveys to improve estimates; research needed to assess the use of existing and proposed refugia to improve reproductive success; and life history studies needed to elevate groundfish species in Tiers 4 through 6 into Tiers 1 through 3. NOAA Fisheries' Stock Assessment Improvement Initiative explicitly addresses these needs, and expanded stock assessment funds have been requested in NMFS proposed budgets. Where data gaps still exist, the Programmatic SEIS provided the information listed above, according to the CEQ guidelines.

As outlined in Section 4.1.1, the impact ratings used in this analysis include three categories that indicate a lack of complete data: unknown, conditionally significant adverse, and conditionally significant beneficial. In cases where these ratings are used, a discussion is included about the nature of the unavailable information and its relevance to this analysis. In cases where a conditional qualifier is used, the analysts, using credible scientific methods, have based their assessment on existing information and specific assumptions based on professional judgement in order to evaluate the reasonably foreseeable adverse or beneficial impacts. Where an unknown significance rating is used, not enough baseline information exists to evaluate the impact of the alternatives.

Section 5.1 catalogs the information that is unknown or unavailable for all resource categories. The section discusses ongoing and proposed research relating to the North Pacific groundfish fisheries, and lists the known data gaps for each resource category. Additionally, the specific research initiatives recommended in the various alternative policies are also identified.

4.1.3 Direct and Indirect Analysis

4.1.3.1 Target Species, Prohibited Species, Other Species, Forage Fish Species, Non-Specified Species

The impacts on target species, prohibited species, other species, forage fish species, and non-specified species were evaluated with respect to five effects: 1) fishing mortality; 2) change in biomass level; 3) spatial/temporal concentration of the catch; 4) prey availability; and 5) habitat suitability. Fishing mortality, biomass changes, and spatial/temporal concentration of the catch are considered direct effects, and prey availability and habitat suitability are considered indirect effects. The significance of these effects was evaluated according to whether they might be reasonably expected to jeopardize the sustainability of each species group within the current fishery management regime. Under FMP 1, all target species are managed within the definitions of Amendments 56/56 to the BSAI and GOA FMPs, which set the overfishing levels and the maximum permissible acceptable biological catch for six tier designations as described in Appendix B. Under FMP 1, only one stock is designated as falling within Tier 1 (eastern Bering Sea [EBS] pollock), and no stocks fall within Tier 2. Of the 21 BSAI target groundfish categories, 11 species are managed under Tier 3, no species are under Tier 4, eight species or species complexes are under Tier 5, and one species group (squid) is under Tier 6. Of the 16 GOA target groundfish categories, eight species are managed under Tier 3, seven species or species complexes are under either Tiers 4 or 5, and one species (Atka mackerel) is under Tier 6. The significance of the effects of the current fishing mortality levels is evaluated with respect to the overfishing mortality rates as set forth in Amendments 56/56.

As a means of evaluating the intensity (significance) of the effects on target species prohibited species, other species, forage fish species, and non-specified species under the alternatives, a system was developed whereby the significance of the five selected effects was evaluated. Additional details for each species or species complex are given in the specific section for that species or species complex. The system consists of four rankings of significance, including significant negative, unknown, insignificant, and significant positive. Recognizing that such general terminology is inherently subjective, we applied criteria where possible to define the terms and rankings. Where metrics were not available, descriptions of the impacts within the text are relied upon to justify the significance evaluation.

For the target species, the multi-species, multi-fisheries simulation projection model provided fundamental dynamics to the model behavior. That is, as the biomass of an FMP species changed in the future, the constraint (via acceptable biological catch/total allowable catch [ABC/TAC] control) also changed. The outputs from the model were primarily intended to reflect these dynamics and the interactions with the species composition of the different fisheries.

4.1.3.2 Habitat

This analysis focuses on the following question: do the alternative management policies result in conditions that offer protection to and minimization of adverse impacts to habitat? For Alaska groundfish, this includes the habitat for all target groundfish species, non-target species, prohibited species, other species, and their prey. When viewed in aggregate, across all species, habitat includes all pelagic and benthic habitat in the Alaska Exclusive Economic Zone (EEZ). However, the focus of this analysis is benthic habitat, which is generally believed to be at greater risk to the impacts of fishing than non-benthic habitat in the water column. In addition, much of the analysis focuses on the impacts of bottom trawling. It is recognized that fixed gear (longlines, pots, and jigs) or pelagic trawl gear that comes in contact with the sea floor can disturb benthic habitat. In some types of habitat, fixed gear may cause an impact due to its ability to be more easily fished on rougher substrates (e.g., boulders with coral) than bottom trawl gear. However, most scientific studies of gear impacts have dealt with bottom trawls and dredging because this gear is the most controversial (Auster and Langton 1999, Jennings and Kaiser 1998, Hall 1999b, NRC 2002).

The impacts of bottom trawling on benthic habitat are described in Section 3.6.4. In general, relative to unfished habitat, areas fished with bottom trawls are expected to have reduced habitat complexity, reduced species diversity, and changes in species composition. The level of habitat complexity depends on the structural components of the living and non-living benthic environment. Habitat complexity is reduced when epifauna that form structures are removed or damaged, Sedimentary bedforms are smoothed, and infauna that form burrows and pits are removed. Worldwide studies of the effects of bottom trawling have generally found that trawling reduces habitat complexity (Auster and Langton 1999). These findings have been confirmed by studies conducted in Alaska (Freese *et al.* 1999, McConnaughey *et al.* 2000). The extent of the impacts depends on many factors, such as habitat type, natural disturbance, recovery rates, and the intensity and spatial distribution of bottom trawling.

Evaluating habitat impacts in marine fisheries is not a well developed field. There are few, if any, known applicable analytical methods for evaluating habitat. During the preparation of the Programmatic SEIS, we developed methods to evaluate impacts of fisheries on benthic habitat. Specific impacts on habitat, as noted above in Section 4.1.1.2, are difficult to predict, however, because the information needed to do so is generally incomplete for Alaskan waters. It may never be possible to fully and quantitatively account for all factors involved in determining how an ecosystem will respond to fishing activities. We have analyzed the direct and indirect effects identified in Table 4.1-4 by using, to varying degrees, four primary sources of information:

1. Estimates of the bycatch of living habitat derived from the multi-species projection model described in Section 4.1.5.

2. The results of a habitat impacts model (Fujioka 2002, Rose 2002) for estimates of the equilibrium levels of biostructure.

3. Estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species.

4. Evaluation of the spatial distribution of bottom trawl closures relative to fishing intensity and habitat types.

We want to emphasize that while the multi-species model, habitat impacts model, and estimates of the amount of area by habitat type closed year round were used initially, these information sources later became peripheral to the habitat impacts analysis. The multi-species projection model was used by Programmatic SEIS analysts as a tool to determine impacts of the alternatives in future years. These data were obtained from the NMFS Observer Program. For the most part, we found that future projections of living habitat bycatch using these data and multi-species model results did not prove useful in analyzing habitat impacts as compared to target species and other fish species impacts. For example, the NMFS Observer Program aggregates all coral species into a single category. While these data are useful in documenting that these benthic organisms are taken as bycatch in various groundfish fisheries, problems arise due to the wide variety of coral species and the vulnerability of hard versus soft corals to different gear types. Differences in recovery rates among species make assessing fishing impacts on these species difficult. All corals likely provide an important biostructure component to habitat for some of the managed species.

In order to run the habitat impact model described by Fujioka (2002; see Section 4.1.6) for the various alternatives, reliable catch and effort projections are needed. For example, for FMPs where the illustrated closure scheme differs substantially from the baseline in the location and amount of areal closures and/or fishing effort (example FMP 2.1, FMP 3.2 and FMP 4.1), the resolution of the data needed to run the model was not available.

Estimates of the amount of area by habitat type and geographic zone closed year round to bottom trawling for all species refers to some simple calculations of the amount of area closed to bottom trawling. While we present these data in the Programmatic SEIS for information purposes, this information was used sparingly to rate the alternatives in terms of habitat impacts.

As a result of these data limitations, our analysis relied most heavily on a comparison of maps of fishing intensity (presented by C. Rose [2002] at the Effects of Fishing Symposium) and closure area illustrations developed by the project team. This qualitative approach was an important part of the Programmatic SEIS analysis. Analysts would have liked to have conducted a more quantitative analysis of the spatial distribution of proposed closures relative to fishing intensity; however, there was only sufficient time to apply the data quantitatively to the status quo FMPs (e.g., FMP 1), and we used our best professional judgment in evaluating the other alternatives.

This analysis does not include impacts of trawling on non-living habitat, such as boulders, cobbles and sandwaves, which can be disturbed by bottom trawls (Auster and Langton 1999). In most cases, the structural integrity, and hence the complexity of the habitat, would not be greatly reduced, but when nonliving substrates are disturbed, the organisms living on them may die or be damaged.

Living Habitat – Direct Mortality of Benthic Organisms

Living habitat includes organisms that provide high microhabitat complexity and serves as cover for fish and their prey. Living habitats include: corals, sponges, anemones, sea whips, sea pens, and tunicates. Criteria to determine acceptable levels of mortality to living habitat have not been established. Such criteria would need to consider fishing induced mortality relative to such characteristics as natural mortality, fecundity, abundance, growth rates, and recruitment. Many deep water areas are characterized as stable environments dominated by long-lived species. In such areas, the impacts of fishing can be substantial and long-term (Auster and Langton 1999). Species such as red tree coral (Primnoa) are very long lived (more than 100 years old) and slow growing, and the habitat they provide does not easily recover if damaged by fishing (Risk *et al.*1998, Andrews *et al.* 1999, Krieger and Wing 2000). Recent studies indicate long recovery rates for deep water sponges that have been damaged or removed by trawling (Freese 2003). A potential quantifiable measure of the expected impact to such habitat are estimates of their living habitat bycatch derived from the multi-species projection model described in Section 4.1.5. Observer data from 1999 to 2001 provides information to estimate baseline levels of this bycatch (Tables 4.1-8 and 4.1-9). For the most part, we found that projections of bycatch of living habitat from the multi-species projection did not provide realistic data to rate the alternatives. Thus, we relied more heavily on application of the habitat impacts model (see Section 4.1.6) as the tool to assess changes to direct mortality of benthic organisms.

There is also unobserved mortality and damage to living habitat that would not be reflected as bycatch (Freese *et al.* 1999, Krieger and Wing 2000, Freese 2003). Assuming that most living habitat caught as bycatch dies, then observed bycatch is a minimum estimate of fishing-induced mortality. We caution about comparing bycatch across gear types and fisheries. For example, if a particular fishery tends to catch more living habitat, this could indicate more impact for that fishery. However, there is little or no information to compare impacts between different gear types. Additionally, one gear type may be particularly efficient at catching and retaining an organism relative to the impact it has on living habitat, while another gear type may not retain the organism while causing a different level of impact. Such variability makes assessing fishing impacts very challenging and, as a result, this has been prioritized for research.

Benthic Community Diversity and Geographic Diversity of Impacts

Areas that are closed to fishing can protect living habitats from damage by fishing activities. In addition, closed areas can allow recovery of habitats already impacted by fishing. Ideally, placement of the closed areas would occur across a range of vulnerable, representative habitat types (National Research Council [NRC] 2002). Areas only seasonally closed to particular fisheries provide little protection to benthic habitat. For example, in the current BSAI and GOA FMPs, seasonal closures to Pacific cod, Atka mackerel, and pollock fishing exist in areas of sea lion foraging. These closures, however, provide little protection to benthic habitat because they are either fished seasonally and/or allow fisheries for other species. Thus, they address sea lion concerns, but fail to address the need to fully protect benthic habitat. Only year-round closures for all species are considered to provide protection to benthic habitat.

Simple calculations of the amount of area by habitat type and geographic zone closed to bottom trawling may provide some data to rate the alternatives. However these data do not provide information on the spatial distribution of closures relative to fishing intensity. Area calculations are mostly provided for information purposes.

Consideration must also be given to the geographic distribution of fishing intensity relative to closures. For instance, if closures are placed primarily in areas where there is little or no fishing then there will be little benefit to habitat over baseline levels. In contrast, if closures are placed primarily in fished areas that have high fish density and the displaced fishing effort moves to areas of low fish density, the result may be more habitat damage because greater effort may be required to catch the same amount of fish. Consideration of the geographic distribution of impact levels allows the habitat unit's distance and direction from other habitat, geographic, and oceanographic features to be accounted for.

We were able to apply the habitat impacts models to the status quo FMP (FMP 1) to quantitatively assess these direct effects. However, for the other alternatives we had to rely on a more qualitative approach. Thus, we used maps of baseline fishing intensity (Rose and Jorgenson 2002), and mapped alternative-specific closure areas to assess changes to benthic community diversity and geographic diversity of impacts.

Given that little is known about the habitat requirements of target, prey, or predator species in the BSAI and GOA and the location of specific habitats in these regions, managers must ask what is the best strategy for distributing fishing impacts over the potential fishing grounds? Should effort be distributed uniformly over the fishing grounds, or should effort be concentrated in certain areas while leaving other areas unfished? If so, how large and in what orientation should the fished or unfished areas be? One may theorize that vast expanses of contiguous fishing effort or impact levels should be avoided. The evaluation of fishing impacts of example FMPs in this Programmatic SEIS operates under the following assertions and assumptions:

1. Knowledge about habitat value and its distribution is of low resolution based on gross bathymetric information, such as shelf, slope, gullies, or large scale geographic or oceanographic features, and we assume that such features capture benthic habitat.

2. Relative to habitat distribution, spatially diverse or patchy fishing impacts are preferable to uniformly distributed impacts (Duplisea *et al.* 2002). Thus, one of the criteria used to evaluate the alternatives will be the spatial and geographic diversity of fishing impacts. The patchiness of fishing effort may be enhanced by having some areas not fished dispersed within historically fished areas. This patchiness promotes habitat diversity.

3. Geographic diversity of impacts and protection is obtained by having a consistent pattern of varying levels of impact within a habitat type. This would be achieved most simply by establishing long-term closure areas over a portion of each habitat type within fished areas. Totally encompassing the habitat type or the cluster of historical fishing intensity within a closure, would not achieve a diverse impact.

4. Bathymetric features such as gullies, banks, shelf, slope, and slope/gully intersections represent individual general habitat types. In addition, clusters of fishing intensity represent an area of unique habitat, perhaps defined only in part by benthic habitat. In the GOA, the spatial resolution of these habitat types is on a much finer scale than the fairly uniform bathymetry of the Bering Sea. Habitat types in the Aleutian Islands are not as easily classified or distinguished, and are on an even finer spatial resolution.

4.1.3.3 Seabirds

Because of differences in foraging behavior, abundance, and distribution, some seabird species are more likely to be directly or indirectly affected by the groundfish fishery than others. Direct effects are those that take place at the same time and place as the fishing activity. Indirect effects are removed in time and/or space from the initial action. The mechanisms and history of direct and indirect effects of fisheries on seabirds are described in Section 3.7.1, along with other natural and human-caused influences on these effects. Details on the extent of each type of effect for each species, to the extent that they are known, are presented in the species accounts of Section 3.7.

For purposes of this chapter, some types of potential effects offer clearer comparisons of the alternatives than others. For seabirds, one direct effect (mortality) and two indirect effects (prey availability and benthic habitat) were analyzed to make the distinction between alternatives. Data on incidental seabird take come from the North Pacific Groundfish Observer Program and include birds that are killed or seriously injured in fishing gear or by striking the vessel or its rigging. Both indirect effects involve changes in the food supply of birds, but the mechanisms are different. Prey availability involves the removal of prey and competitors for that prey from the water column. Benthic habitat describes changes in the physical and biotic structure of the ocean bottom that potentially affect the capacity of that habitat to support the food web important to seabirds. Consumption of fishery wastes has implications for both incidental take (attracting birds and resulting in increased vessel interactions) and food availability. Since incidental take is addressed in different ways by the different alternatives, and the production of fishery wastes is closely linked to overall TAC, consumption of fishery wastes will be incorporated into the analysis of effects on prey availability, which is related to fishing effort. The effects on benthic habitat are analyzed separately because they are more defined in space, and the alternatives vary considerably and specifically with fishing area closures.

Other potential effects, such as oil spills, plastic pollution, and introduction of nest predators, are the result of vessel traffic rather than fishing effort. An oil spill from a shipwrecked fishing vessel or the accidental release of rats from a ship to a seabird colony could have very substantial repercussions for one or more seabird species. However, the magnitude of the effect will depend on a host of variables that cannot be predicted. In addition, the risks of these types of events occurring are not necessarily proportional to fishing effort. Even the closure of the fishery would not eliminate these risks because the fishing and processing vessels would likely be used in other fisheries or brought to port where they may actually increase the risk of an effect (i.e., introduction of nest predators). Because these types of effects do not lend themselves to distinguishing between the alternatives, they will not be analyzed in the direct/indirect effects of each FMP. However, they are important to the overall effects of the fishery and are included as part of the baseline condition and as contributions to the cumulative effects.

Significance criteria were based on whether the proposed action would be likely to result in population-level effects, which are defined as changes in the population trend outside the range of natural fluctuations (see Section 4.1.1 for further details). The projection model was used for predictions of fishing effort under the different FMP bookends, especially with respect to different gear types. The analysis includes other factors such as spatial/temporal restrictions and potential gear modifications for seabird avoidance. However, because there are a large number of unpredictable variables and gaps in our knowledge about the natural history and populations of particular species, as well as many kinds of ecosystem effects, it was not possible to ascertain significance on a strictly quantitative basis. Conclusions are based on professional judgements of pertinent data, literature review, and the likelihood of certain conditions occurring.

4.1.3.4 Marine Mammals

Effects of the groundfish fishery management alternatives on marine mammals will be examined by focusing analyses around four core questions, which were modified from Lowry (1982):

- Is the alternative management regime consistent with efforts to avoid direct interactions with marine mammals (incidental take and entanglement in marine debris)?

- Does the alternative management regime result in harvests of fish species that are of particular importance to marine mammals as prey, at levels that could compromise foraging success (harvest of prey species)?

- Does the alternative management regime result in temporal or spatial concentration of fishing effort in areas used for foraging by marine mammals (spatial/temporal concentration of removals with some likelihood of localized depletion)?

- Does the alternative management regime modify marine mammal or forage behavior to the extent that population-level impacts could occur (disturbance)?

The existing environmental conditions under and independent of the 2002 fishery management measures were used as the baseline for comparing the alternatives with respect to effects on marine mammals, using the above questions to determine impacts. The expected effects of each alternative were compared to the effects as they exist under the baseline conditions to determine the relative significance of the impacts on marine mammals.

Direct Effect – Incidental Take/Entanglement in Marine Debris (Question 1)

Groundfish fisheries directly affect marine mammals when animals are incidentally caught or become entangled in fishing gear. When animals are incidentally taken or entangled, serious injury or mortality may or may not result. Some species are more susceptible than others to interactions with fishing gear, depending on the extent of spatial overlap with the fisheries and on the animals ability to detect and avoid gear. Fishery/marine mammal encounters that result in high levels of mortality and serious injury may have the potential to cause population-level effects. The level of incidental take and entanglement that results in population-level effects will vary according to the status and trajectory of each stock.

The MMPA requires that take of ESA- or MMPA-listed marine mammals incidental to commercial fisheries be authorized under a 101 (5)(E) permit upon determination that the incidental mortality and serious injury from these fisheries will have a negligible impact on the species or stock. For most activities, a negligible impact is defined as having a duration and intensity which results in an insignificant effect on the population. For fishing activities, the intensity of the effect is a more important consideration than the duration of the effect. If an impact is expected to cause no more than a ten percent delay in recovery of an ESA- or MMPA-listed species, then the impact is deemed negligible and will thus be insignificant. If incidental take and entanglement in fishing gear is expected to occur at a level which would delay recovery of a stock by more than ten percent than would be expected under baseline conditions, the impact will be significant. This approach allows for the incorporation of parameters specific to each population and thus accounts for the variable effects of incidental take according to the status and trajectory of each stock.

To calculate the delay in recovery imposed by additive mortality and injury incidental to fishing operations, definitions of the following are needed: the point at which the population is considered to be recovered, the current population size, and the intrinsic rate at which the population is increasing. For species with increasing population trajectories, it is possible to estimate the time until the population will be recovered. For species with negative population trajectories (declining stocks), the time period over which the population would be expected to go extinct can be estimated. If the additional mortality and serious injury resulting from incidental takes in commercial fisheries does not accelerate the estimated time to extinction by more than ten percent, the impact will be determined to be negligible at the population level, thus rendering it insignificant for purposes of this analysis.

Under the best-case scenario, incidental take and entanglement of marine mammals in fishing gear would be zero animal. Yet even under this scenario, the population effect on the species would be insignificant; therefore, effects ratings of (conditionally) significant beneficial are not applicable to this analysis.

Direct/Indirect Effect – Harvest of Key Prey Species (Question 2)

Direct and indirect interactions between marine mammals and groundfish fisheries occur due to overlap in the size and species of groundfish harvested in fisheries that are also important prey for marine mammals, and due to the spatial/temporal overlap in marine mammal foraging and commercial fishing activities. By design, fishing significantly reduces the spawning biomass of harvested species. The relevant question is whether fishing under these global (e.g., large-scale, such as BSAI- or GOA-wide) exploitation strategies reduces the environmental carrying capacity of marine mammals by affecting the prey on which they depend for survival.

Fishery removals of marine mammal prey may cause food availability to become the limiting factor regulating the size of the marine mammal population. If fisheries remove more of a prey species' standing biomass than is required to maintain a marine mammal population at the current size, the fishery would be deemed to have a significant adverse effect at the population level. Alternately, if a fishery management regime is expected to increase the available standing biomass of a prey species to a level such that the size and/or health of the marine mammal population is expected to increase, the fishery would be deemed to have a significant beneficial effect at the population level.

To make a determination of the point at which the alternate fishery regimes affect the availability of key prey species relative to the baseline to the extent that marine mammals experience population-level effects, it is necessary to know the following: the marine mammal's energy requirements; the relative contribution of each prey species to those energy requirements; the adequacy of the existing standing biomass of prey; the standing biomass of the prey species before and after the fishery; and how the change in the standing biomass equates to changes in the marine mammal population's vital rates or carrying capacity. With the best available scientific and commercial data, our current understanding of marine mammal bioenergetic requirements does not allow such a determination.

Due to the limited state of knowledge regarding the effects of the harvest of marine mammal prey species, we relaxed the requirement that varying levels of fishery removals be directly linked to effects which would be detectable at the population level. The significance criteria for this category of effects was selected to allow for informative comparisons of each fishery management alternative relative to the baseline. A 20 percent change in the fishing mortality rate relative to the baseline was selected as the significance threshold, as it was judged to result in large enough changes to the prey field such that significant impacts on marine mammal populations would reasonably be expected due to changes in the standing biomass of their key prey. Predicted fisheries harvest rates were modeled for each FMP scenario and FMP bookend using the Multi-species Analytical Model. Scenarios in which the fishing mortality rate (*F*) of key prey species is projected to increase by at least 20 percent were determined to have significant adverse effects on marine mammals, whereas a decrease in F of at least 20 percent was determined to have a significant beneficial effect. The effect of harvest of prey species was determined to be unknown when there was insufficient diet information for a given marine mammal species to determine if there would be overlap with the fisheries. After assessing the predicted change in fishing mortality rate of individual key prey species, a judgement was reached on the aggregate change in available standing biomass of marine mammal prey based on the factor discussed above, and whether this aggregate change from the baseline would have population-level effects on a species. This method of assessing the availability of prey is similar to the analysis used int the Steller Sea Lion Protective Measures EIS and the Steller Sea Lion BiOp. (NMFS 2001b and 2001c). In some cases the baseline availability of prey is considered adverse for an individual marine mammal species; therefore lack of a change from the baseline would continue to be adverse.

Indirect Effect – Spatial/Temporal Concentration of the Fishery (Question 3)

Overall effects of fisheries on marine mammal populations vary according to the spatial/temporal concentration of the fishery. Although global fishery removals are designed to be precautionary, such that the productivity of target stocks and their ability to support natural predators are not compromised. In the times and locations where fisheries and marine mammals overlap, fisheries compete with marine mammals such that the resource can become limited. The intensity of the effects on marine mammals will vary according to the extent of competition (amount of overlap and degree of resource limitation) and the importance of the resource to marine mammals in a particular season or area. Because it is not possible to quantify the amount of competition between fisheries and marine mammals, nor to state the level of competition that results in changes at the population level, the effects of spatial/temporal fishing concentrations under the various alternatives were assessed qualitatively according to the spatial and seasonal foraging requirements of marine mammals. Alternatives were categorized as having significant adverse effects on marine mammal populations if there was much more spatial/temporal concentration in important foraging habitat and/or critical periods over baseline conditions (fishery conditions under 2002 rules and regulations). Significant beneficial effects were assigned if there was a much lower concentration of the fishery in key areas and seasons compared to baseline conditions. Unknown effects were assigned when there was insufficient information to determine what constitutes the key areas and seasons for a given marine mammal species.

Direct Effect – Disturbance (Question 4)

Activities related to groundfish fisheries in the BSAI and GOA have the potential to affect marine mammal behavior. Disturbance to marine mammals may result from vessel traffic, fishing operations, or underwater noise, such that otherwise normal behavior or movement patterns are altered. As defined here, these disturbances have significant adverse effects on marine mammal populations when marine mammal or forage behavior is modified to the extent that population level impacts could occur. Because it is not possible to quantify disturbance resulting from fisheries, nor to state the level of disturbance that results in changes at the population level, the level of disturbance expected to occur under the various alternatives was compared qualitatively to the baseline level of disturbance to evaluate the significance of the alternatives. The effects analysis for this category incorporated projections from the multi-species management model to determine changes in fishery patterns and information on marine mammal distributions and behavior to infer potential disturbance levels. The significance criterion was similar to that for evaluating fishery concentrations in time and space with substantially more disturbance from baseline conditions leading to a significant adverse finding. Insignificant effects were assigned for those species that do not appear to be disturbed by fishing vessels, and in cases where the level of disturbance was not expected to fluctuate to a large degree relative to the baseline. Under the best-case scenario, disturbance of marine mammals resulting from groundfish fishing activities would be zero. Even under this scenario, the population effect on the species would be insignificant; therefore, effects ratings of conditionally significant beneficial are not applicable to this analysis. Unknown effects were assigned when there was insufficient information to determine what constitutes disturbance for the species.

Marine Mammal Species and Species Groups

The effects of the alternative FMPs were analyzed on either individual species/stocks of marine mammals or on aggregate groupings of marine mammals according to the level and intensity of the expected effects or according to the status of the marine mammal stock. Species or stocks analyzed individually includes the western stock of Steller sea lions, the eastern stock of Steller sea lions, northern fur seals, harbor seals, transient killer whales, and sea otters. Marine mammals analyzed in aggregate include other pinnipeds, toothed whales (including resident killer whales), and baleen whales occurring in the BSAI and GOA groundfish fisheries. Western and eastern Steller sea lion stocks were split in the analysis due to the differences in their population trajectories, ESA listing status, and degree of overlap with groundfish fisheries. Northern fur seals and harbor seals were broken out from the other pinnipeds because they are expected to be more affected, directly or indirectly, by groundfish fisheries than the other pinniped species in the affected area. Transient killer whales were split out from the other toothed whales because their diets differ substantially from the other species in this category.

4.1.3.5 Socioeconomic Effects

Assessment of socioeconomic impacts considers the following important factors:

- Impacts on harvesting and processing sectors, including: catcher vessels, catcher processors, and inshore processors and motherships. Catches of all groundfish species, groundfish ex-vessel value and product value, groundfish employment and payments to labor, excess capacity, product quality, product utilization rates, average costs, and fishing vessel safety were used as variables.

- Regional impacts, on six regions (Alaska Peninsula and Aleutian Islands, Kodiak Island, Alaska southcentral, southeast Alaska, Oregon coast, and Washington inland waters), using processing, harvesting, payments to labor, and employment variables.

- Community Development Quota (CDQ)-related impacts, including changes to the CDQ program and changes to the CDQ species TACs.

- Impacts related to subsistence use of groundfish, Steller sea lions, and salmon, as well as opportunities for practicing subsistence.

- Environmental justice impacts resulting from changes in fishing activity, or impacts to the CDQ program or subsistence.

- Impacts on consumer benefits (U.S. consumers of groundfish products).

- Impacts on benefits from marine ecosystems (other than those benefits related to commercial groundfish fisheries), including non-market (existence value and option value, etc.), and other uses of the ecosystem, such as recreational fishing or tourism.

The socioeconomic impacts of the alternatives have been assessed using the Sector Model to estimate catch and processing amounts and revenues for the fishing and processing sectors and regions described in Section 3.9.2. The Sector Model uses output from the multi-species management model, combined with the historical harvest and processing proportions, to estimate the distribution of catch and processing among the various sectors and regions that rely on the groundfish fishery.

The Sector Model is a three-step process that:

- Estimates total catch and deliveries to processors.
- Proportions out deliveries to specific catcher vessel sectors.
- Distributes catches and processing amounts among the various regions where processors are located or vessels are owned.

In each step of the Sector Model, the catch of each species by gear and subarea is distributed to successive sectors based on the historical distribution from 2001 (the baseline condition for socioeconomic effects). The model and analytical framework used in the analysis for the harvesting and processing sectors are described in Section 4.1.7.

4.1.3.6 Ecosystem

Ecosystems consist of populations and communities of interacting organisms and their physical environment that form a functional unit with a characteristic trophic structure and material cycle (i.e., how energy or mass moves within the unit). Fishing has the potential to influence ecosystems in several ways. Fishing may alter the amount and flow of energy in an ecosystem by removing energy and altering energetic pathways through the return of discards and fish processing offal back into the sea and through mortality of organisms not retained in the gear. The recipients, locations, and forms of this returned biomass may differ from those in an unfished system. Selective removal of species and/or sizes of organisms that are important in marine food web dynamics such as nodal prey species or top predators has the potential to change predator/prey relationships and community structure. Removals concentrated in space and time may impair the foraging success of animals tied to land such as pinnipeds or nesting seabirds; these animals may have restricted foraging areas or critical foraging times that are key to survival or reproductive success. Introduction of non-native species may occur through emptying of ballast water or introduction of hull-fouling organisms from ships from other regions (Carlton 1996). Introductions of such species have the potential to cause large changes in community dynamics. Fishing can alter different measures of diversity. Species-level diversity, or the number of species, can be altered if fishing essentially removes a target or nontarget species from the system. Fishing can alter functional diversity if it selectively removes a trophic or other ecosystem member and changes the biomass distribution among a trophic groups. Fishing gear may alter bottom habitat and damage benthic organisms and communities that serve important functional roles as structural habitat or within the food web. Fishing can alter genetic-level diversity by selectively removing faster growing fish or removing spawning aggregations that might have different genetic characteristics than other spawning aggregations.

A great deal of literature addresses possible indicators of ecosystem status in response to perturbations (e.g., Odum 1985, Pauly *et al.* 1998, Rice and Gislason 1996, Murawski 2000). These indices can show changes in energy cycling and community structure that might occur due to some external stress such as climate or fishing. For example, fisheries might selectively remove older, more predatory individuals. Therefore, we would expect to see changes in the size spectrum (the proportion of animals of various size groups in the system), mean age, or proportion of r-strategists (faster growing, more fecund species, such as pollock) in the system. These changes can increase nutrient turnover rates because of the shift towards younger, smaller organisms with higher turnover rates. Total fishing removals and discards also provide a measure of the loss and re-direction of energy in the system due to human influences. Total fishing removals relative to total ecosystem energy could indicate the importance of fishing removals as a source of energy removal in an ecosystem. Changes in scavenger populations that show the same direction of change as discards could be an indicator of the degree of influence discards have on the system. Discards as a proportion of total natural detritus would also be a measure that could indicate how large discards are relative to other natural fluxes of dead organic material. Levels of total fishing removal or fishing effort could indicate the potential for introduction of non-native species through ballast water in fishing vessels. Fishing practices can selectively remove predators or prey; tracking the change in trophic level of the catch may provide information about the extent to which this is occurring (e.g., Pauly *et al.* 1998). Thus, in this analysis, we use measures of total catch, total discard, and information about the changing mean size of organisms to indicate the potential of each of the alternatives to impact ecosystem energy flow and turnover.

Total catch and trophic level of the catch will provide information about the potential to disrupt predator/prey relationships through introduction of non-native species or altering the food web through selective removal of predators, respectively. Pelagic forage availability will be measured quantitatively by looking at population trends of pollock and Atka mackerel, target species that are key forage for many other fish and marine mammal species in the BSAI and GOA. Bycatch trends of nontarget species, such as the managed forage species group and herring, will be used as indicators of possible fishery impacts on those pelagic forage groups. Angermeier and Karr (1994) recognized that an important factor affecting the trophic base is spatial distribution of the food. The potential for fishing to disrupt this spatial distribution of food, which may be particularly important to predators tied to land, will be evaluated qualitatively to determine the degree of spatial/temporal concentration of fishery removals of forage. We will evaluate these factors to determine the potential of each of the alternatives to disrupt predator/prey relationships.

The scientific literature on diversity is somewhat mixed about what changes might be expected due to a stressor. Odum (1985) thought that species diversity (number of species) would decrease and dominance (the degree to which a particular species dominates the system in terms of numbers or biomass) would increase, if original diversity was high. The reverse might occur, if original diversity was low. Significance thresholds for species-level diversity due to fishing are catch removals high enough to cause the population of one or more target or non-target species to fall below minimum biologically acceptable limits. The MSST for target species, would either trigger ESA listing or would prevent recovery of an ESA-listed species. Genetic diversity can be altered by humans through selective fishing (removal of faster growing individuals or certain spawning aggregations). Accidental releases of cultured fish and ocean ranching tends to reduce genetic diversity (Boehlert 1996). Significance thresholds for genetic diversity impacts due to fishing would be catch removals high enough to cause a change in one or more genetic components of a target or non-target stock that would cause it to fall below minimum biologically acceptable limits (e.g., MSST for target species, ESA listing or non-recovery of ESA-listed species). More recently, there is growing agreement that functional (trophic or structural habitat) diversity might be the key attribute for ecosystem stability (Hanski 1997). This type of diversity ensures there are a sufficient number of species that perform the same function. If one species declines for any reason (human or climate-induced), then alternate species can maintain that particular ecosystem function, and there we would be less variability in ecosystem processes. However, measures of diversity are subject to bias, and we do not know how much change in diversity is acceptable (Murawski 2000). Furthermore, diversity may not be a sensitive indicator of fishing effects (Livingston *et* *al.* 1999, Jennings and Reynolds 2000). Nonetheless, we will evaluate the possible impacts that the alternatives may have on various diversity measures.

Quantitative measures of some of the indicators mentioned above have been identified for each of the alternatives. These include total catch, trophic level of the catch, total discards, total groundfish biomass, trophic level of groundfish biomass, bycatch amount of forage, top predator species, and habitat area of particular concern (HAPC) biota for the BSAI and GOA. We will address for each of the alternatives the possible impacts on predator/prey relationships, including introduction of non-native species; energy flow and redirection (through fishing removals and return of discards to the sea); and diversity.

4.1.4 Cumulative Effects Methodology

4.1.4.1 Introduction

Analysis of the potential cumulative effects of a proposed action and its alternatives is a requirement of NEPA. An EIS must consider cumulative effects when determining whether an action significantly affects environmental quality. The CEQ guidelines for evaluating cumulative effects state that "…the most devastating environmental effects may result not from the direct effects of a particular action but from the combination of individually minor effects of multiple actions over time" (CEQ 1997).

The CEQ regulations for implementing NEPA define cumulative effects as

> *the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).*

Cumulative effects are linked to incremental actions or policy changes that individually may have small outcomes, but that in the aggregate and in combination with other factors can result in greater effects in the BSAI and GOA. At the same time, the CEQ guidelines recognize that it is not practical to analyze the cumulative effects of an action on the universe, but to focus on those effects that are truly meaningful.

The cumulative effects analysis assesses the potential direct and indirect effects of groundfish FMP policy alternatives in combination with other factors that affect physical, biological, and socioeconomic resource components of the BSAI and GOA environment. Peer reviewed literature and quantitative research on the cumulative effects of fishing activities in the Bering Sea and GOA are limited. The cumulative effects analysis presented for each of the FMP policy alternatives addresses the potential magnitude of effects and is somewhat qualitative in nature.

The intent of the cumulative effects analysis is to capture the total effects of many actions over time that would be missed by evaluating each action individually. A cumulative effects assessment describes the additive and synergistic result of the actions proposed in this Programmatic SEIS as they interact with factors external to those proposed actions. To avoid the piecemeal assessment of environmental impacts, analysis of cumulative effects were included in the 1978 CEQ regulations, which led to the development of the CEQs cumulative effects handbook (CEQ 1997) and federal agency guidelines based on that handbook (e.g., USEPA 1999). Although predictions of direct effects of individual proposed actions tend to be more certain, cumulative effects may have more important consequences over the long-term. The possibility of these hidden consequences presents a risk to decision-makers, because the ultimate ramifications of an individual decision might not be obvious. The goal of identifying potential cumulative effects is to provide for informed decisions that consider the total effects (direct, indirect, and cumulative) of alternative management actions. This section characterizes the incremental cumulative effects that potentially arise from external factors in combination with the direct and indirect effects.

4.1.4.2 Methodology

The methodology for cumulative effects analysis in this Programmatic SEIS consists of the following steps:

- *Identify characteristics and trends within the affected environment that are relevant to assessing cumulative effects of the FMP policy alternatives, including lingering effects and how they have contributed to the comparative baseline.* This information is presented in Chapter 3 of this Programmatic SEIS and summarized in the cumulative effects sections for each of the alternatives.

- *Describe the potential direct and indirect effects of each of the four FMP policy alternatives.* This information is presented in detail in Sections 4.5 through 4.9 of this Programmatic SEIS, and is summarized in the cumulative effects ranking tables. The cumulative effects analysis uses the specific direct and indirect effects that have been evaluated for comparison with external factors.

- *Identify past, present, and reasonably foreseeable external factors such as other fisheries, other types of human activities, and natural phenomena that could have additive or synergistic effects.* Past actions must be evaluated to determine whether there are lingering effects that may still result in synergistic or incremental impacts when combined with the proposed action alternatives. The CEQ guidelines require that cumulative effects analysis assess reasonably foreseeable future actions. Because analysis of relevant past, present, and future effects depends on the resource or characteristic being evaluated, the time period for looking at past and reasonably future effects will vary. Both past BSAI and GOA FMP amendments and pertinent external factors used to evaluate potential effects are described further in this introduction.

- *Use cumulative effects tables to screen all of the direct/indirect effects with external factors to capture those synergistic and incremental effects that are potentially cumulative in nature.* Both adverse and beneficial effects of external factors on the criteria used for direct and indirect effects are assessed, and then evaluated in combination with the direct and indirect effects to determine if there are cumulative effects.

- *Evaluate the significance of the potential cumulative effects using criteria established for direct and indirect effects and the relative contribution of the action alternatives to cumulative effects.* Of particular concern are situations where insignificant direct and indirect effects lead to significant cumulative effects or where significant external effects accentuate significant direct and indirect effects.

- *Discuss the reasoning that led to the evaluation of significance, citing evidence from the peer-reviewed literature and quantitative information where available.* As with direct and indirect

> effects, the term conditional significance has been used where conclusions of significance have been based on reasoned assumptions, and the term unknown is used where there is not enough information to reach a conclusion of significance.

The advantages of this approach are that it closely follows CEQ guidance, employs an orderly and explicit procedure, and provides the reader with the information necessary to make an informed and independent judgment concerning the validity of the conclusions.

The CEQ (1997) has established step-by-step guidelines for conducting a cumulative effects analysis. The guidelines set forth 11 steps that can be classified into four basic stages: scoping, organizing, screening, and evaluating. Table 4.1-10 shows how the cumulative effects assessment for groundfish fisheries management was adapted to closely follow the CEQ guidelines.

4.1.4.3 Scoping

A historical review of the BSAI and GOA FMP amendments was conducted, looking at the intent and consequences of FMP amendments since 1980. This information was used to prepare the comparative baseline that is presented in Chapter 3 and summarized in Section 4.4. In addition to issues that were derived from the historical FMP amendment review, both the scoping process and public review of the first draft of the Programmatic SEIS identified issues to be addressed in the cumulative effects analysis. The scoping comments identified two major issues associated with analysis of potential cumulative effects: the consideration of the additive effects of management actions over time and the cumulative effects of the management regime as a whole, and the consideration of impacts of natural events versus fisheries management on the ecosystem, including the human component (socioeconomic and subsistence) of fishing communities.

Public comments on the first draft of the Programmatic SEIS identified 15 themes associated with the scope and conclusions of the analysis of potential cumulative effects. Among the suggestions was that the cumulative effects analysis use a different baseline to compare the alternatives than the status quo management system. A summary of these issues can be found in the Scoping Summary Report (NMFS 2000a) and Comment Analysis Report (Appendix G).

4.1.4.4 Additive and Cumulative Effects of Past FMP Amendments

The potential effects of the original BSAI and GOA FMPs and their amendments are difficult to substantiate quantitatively. Given the inherently large fluctuations that occur naturally in fish populations and the complexity of the North Pacific fishery, it is not feasible to identify biological responses to managerial decisions designed to fine tune fishery harvests under the mandate of both preserving stocks and maximizing commercial exploitation. Intended and unintended socioeconomic effects on the fishing industries and regions and communities that participate in the groundfish fishery are easier to assess. The analysis of FMP amendments was used to develop the comparative baseline presented in Chapter 3 and summarized in Section 4.4, and to identify lingering effects to carry forward into the cumulative effects analyses in Sections 4.5 through 4.9.

4.1.4.5 Identification of External Factors and Effects

A cumulative effects analysis takes into account the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions (40 CFR 1508.7). External factors play an important role in developing the comparative baseline used to evaluate the effects of the proposed action and its alternatives, and to identify present and reasonably foreseeable future actions that are relevant to the cumulative effects analysis. For the purposes of this Programmatic SEIS, the definition of external actions includes both human controlled events such as other fisheries, pollution, and industrial development, and natural events such as disease, winter mortality, and short-and long-term climate change.

In order to ascertain the importance of the external impacts in the cumulative effects analysis, a comprehensive checklist was produced for each resource category (marine mammals, seabirds, target species, non-target species, prohibited catch species, habitat, socioeconomic characteristics, and ecosystem). Information presented in the checklists was obtained from reviewing EISs, reports and resource studies, and peer-reviewed literature. The identified external factors were discussed in meetings with staff of the NOAA Fisheries Alaska Fisheries Science Center (AFSC) to confirm accuracy, identify any effects that might have been missed, and explore pathways through which the external influences might act in an additive or interactive fashion with the alternatives to produce cumulative effects.

Within each resource checklist the effects were divided into the two main categories: human controlled events, and natural events. Due to inherent differences between socioeconomic resources and biological resources and systems, external effects impacting the socioeconomic category were developed to consider different events and topics, or different aspects of the same event. For example, potential biological factors of other fisheries include disturbance and habitat damage, whereas potential socioeconomic factors include the contribution of participation in other fisheries to the overall viability of fishing industry harvesters and processors. Table 4.1-11 summarizes the external effects that have been incorporated into the cumulative effects analysis.

4.1.4.6 Organizing the Cumulative Effects Analysis

Potential cumulative effects of each of the policy alternative FMPs are presented in Sections 4.5 through 4.9. For each of the alternatives, the analysis of cumulative effects follows the analysis of direct and indirect effects within the discussion of each of the major resource topics (e.g., Target Fish, Marine Mammals, Socioeconomic Characteristics). The structure of the cumulative effects analysis also parallels the direct and indirect effect analysis in the organization of the impact screening tables. The categories of effects evaluated for each of the direct/indirect analyses are used to organize the cumulative effects screening tables.

The categories of effects to be evaluated were developed jointly by analysts preparing the direct/indirect and cumulative effects analyses. These effects appear in the far left hand column of both the direct/indirect and cumulative effects matrices. This approach facilitates evaluating the additive and synergistic effects of the FMP policy alternatives with past FMP amendments and external effects. It also provides transparent logic for those reviewing the Programmatic SEIS.

4.1.4.7 Screening Potential Cumulative Effects

The screening process for the cumulative effects analyses consists of the following steps:

- Identify the cause and effect relationships and incorporate them into the categories of effects to be evaluated for the direct/indirect and cumulative effects analyses.

- Identify whether potential effects on a given resource from past external actions remain, and whether they have a lingering effect on the resource that contributes to the significance of potential cumulative effects.

- Identify potential effects on a given resource from both direct and indirect effects of the policy alternative FMPs and from present and reasonably foreseeable external actions.

- Develop and utilize matrices as the organizational structure to incorporate past effects, direct/indirect effects, and the potential effects of present and reasonably foreseeable events in evaluating the potential for and significance of cumulative effects.

As indicated above, parallel impact assessment tables or matrices have been constructed to screen and evaluate direct, indirect, and cumulative effects, and to ensure that the evaluation is orderly and systematic. Each direct and indirect matrix scores the alternatives with respect to the impacts they could produce on the subject resource component. The range of scores includes insignificant, significant, conditionally significant, and unknown. A plus (+) or minus (-) is added to the significant or conditionally significant score to indicate a beneficial or adverse effect, respectively.

A second series of matrices was prepared for each resource component under each alternative. The cumulative effects matrices tabulate the external factors identified in the scoping process (columns) against the direct and indirect effects that have been identified. Under a single resource category (e.g., marine mammals), a separate cumulative effects matrix was prepared for each resource component (e.g., Steller sea lion, northern fur seal, harbor seal, etc.). The matrices include both beneficial and adverse environmental effects associated with past, present, and potential future management decisions related to the four policy alternatives. External effects that could function additively or interactively with the direct and indirect effects of the alternatives are organized into two major categories of human controlled and natural events.

4.1.4.8 Evaluating the Significance of Potential Cumulative Effects

The potential for cumulative effects and their significance was evaluated for the resources and characteristics of the human environment described in Chapters and 3 and 4. For biological, habitat, and ecosystem resources and characteristics, significance criteria and thresholds take into account the geographic scope, population level implications, and regulatory aspects of potential effects. Significance criteria and thresholds for socioeconomic characteristics take into account the relative magnitude of change, the geographic distribution of effects, and the regulatory aspects of potential effects.

Table 4.1-12 is an example matrix illustrating the approach taken to evaluate cumulative effects. Starting in the far left-hand column, the category of effect used in both the direct, indirect, and cumulative effects analysis is presented, along with a significance rating for the direct and indirect effect. Any persistent past effects to be carried forward in the cumulative effects analysis are identified. Next, reasonably foreseeable future human controlled and natural effects are identified and briefly described, along with the nature of contribution to cumulative effects. Categories include potential adverse or beneficial contribution, not a contributing factor, and unknown. The direct and indirect, persistent past, and external effects are then integrated to determine whether there is a cumulative effect and its significance. The far right hand column summarizes the cumulative effect and whether it is significant, conditional significant, insignificant, or unknown. Several rules of logic are applied to the process. If the direct/indirect effect is unknown, it is not possible to determine the cumulative effect, which is also unknown. If there are no persistent past effects and there are no reasonably foreseeable future effects (not a contributing factor), then there are no cumulative effects for a specific effects category. The logic for applying ratings of conditional significance and unknown is the same for direct and indirect effects (see Sections 4.1.2 and 4.1.3). The cumulative matrix tables are supported by text that describes in more detail the persistent past effects, relevant external factors, and the logic in determining the significance of cumulative effects.

4.1.5 Description of the Multi-Species Analytical Model and its Assumptions

4.1.5.1 Background

In the Draft 2001 Programmatic SEIS, simulation models were developed that evaluated individual stocks independently, as if each species could be caught separately from other species. The simulation model thus failed to reflect the multi-species character of nearly all Alaska groundfish fisheries, which catch a wide variety of species even when targeting a single species. This meant that in many cases, single-species simulations did a poor job of representing the likely consequences of alternative management scenarios. For this revised Programmatic SEIS, simulation models have been developed that reflect the multi-species nature of the fisheries and their management.

Current groundfish management in federal waters of Alaska consists of strict quota management for FMP-managed species. These quotas are closely monitored, and as quotas are approached in a given year, with reserves set aside for bycatch in other fisheries, directed fisheries become closed. Prohibited species catch (PSCs) limits are also closely monitored and affect fishing season length and area openings. These quotas and PSCs effectively become constraints for all groundfish fisheries operating in the GOA and BSAI regions. These constraints are established based on area-specific TACs. The TACs are derived from the NPFMC's annual recommendations for ABC levels. As a matter of policy, the NPFMC's TAC for a given species or species group has always been less than or equal to the ABC for that species. The resulting management system is one that strives to meet the objective of providing fishing opportunities subject to a large number of constraints. Analysis of this type of fisheries regime has been modeled using Linear Programming (e.g., Brown *et a*l. 1979, Siegel *et al.* 1979, and Murawski and Finn 1986). In this Programmatic SEIS, we attempt to mimic management of complex interacting fisheries and their impact on GOA and BSAI living marine resources using a similar approach.

Simulating current groundfish management in the U.S. North Pacific economic zone involves considering interactions between a large number of species, areas, and gear types. These fisheries are managed subject to a large number of constraints (e.g., ABCs and PSCs). Management decisions are based on expectations about the array of species likely to be captured by different gear types and the cumulative effect that each individual fishery has on the allowable catch of each individual species or species group. The expectations of capture by different fisheries are based on historical catch data of each species within area and gear strata. The ABC constraints come from probabilistic projections of future stock dynamics for each individual species. Given these constraints, the predicted catch for each example FMP is then computed from an inseason management model. This management model accounts for the technical multi-species interactions of the groundfish fisheries (see Ackley 1995 for an example application of within-year patterns for the EBS fishery). Finally, the predicted catches are fed back into the age-structured information for each species to compute the correct fishing mortality level and are then projected through each year. This provides a reasonable representation of the current fisheries management practice for dealing with the multi-species nature of bycatch in target fisheries. Fisheries are defined by distinct target species, gear type, and area. The optimal decision-making process related to actual removals is simulated using historical information on catch composition of these fisheries. A schematic of the modeling approach is presented in Figure 4.1-1.

This section begins with a description on how individual stocks are treated and projected into the future, including details on how the constrained optimization is used to mimic management. A critique of the approach and assumptions follow. The subsequent section describes how catch estimates were derived, followed by how specific alternatives were modeled (including the data that were used). This section then concludes with a brief description on how model results were applied in different resource categories (e.g., to assess the impact on marine mammals).

4.1.5.2 Methods

Treatment of Stocks

For the stocks with age-structure information, the model is very similar to those used for the stock assessments upon which ABC recommendations are currently based, and it contains features and assumptions common to many fishery population dynamics models. Parameters and other inputs were obtained for each stock. They were taken directly or inferred from the most recent Stock Assessment and Fishery Evaluation (SAFE) report or obtained from AFSC scientists. The simulations began with numbers of a given age in 2002, which were projected forward using a random recruitment simulator (Inverse Gaussian) and a fishing mortality rate defined by the FMP under consideration. Recruitments were drawn from a statistical distribution that is described below. The parameters consisted of maximum likelihood estimates obtained from the recruitments listed in the 2002 SAFE report. Recruitment estimates after 1978 were used to estimate distribution parameters. No serial correlation was assumed. The age of recruitment varied between stocks, corresponding to the minimum age used in the respective assessment models. For stocks where age-structure information is not available, but ABCs are set, the model used the most recent estimates of ABC as the upper limit on total catch. The list of species considered for the BSAI and GOA is presented in Table 4.1-13. The actual age-structure data used for the analyses are available online at www.fakr.noaa.gov/sustainablefisheries/seis/data.

Projection Model

The following presents details on the steps of the projection simulations. A glossary of notation is provided at the end of this section for reference.

Step 1: Select the Catch Composition Array Appropriate for the Alternative

As presented below, separate hypothetical catch-composition arrays were developed for each alternative. A catch-composition array can be simply thought of as a table where the rows represent a specific fishery defined by target species, area, and gear type, and the columns represent the catch by species group or stock (See www.fakr.noaa.gov/sustainablefisheries/seis/data).

Step 2: Project Recruitments for all Years and Simulations

Recruitment estimates for the years 1978 through 2001, or the largest available subset thereof, were obtained from each of the respective 2002 stock assessments. For each stock, these recruitments were used to find maximum likelihood estimates for the inverse Gaussian distribution parameters. The distribution was parameterized such that one of the parameters represented the distribution mean. A recruitment time series was obtained for each simulation by drawing randomly from this parametric distribution.

Step 3: Estimate Actual Fishing Mortality Rates for the Initial Year

The steps in this part of the model are described below. Because the example FMPs were assumed not to take effect until after 2002, these steps were conducted only once, rather than separately for all eight FMPs. Compute the fishing mortality rate that would set catch equal to C_t by solving the following implicit equation:

$$C_{2002} = F_{2002} \sum_{a=1}^{n_{age}} \left[N_{a,2002} \left(\frac{1 - \exp\left(-M_a - F_t \sum_{k=1}^{n_{gear}} s_{a,k} d_k \right)}{M_a + F_t \sum_{k=1}^{n_{gear}} s_{a,k} d_k} \right) \sum_{k=1}^{n_{gear}} w_{a,k} s_{a,k} d_k \right]$$

Step 4: Project Numbers at Age for all Ages, Years, and Simulations

For each example FMP, 200 projection simulations were conducted. The projected numbers at age in each year were based on an annual feedback of actual catch obtained from the linear programming constrained optimization algorithm, hereafter referred to as the LP. The steps for these projections for a given species were as follows:

1. Initialize the simulation index:

   $u = 0$

2. Increment the simulation index:

   $u = u + 1$

3. Initialize the time index:

   $t = 1$

4. Compute numbers at age for initial year of simulation *u*:

   $N_{a,t,u} = R_{t,u}$ for $a = 1, t = 1$

   $N_{a,t,u} = n_a$ for $a > 1$

5. Set fishing mortality rate for initial year of simulation *u*:

   $F_{t,u} = F_{2002}$

6. Increment time index:

   $t = t + 1$

7. Compute numbers at age in year t of simulation *u*:

   $$N_{a,t,u} = R_{t,u}, \qquad R_{t,u} \sim \text{InvGaussian}\left(\beta, \gamma\right) \qquad \text{for } a=1$$

   $$N_{a,t,u} = N_{a,t-1,u} \exp\left(-M_a - F_{t-1,u} \sum_{k=1}^{n_{gear}} s_{a,k} d_k \right) \qquad \text{for } 1 < a < n_{age}$$

   $$\begin{aligned} N_{a,t,u} = N_{a,t-1,u} &\exp\left(-M_a - F_{t-1,u} \sum_{k=1}^{n_{gear}} s_{a,k} d_k \right) + \\ N_{a-1,t-1,u} &\exp\left(-M_{a-1} - F_{t-1,u} \sum_{k=1}^{n_{gear}} s_{a-1,k} d_k \right) \end{aligned} \qquad \text{for } a = n_{age,}$$

8. Compute the ABC fishing mortality rate that establishes the TAC for year *t* of simulation *u*.

   The appropriate fishing mortality rate was determined by the projection year and the relative spawning biomass of the stock as shown in the table below (B_{ref} corresponds to $B_{40\,percent}$ in all cases unless otherwise specified). F_{ref} corresponds to the fishing mortality specified as the F_{ABC} value.

Relative spawning biomass	**Fishing mortality rate**
$B_{t,u} < \alpha B_{ref}$	$F_{t,u}^{ABC} = 0$
$\alpha B_{ref} \le B_{t,u} < B_{ref}$	$F_{t,u}^{ABC} = F_{ref}\left(\dfrac{B_{t,u}}{B_{ref}} - \alpha\right)/(1-\alpha)$
$B_{ref} \le B_{t,u}$	$F_{t,u}^{ABC} = F_{ref}$

where $B_{t,u} = \sum_{a=1}^{n_{age}} N_{a,t,u} m_a w_a \phi_{a,t,u}$ and $\phi_{a,t,u}$ is the total mortality rate between the beginning of the year and the time of spawning. The value of $B_{t,u}$ was computed iteratively (since it can be a function of fishing mortality). Note also that for some FMPs described below these rules change for some species. For a given FMP *I,* the fishing mortality is treated as a function of the F_{ABC} value.

$F_t^{Alt} = f\left(F_{t,u}^{ABC}\right)$ as specified by the FMP.

9. Compute the TAC value as annually varying limit on catch. For a given species and value of (for $F_t^{Alt_l}$ alternative *l*) the projection model computes the TAC used in the constraint as

$$TAC_t^{Alt_l} = \sum_{k=1}^{n_{gear}} \sum_{a=1}^{n_{age}} N_{a,t} w_{a,k} \frac{F_t^{Alt_l} s_{a,k} d_k}{F_t^{Alt_l} s_{a,k} d_k + M_a^p} \left[1 - e^{-F_t^{Alt_l} s_{a,k} d_k - M_a^p} \right]$$

10. Compute the actual catch, $C_{t,u}$, given the suite of constraints from the LP optimization described below.

11. Solve for the fishing mortality rate $X_{t,u}$ that would set catch equal to $C_{t,u}$ in year *t* of simulation *u* as estimated from the multi-species management constrained optimization problem described below and varies by FMP by solving the following implicit equation:

$$C_{t,u} = X_{t,u} \sum_{a=1}^{n_{age}} \left[N_{a,t} \left(\frac{1 - \exp\left(-M_a - X_{t,u} \sum_{k=1}^{n_{gear}} s_{a,k} d_k \right)}{M_a + X_{t,u} \sum_{k=1}^{n_{gear}} s_{a,k} d_k} \right) \sum_{k=1}^{n_{gear}} w_{a,k} s_{a,k} d_k \right]$$

12. Check to see if all years of simulation *u* have been completed, then continue as necessary:

    If $t<n_{pro}+1$, return to (6)
    If $t=n_{pro}+1$, end simulation *u*.

13. Return to (2) until all simulations are complete.

Step 5: Store Stock Performance Statistics from the Above Projections

A series of individual stock performance indicators for species with specified age-structure results were computed separately for each FMP as follows:

Total biomass in each year and simulation:

$$T_{t,u} = \sum_{a=1}^{n_{age}} N_{a,t,u} w_a$$

Spawning biomass and catch, as specified above, were stored for each species, year, and simulation. Approximate confidence bounds were computed from the simulation output by simply ranking results from the simulations and computing the percentile values corresponding to the desired intervals (here taken as the 10th and 90th percentile). Also computed was the implied spawning biomass per recruit (SPR) rate, given the level of catch in a single year and simulation. (For example, the theoretical percentage of unfished spawning output expected from a single recruit if fishing mortality were equal to the estimated fishing mortality over the life of the species.)

Average age for each stock in the final projection year across all simulations was computed as:

$$A = n_{sims}^{-1} \sum_{u=1}^{n_{sims}} \frac{\sum_{a=1}^{n_{age}} a\, N_{a,2002+n_{pro},u}}{\sum_{a=1}^{n_{age}} N_{a,2002+n_{pro},u}} + a_{\min} - 1$$

The Linear Programming Algorithm

LP is an active research branch of operation research that has proved to be useful in resource management. In this context, an optimization problem is considered linear if all objective function and constraint coefficients can be arranged in a linear way. The linear optimization problem, in this case, consists of finding the optimal catch allocation in order to maximize the overall catch or total revenue across all fisheries and subject to a certain number of linear constraints. We used a revised Simplex algorithm (Press *et al.* 1992) to find the optimal vertex in this multidimensional space.

The objective function and constraint coefficients were computed primarily from the NOAA Fisheries, Alaska Region blend dataset. The data were averaged over the period 1997 to 2001, so all the coefficients represent averages from this time period. FMP-specific constraints were developed for both the BSAI and GOA. Namely TAC constraints for each FMP area complex, special gear sconstraint for some species, lower and upper bound constraints on the variation of catch relative to average levels for each fishery, and constraints of the maximum allowable biological removals of each system.

Objective Function Coefficients

The target function consisted of coefficients derived from the blend data set for FMP-managed species across different fisheries. The ex-vessel value ($V_{j,g}$) for each species and proportion retained by each fishery were used to compute the coefficients of the linear objective function:

$$A_g = \sum_{j=1}^{n_{species}} \sum_{k=1}^{n_{area}} V_{j,g} C^{N}_{j,k,g} R_{j,g}$$

with the overall objective function to be maximized in year t is given as:

$$\Theta_t = \sum_{g=1}^{n_{fsh}} A_g Y_{t,g}$$

where

A_g Objective function coefficients applied to each fishery

$C^{N}_{j,k,g}$ Catch data from the blend dataset by species, sub-area and fishery

$R_{j,g}$ Retained fraction of catch

$Y_{t,g}$ Relative total catch between fisheries within each year (main result returned from the constrained optimization)

$V_{j,g}$	Estimated ex-vessel value of each species within different fisheries
t	Year
j	Species
k	Sub-area
g	Fishery
h	Gear-type

Linear Constraints

In our optimization problem there are two types of constraints: values that are maxima or upper bounds, and values that are minima or lower bounds. There were five types of upper-bound constraints and one type of lower-bound constraint, these are presented below in consecutive order. The coefficients were computed only once for a specific FMP since the catch-composition data is constant for this model version over time and assumed known without error.

The bounding information or constraints were based on a number of sources detailed below. Note that some constraints change over time (e.g., the ABC/TAC constraints).

Acceptable Biological Catch (ABC/TAC) Constraints

These constraints determined an upper bound equivalent to the TAC for each species in each sub-area. Each constraint has one coefficient and represents the average annual catch by FMP species and area as:

$$\sum_{g=1}^{n_{Fsh}} Y_g a_{j,k,g}^{ABC} \leq b_{j,k}^{ABC_t}$$

$$a_{j,k,g}^{ABC} = C_{j,k,g}^{N}$$

$$b_{j,k}^{ABC_t} = TAC_{t,j,k}\ f_k$$

where $TAC_{i,j,k}$ = Total allowable catch for species *j*, in sub-area *k* in year *I* and f_k is the split by area for a particular species, and the bounds of the constraints are calculated as a function of a fixed allocation fraction of the TAC across sub-areas and the estimates for TAC by year.

Gear Type (G) Constraints

Gear allocations for a specific annual TAC were included to reflect the current practice. In the model, these constraints were specified as

$$\sum_{g=1}^{n_G} Y_{t,g} a_g^G \leq b^G$$

$$a_g^G = \sum_{g=1}^{n_{area}} C_{k,g}^N$$

$$b^G = TAC_e f_k^G$$

where e = Index for species with gear restrictions

f_k^G = Proportion of TAC allocated to each gear type, *G*, of each species in sub-area *k*.

For example, sablefish TAC's are allocated between longline fixed gear and trawl gear. The model accounts for these allocations as added constraints.

Fishery Expansion Constraints

Upper-bound constraints on relative catch are placed by FMP species upper limit (UL) so that relative catch does not grow unreasonably beyond the baseline data or 1997 to 2001 average.

$$Y_{t,g} a_g^{UL} \leq b_g^{UL}$$

b_g^{UL} values typically ranged from 1.3 to 3. However, some alternatives specified different values as detailed in Section 4.1.5.5 Description of the Alternatives.

Fishery Contraction Constraints

Based on extensive initial runs of this model, the optimal solution often eliminated a number of fisheries. To prevent this, and to ensure that the catch remains positive, the following set of lower-limit (LL) constraints were applied.

$$Y_g a_g^{LL} \geq b_g^{LL}$$

where a_g^{LL}, is a scalar for fishery *g*.

Overall Optimum Yield (OY) Constraint

The specification that the OY cap could not be exceeded was given as:

$$\sum_{g=1}^{N_{fis}} Y_{t,g} a_g^{OY} \leq b^{OY}$$

$$a_g^{OY} = \sum_{e=1}^{N_{sp}} \sum_{k=1}^{N_{Area}} C_{e,k,g}^N$$

$$b^{OY} = OY$$

where OY = optimum yield summed for the geographical area (e.g., BSAI) for all target FMP species

e = index of target species used for optimum yield.

Note that this was generally two million metric tons (mt) for the BSAI and 800,000 mt for the GOA. However, some alternatives specified different values as detailed below in the FMP descriptions section.

Optimizing the Objective Function Subject to the Constraints

To find the optimum solution in standard tableau notation (Press *et al.* 1992), we can reduce the system of equations to the following array with columns 2 to $g+1$ corresponding to each fishery:

where

m_{ABC}	Number of ABC type of constraints (number of species that have TAC)
m_G	Number of gear type of constraints
m_{UL}	Number of upper limit constraints on relative catch of FMP species
m_{LL}	Number of lower limit constraints on relative catch of FMP species
m_{OY}	Number of optimum yield constraints (only one)

Some of the coefficients (A_i , a_i^j) are zero but they are presented here in a general notation.

$$
\begin{array}{cccccc}
0 & A_1 & \cdots & A_i & \cdots & A_g \\
b_{i,j,k}^{ABC_1} & -a_{j,k,1}^{ABC_1} & \cdots & -a_{j,k,i}^{ABC_1} & \cdots & -a_{j,k,g}^{ABC_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b_{i,j,k}^{ABC_{m_{ABC}}} & -a_{j,k,1}^{ABC_{m_{ABC}}} & \cdots & -a_{j,k,i}^{ABC_{m_{ABC}}} & \cdots & -a_{j,k,g}^{ABC_{m_{ABC}}} \\
b^{MC_1} & -a_1^{MC_1} & \cdots & -a_i^{MC_1} & \cdots & -a_g^{MC_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
 & & & & & \\
b^{G_1} & -a_1^{G_1} & \cdots & -a_i^{G_1} & \cdots & -a_g^{G_1} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{G_{m_G}} & -a_1^{G_{m_G}} & \cdots & -a_i^{G_{m_G}} & \cdots & -a_g^{G_{m_G}} \\
b^{UL_1} & -a_1^{UL_1} & 0 & 0 & 0 & 0 \\
\vdots & 0 & 0 & -a_i^{UL_n} & 0 & 0 \\
b^{UL_{m_{UL}}} & 0 & 0 & 0 & 0 & -a_g^{UL_{m_{UL}}} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{OY} & -a_1^{OY} & \cdots & -a_i^{OY} & \cdots & -a_g^{OY} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
b^{LL_1} & -a_1^{LL_1} & 0 & 0 & 0 & 0 \\
\vdots & 0 & 0 & -a_i^{LL_{m_{LL}}} & 0 & 0 \\
b^{LL_{m_{LL}}} & 0 & 0 & 0 & 0 & -a_g^{LL_{m_{LL}}}
\end{array}
$$

4.1.5.3 Data

Estimation of the 1997 to 2001 Catch by Species and Fisheries

We used the NOAA Fisheries, Alaska Region blend estimates of catch by area, species, gear, and target species combined with observer fish ticket data. The fish tickets are landing receipts recorded by Alaska Department of Fish and Game (ADF&G) statistical areas.

The North Pacific Groundfish Observer Program currently provides all of the information we have on fishery interactions with non-target species. Observers estimate total catch and species composition of the catch in a random sample of hauls. All animals are counted, weighed, and identified to the lowest practical taxonomic level, regardless of their status as a target species, or whether they will later be discarded by the vessel. The Observer Program is extensive, covering the majority of fishing effort in the BSAI and up to 30 percent of fishing effort in the GOA.

Despite the large size and extent of the Observer Program, not all fishing is observed at all times. Only fishing vessels over 124 feet (ft) in length must carry an observer for all days fishing. Smaller vessels (60-124 ft) are only required to carry an observer for 30 percent of days fishing, and vessels under 60 ft are never required to carry an observer. Therefore, we had to extrapolate the data collected by observers to the reported catch from all observed and unobserved fishing in order to estimate the total catches of non-target species groups from all fishing for this analysis. This assumes that observed fishing and unobserved fishing have the same catch composition. Although this assumption is unverified, observer data is the best and only source of information on non-target species catch.

Catches were estimated by species group for the recent domestic fishery, 1997 to 2001, using the following method: within each year, each vessel's observed catch of a given species group was summed within statistical area, gear type, and week. A target fishery was then assigned to each vessel's weekly catch, generally by assuming that the species with the highest retained catch for that week was the target species. The Programmatic SEIS describes target fishery designations and the specific algorithm for assigning targets. This is consistent with target assignments done as part of the inseason management system at the regional office. Catch by target species and non-target species, where available, was then summed for each year over all observed vessels within each area, gear, and target fishery. The ratio of observed non-target species catch to observed target species catch within each area, gear, and target fishery was multiplied by the total reported (regional office blend-estimated) target species catch within that area, gear, and target fishery. Data from years prior to 1997 could not be assigned to target fisheries in a way that is consistent with total catch targets assigned by the NOAA Fisheries Alaska regional office due to changes in the structure of the observer database. We do not consider this a problem because the most recent years of catch information are most valuable for the purposes of this analysis. Catches of other species, forage fish, and grenadiers were estimated for 1990 through 2001 as part of the annual stock assessment process and are reported in annual SAFE documents for the BSAI and the GOA.

The catch-composition data were processed to reflect area and time closures specific to each alternative. Since the catch-composition estimates were assigned to spatial/temporal strata, then the effect of changes in management measures could be reflected by modifying the catch-composition arrays accordingly. For example, if an alternative had specific closed areas, then the catch-composition data that fell within those categories were deleted. The notion here was simply to try to reflect how catch-composition might change under alternative area-time constraints.

Methods Used to Apportion the Estimates of Total Catch, Retained Catch, and Ex-Vessel Value by Processor Group and Vessel Class and to Estimate Product Value by Processor Group

We used blend estimates of total catch and retained catch and fish ticket estimates of retained catch for 1999 to 2001 to apportion the catch and ex-vessel value projections discussed above by processor group and vessel class. The resulting estimates of retained catch by processor group were used with 2001 estimates of product value per mt of retained catch to generate the estimates of product value. The methods used are discussed below.

Step 1: Define Processor Groups and Identify the Processors in Each Group

We defined the following six groups of inshore processors and six groups of at-sea processors to assist in analyzing the economic and social effects of the GOA and BSAI groundfish fisheries both historically and for the alternatives being considered in this Programmatic SEIS.

1. Large BSAI pollock processors (the American Fisheries Act [AFA] inshore sector processors that operate in or near Unalaska and Akutan.
2. Other Alaska Peninsula and Aleutian Island processors.
3. Floating processors (non-AFA floating processors).
4. Kodiak processors.
5. Southcentral processors.
6. Southeast processors.
7. Surimi factory trawlers.
8. Fillet factory trawlers.
9. Head and gut factory trawlers.
10. Longline catcher processors.
11. Pot catcher processors.
12. Motherships.

We then identified the processors in each of these mutually exclusive groups.

Step 2: Distribute Catch and Ex-vessel Value Projections by Processor Group

We used blend estimates of total catch and retained catch by fishery, species (for the TAC species), and processor group from 1999 to 2001 to estimate the shares of total catch and retained catch by fishery and species associated with each processor group. The fisheries were defined by target species, gear, and area. We then applied the total catch shares to the alternative-specific total catch projections to estimate alternative-specific total catch by fishery, species, and processor group. The retained catch shares were used in a similar way with the alternative-specific retained catch and ex-vessel projections to generate comparable estimates of retained catch and ex-vessel value. Data for 1999 to 2001 were used because the AFA was implemented in 1999, significantly changing the shares of catch among processor groups.

Step 3: Estimate Product Value by Processor Group

For each inshore processor group, we used 2001 Alaska Commercial Operator's Annual Report (COAR) estimates of groundfish purchases and product value by species to estimate product value per mt of retained catch. For each at-sea processor group, we used 2001 COAR product price data for at-sea processors, supplemented by 2001 product price data provided by representatives of the Head and Gut Factory Trawlers, together with Weekly Production Report production and retained catch data to estimate product value per mt of retained catch.

Step 4: Define Catcher Vessel Classes and Identify the Catcher Vessels in Each Group

We defined the following nine classes of groundfish catcher vessels to assist in analyzing the economic and social effects of the GOA and BSAI groundfish fisheries both historically and for the alternatives being considered in this Programmatic SEIS.

Bering Sea pollock trawl catcher vessels greater than or equal to 125 ft in length

- Bering Sea pollock trawl catcher vessels 60 to 124 ft in length.
- Diversified AFA-eligible trawl catcher vessels greater than or equal to 60 ft in length.
- Non-AFA trawl catcher vessels greater than or equal to 60 ft in length.
- Trawl catcher vessels less than 60 ft in length.
- Pot catcher vessels less than or equal to 60 ft in length.
- Longline catcher vessels less than or equal to 60 ft in length.
- Fixed gear catcher vessels 33 to 59 ft in length.
- Fixed gear catcher vessels less than or equal to 32 ft in length.

We then identified the catcher vessels in each of these mutually exclusive vessel classes.

Step 5: Estimate Retained Catch and Ex-vessel Value by Catcher Vessel Class

We used State of Alaska fish ticket estimates of retained catch by species, area, processor group, and vessel class from 1999 to 2001 to estimate the share of retained catch by species and area associated with each catcher vessel class. We then applied the retained catch shares to the alternative-specific retained catch and ex-vessel value projections by processor group to generate alternative-specific estimates of retained catch and ex-vessel value by species, area, and catcher vessel class.

Assumptions

The resulting estimates of total catch, retained catch, ex-vessel value, and product value are based on the assumptions that the following will not vary, either by alternative or from what has been observed recently for the BSAI and GOA groundfish fisheries:

- Species composition (i.e., bycatch rates) of TAC species in any individual fishery, where a fishery is defined by area, gear, and target species.
- Distribution of catch among processor groups in any individual fishery.
- Retention rates for a fishery, species, and processor group.
- Product mix for a species and processor group.
- Distribution of retained catch among catcher vessel classes for each processor group.
- Ex-vessel prices.
- Product prices.

We do not believe these assumptions are either equally valid for all the alternatives or valid for most of the alternatives. Unfortunately, the information necessary to estimate alternative-specific differences in bycatch rates, the distribution of catch among processor groups and vessel classes, retention rates, product mix, ex-vessel prices, or product prices is not available. This problem is addressed qualitatively in the sections that present the projections of ex-vessel value and product value for the various alternatives.

Estimates of Ex-Vessel Value Per Metric Ton of Retained Catch

We used 2001 Alaska COAR groundfish purchase data to estimate ex-vessel value per mt of catch by species, gear, and area for the species that are not almost exclusively processed at sea. For the other species, such as BSAI Atka mackerel, flatfish, and rockfish, we estimated that the ex-vessel value per mt of retained catch was 40 percent of the product value per mt of retained catch.

Description of the Fishery Definitions Used in the Model

In the GOA, 32 different fisheries were defined as having gear-area-target significance. These are listed in Table 4.1-14. Table 4.1-15 lists the 35 fisheries defined for the eastern BSAI regions (Figures 4.1-2 and 4.1-3).

To summarize characteristics of each ,fishery we devised a method to show the diversity of species mix observed in the catch. We used Simpson's (1949) index of diversity (κ) commonly used in population biology. For each fishery the index is computed as

$$\kappa = \frac{1}{\sum_{i=1}^{nspp} p_i^2}$$

where p_i is the proportion of catch in biomass over all species or species groups (55 different categories in the GOA and 56 in the BSAI). This index can be interpreted as roughly the effective number of species. For example, Figure 4.1-4 illustrates a hypothetical catch composition of five species caught in four different fisheries at different proportions. The effective number of species for Fishery A is very close to 1.0 (1.02) due to the fact that 99 percent of the catch is attributed to Spp_1. At the other extreme, Fishery D caught all five species in equal proportions leading to an index value exactly equal to 5. In Fishery B, only two species are caught in equal proportion, hence the effective number of species is exactly 2. In Fishery C, all five species occur, but in diminishing proportions; therefore, the effective number of species is slightly lower than 3.

Presenting the species mix for fisheries in this way provides a simple way of examining the differences between fisheries. More importantly, it can be used to show the effect of how sampling variability and time trends may affect the estimated catch composition of each fishery. For example, computing the effective number of species using five-years of NOAA Fisheries blend data in aggregate average catch by species and fisheries showed that for both the GOA and BSAI regions, flatfish and rockfish fisheries tend to have higher catch diversity, since these are fundamentally mixed-species fisheries. Pollock fisheries and fisheries using pot gear tended to have the lowest diversity (Figures 4.1-5 and 4.1-6). However, these figures show that the catch diversity in some fisheries can be quite different between years. This is presumably largely due to sampling error and partly due to real changes in catch composition. Another contribution to this variability could be how target fisheries are defined. (i.e., a target fishery is defined based on the dominant species catch reported by week). If a vessel actually targets multiple species within a week, then the diversity of the reported catch may be unrealistically high. These factors highlight important caveats regarding the ability to accurately predict how catch diversity levels may change from one year to the next. These problems would be exacerbated by using subsets of catch composition data within years that have closed areas. For this reason, we chose to assume that the best available estimates of fisheries catch composition were based on data aggregated from 1997 to 2001. Since many of these fisheries defined may reflect relatively small levels of catch, we evaluated this index for the major fisheries and examined the trend over time. For the GOA, 11 of the 32 fisheries represented 80 percent of the catch. These fisheries still had considerable inter-annual variability in catch diversity (Figure 4.1-7), but no apparent trend. In the BSAI, 8 fisheries represented 91 percent of the catch and had less inter-annual variability (Figure 4.1-8). The flatfish fisheries appeared to have a slightly increasing trend in diversity from 1997 to 2001. This suggests that the assumption of constant species compositions may be inappropriate. Further research on what has caused this apparent trend in catch diversity is warranted.

4.1.5.4 Critique of Assumptions and Approach

Forecasting fisheries behavior is an endeavor fraught with uncertainty. Even under a relatively constant management system, changes in socioeconomic and environmental conditions can result in substantial future uncertainty. Add in a complex set of alternative management measures, such as those presented in this document, and the uncertainty is magnified. The following describes an attempt to model key aspects of the current fisheries management system and, to the extent possible, modifications according to the specific management measures for the four alternatives and their range. The model's predictive power given the system complexity is poor. However, this multi-species technical interaction model does provide a more objective approach to evaluate alternative management actions compared to single species examinations.

The NPFMC Scientific and Statistical Committee (SSC) provided feedback on the modeling approach. In particular, they raised a number of concerns about using this type of approach (i.e., using LP to mimic fisheries management). For example, using ex-vessel value estimates as part of the objective function fails to reflect the costs. Unfortunately, extensive cost data are unavailable. The SSC noted that ex-vessel prices are likely to change over time. While modeling how these may change over time would be valuable, the degree of difficulty and added complexity prohibited development along these lines. This aspect seems unlikely to have a large-scale effect over the five-year simulation projection.

Within alternatives, the catch-composition array is assumed to be constant. That is, there is no random variability, nor are there trends in the underlying catch composition within a fishery. In reality, catch-composition values are likely to vary from year to year. Observation error and other sources of variability and potential biases mask this variability. The model was developed so that catch-composition variability can be implemented in the simulation. However, since available data are limited to five years, the magnitude of this uncertainty could not be assessed in time for this analysis. Explicitly modeling the catch composition of each fishery is an area of research that needs to be pursued, particularly as dynamic species interactions are introduced.

The fact that the catch-composition array is constant over time may not be unreasonable given the short time frame of the main projections (2003 to 2007). However, the long-term projections assess conditions to 2023; these results should be viewed much more cautiously. These long-term projections were done to provide some indication of general trends between stocks. For the five-year time frame used for estimating the catch composition by fisheries and species matrix (1997-2001), there appeared to be little or no trend in the diversity of the catch for the main fisheries (e.g., Figure 4.1-8). The annual variability in the diversity of the catch highlights the importance of including details on the effect of area closures on catch by species and fisheries matrices. Clearly, sampling error plays a large role, and, as finer geographic resolution is included, the effect of sampling error will increase. This will likely compromise real changes in bycatch patterns due to area closures.

The uncertainty in current abundance levels is not modeled. The point estimates for parameter values (e.g., the numbers-at-age) in the assessments published in the 2002 SAFE are used. This clearly underestimates the variability in the current abundance levels for all species of groundfish. Under FMP 3.2, estimation uncertainty is accounted for and is applied as a risk-averse adjustment. It is possible to add this type of estimation uncertainty explicitly within the projection model. However, time limitations and the additional complexity in the presentation of the results would detract from the analysis.

Another factor that tends to underestimate variability to some extent is the omission of stock-recruitment relationships from the projection model. The reason for this omission is that, with the exception of EBS walleye pollock, reliable estimates of the stock-recruitment relationship do not exist for any BSAI or GOA groundfish stock. When making projections over the long-term, omission of the stock-recruitment relationship will tend to understate the impacts on biomass and recruitment resulting from a sustained change in the harvest rate. However, when projections are restricted to the near future, as they are for the most part in this document, it is less likely that omission of the stock-recruitment relationship will bias results significantly unless one or more of the following conditions holds: 1) the stock-recruitment relationship for a stock is extremely strong, 2) the average lifespan of individuals in a stock is extremely short, or 3) the average harvest rate for a stock is extremely different from that which generated the initial conditions. Examination of existing stock-recruitment data for BSAI and GOA target groundfish stocks indicates that none of them appear to exhibit extremely strong stock-recruitment relationships, which is one of the reasons why it has proven so difficult to estimate such relationships in the past. Furthermore, none of the BSAI or GOA target groundfish species is extremely short-lived. Finally, while the average harvest rates for Alternatives 2 through 4 typically differ to some extent from the average harvest rates in Alternative 1, the only cases in which the differences are truly extreme occur under Alternative 4. Therefore, it is unlikely that omission of the stock-recruitment relationship will lead to significant biases in the results, with the possible exception of results pertaining to stocks whose average harvest rates under Alternative 4 diverge sharply from the corresponding average harvest rates under Alternative 1.

The SSC also recommended that alternative objective functions be considered. They noted that the purpose of the model is to project likely management actions under the alternatives. Hence, it might be useful to express the objective as a minimization of the weighted sum-of-squared deviations between actual and target levels of catch, where the weights reflect management preferences for meeting TACs. This would provide a non-linear, quadratic objective function with linear constraints, and would add a seemingly desirable feature to the model, at least for the status quo (FMP 1) specification. Time limitations precluded implementation of a Quadratic Programming approach. Furthermore, this approach would require subjective specification of the weights for the different alternatives. For the Linear Programming approach used here, the imperfect objective function requires fewer assumptions about how weights may change by alternative.

For this implementation, the results were largely insensitive to the objective function specification. Some of the assumptions that constrained the solution space most severely were limits placed on the ability of individual fisheries to expand and contract relative to the patterns observed during 1997 through 2001. Sensitivity analysis showed that as these bounds were relaxed, the overall catch and revenue based on ex-vessel value increased at the expense of greater departures from the status quo, and increased sensitivity to the objective function. For these sets of model specifications, bounds were selected based on discussions with economists in the iterative process of examining model results. There is clearly room for improvement in specifying these sets of constraints. One approach would be to poll a wider group of experts to arrive at more refined sets of limits. Such a setting would also provide needed feedback for model improvements and may provide insights to management on the relative benefits of different fisheries.

In summary, the complex interactions among changes in biomass levels, fisheries economic performance, and management effectiveness are just some of the reasons why any such forecast must be viewed cautiously.

4.1.5.5 Description of the Alternatives

The projection model was designed to approximate the general patterns of catch that might be expected given the multi-species nature of groundfish fisheries. The analyses rely on two main sources of information: observer and fish ticket data, the blend data and stock assessment estimates of population parameters, abundance-at-age in 2002, and recruitment variability. The first step in developing model configurations for each of the example FMPs was to process the observer catch-composition data to reflect, to the extent possible, the impact of each FMP. The baseline catch-composition data was derived from observer and fish ticket reports for the period 1997 through 2001. For certain fisheries where characteristics changed dramatically, such as the implementation of the AFA in 2000, the number of years included differed from this baseline. The details of estimating the catch-by-fisheries data used in the model is presented in a separate section below.

The second part of setting up alternative specifications involved limiting TACs either through different harvest control rules or specific ABC reductions. The following sections provide some descriptions about how the model is affected by the different alternatives.

For the main reported species, the PSC species and the other non-target species have been compiled for gear-area-target fisheries using 1997 to 2001 as the baseline average. For all FMPs, except FMP 2.2, the EBS pollock fishery and the Aleutian Islands Atka mackerel fisheries, the average of 2000 and 2001 data were used to better reflect the AFA and other recent management measures. Unless otherwise noted, the values for retention rates are shown in Tables 4.1-16 and 4.1-17, while the estimated average ex-vessel price by species and gear type is given in Tables 4.1-18 and 4.1-19. The catch by species and fisheries for the GOA and BSAI is available from the web (www.fakr.noaa.gov/sustainablefisheries/seis/data). An overview of the key differences between the alternatives as modeled is given in Table 4.1-20. It is important to note that yield and biomass results for any alternative cannot typically be attributed to any single aspect of alternative specification since all aspects are being implemented simultaneously.

FMP 1

This alternative is considered the baseline status quo relative to the 2001 fishing year. The ABC follows Amendment 56 for setting quotas. Furthermore, the ABC setting for FMP 1 is adjusted downward as appropriate and is typically based on recommendations from assessment authors and NPFMC.

For example, in the 2002 SAFE, the ABC fishing mortality for a number of species was set at $F_{t,u}^{Alt1} = \omega F_{t,u}^{ABC}$ where ω is 0.87 for Pacific cod in both the BSAI and GOA. For pollock ω is an added buffer added as a function of spawning biomass, as presented in the GOA pollock SAFE by Dorn *et al.* (2002). For non-Steller sea lion forage species $\alpha = 0.05$, while for pollock, Pacific cod, and Atka mackerel, $\alpha = 0.5$. In the BSAI, an overall OY cap of 2 million mt of groundfish catch was an added constraint, while for the GOA the cap was set at 800,000 mt (FMP species only).

FMP 2.1

For this alternative, the catch-composition data are the same as FMP 1, with one exception: the pre-Individual Fishing Quota (IFQ), catch-composition rates for sablefish fisheries and earlier estimates of halibut mortality were used. The use of earlier data represents only a small difference when compared to the current estimates; and is available on the website (www.fakr.noaa.gov/ sustainablefisheries/seis/data). The F_{ABC} for this FMP is set equal to F_{OFL}, or the overfishing level (OFL), which, by NPFMC definitions, equals the point estimate of F_{msy}. This fishing mortality rate is held constant over all stock sizes, including as the stock drops below $B_{40\%}$ (i.e., $F_{t,u}^{ABC} = F_{msy}$ for $B_{t,u} > 0$). For all age-structured stocks, the F_{msy} was set equal to the SPR fishing mortality rate of $F_{35\%}$. For survey biomass stocks Tier 4 through 6 from Amendment 56, the ABC was set equal to the overfishing level (OFL). Additional measures for Steller sea lion prey species were omitted.

In FMP 2.1, the OY is set to the sum of ABC's in both the GOA and BSAI. Also, there are no constraints due to PSC limits. For example, bycatch of Pacific halibut will not constrain fishery development. The fishery-expansion constraint is set to 100 (i.e., fisheries can expand effort beyond the average level observed over 1997 through 2001).

FMP 2.2

Example FMP 2.2 is similar to FMP 1, except that the OY is set to the sum of ABCs in both the GOA and BSAI, instead of at a fixed cap. Also, the maximum permissible ABC value was used instead of the author's adjustment (see ☞ for FMP 1).

FMP 3.1

This FMP is similar to FMP 1, except that the constraint on Pacific halibut mortality is reduced by 10 percent and, therefore, more constraining. Also, the author's recommendation for ABCs (see ☞ for FMP 1) is omitted (e.g., the GOA pollock OFL buffer).

FMP 3.2

For example FMP 3.2, catch species by fishery data are modified to reflect improved rationalization. That is, the bycatch of discarded species is reduced by using existing total catch estimates and changing the fraction that is discarded. Specifically, for given species and fishery, the catch that has been estimated as being discarded in the data will be reduced by 20 percent. This means that under fisheries rationalization, the fishing behavior will change such that the actual incidental catch will be reduced. This change is implemented by modifying the input data on catch species by fishery and is sometimes referred to as the bycatch matrix. These data are available on the NOAA Fisheries website: http://www.fakr.noaa.gov/sustainablefisheries/seis/data.

Another aspect of improve rationalization specifies that the retention rates of what is caught in the future will increase; in other words, at which species are discarded the rate will be reduced 20 percent. This change is implemented by modifying the retention rate matrices for GOA and BSAI shown in Tables 4.1-21 and 4.1-22.

For example FMP 3.2, the OY is set to the sum of ABCs instead of the current 2 million mt capacity. Also, the halibut mortality limit is reduced by 30 percent relative to FMP 1.

One objective under FMP 3.2 was to incorporate formal estimates of uncertainty already estimated in many of the stock assessments. A large-scale research effort on developing methods to use fully Bayesian risk-averse methods is in progress, and a version of this development is used here.

Under the current system a common assumption is that the $F_{35\,\%}$ rate is a good proxy for F_{msy}, and thereby determines the F_{OFL}. Similarly, $B_{35\,\%}$ is commonly taken as a good proxy for B_{msy}. Given the parameter values from stock assessment results to determine these quantities, the NPFMC has implicitly accepted that the $F_{40\,\%}$ fishing mortality rate is suitably risk-averse regardless of uncertainty in future recruitment and current stock size. The risk-averse adjustment to the F_{msy}, here assumed to be $F_{35\,\%}$, formally accounts for the uncertainty in current stock size and future recruitment. In addition to the standard selectivity, average mass-at-age, natural mortality, current numbers-at-age, and maturity-at-age schedules, the method developed requires estimates of the covariance matrix of the current numbers-at-age and the time series of recruitment estimates. The advantages of the method developed include: 1) that the upper bound of the F_{ABC} is set to a constant level of risk-aversion; 2) simulations to determine the appropriate adjustment level can be avoided; 3) analytical solutions are available for all steps except one final maximization; and 4) the ability to assess the value of improving estimates and reducing variance of current stock size. A key feature of this analysis is the development of a method for calculating the stock-recruitment relationship given estimates of B_{msy} and F_{msy} and the other age-specific schedules listed above. The actual values for the adjustment are shown in Table 4.1-23 and a presentation of two scenarios where the risk-averse adjustment appears to be due to different sources is shown in Figure 4.1-9.

The application of the risk-averse adjustment was applied for all stocks:

$$F_{Har} = F_{msy} * \text{Adjustment}$$
$$F_{ABC} = \min(F_{Har}, F_{40\,\%}, F_{OFL\_Alt1})$$

While for rockfish species an added measure of precaution was applied where

$$F_{ABC\_RF} = \min(F_{60\,\%}, F_{Har})$$

FMP 4.1

In this example FMP, the OY constraint is set to the sum of ABCs. Note that this is effectively the same as omitting an OY constraint since the individual species" ABCs are constraints themselves. The species catch by fishery was modified so that fisheries with more than 33 percent bycatch of a species not listed as the target specie was eliminated. Pacific cod, pollock, and arrowtooth flounder were not included as a bycatch species to these fisheries.

Uncertainty corrections to the ABCs were based on survey catcher vessels Also, the F_{ABC} was set to $F_{75\%}$ for all Steller sea lion prey species and for all species of rockfish. Note that uncertainty corrections applied to the $F_{75\,\%}$ values, too.

Agency analysts discussed how to incorporate the formal estimates of uncertainty already estimated in some of the stock assessments (e.g., AD Model Builder applications or Bayesian analyses). This is an ongoing area of research; however, the example regime was deliberately designed to be applicable to all stock assessments regardless of the software used. Incorporating formal estimates of uncertainty available for some stocks would continue to impose the largest adjustments only on the best known stocks. For example, the current process for TAC setting does not reduce harvest levels when the reference biomass level ($B_{40\%}$) cannot be estimated for stocks in Tiers 4 to 6 of Amendment 56/56 ABC and OFL definitions. Stocks qualify for management under Tiers 4 to 6 only if reference stock levels cannot be estimated reliably.

The formal incorporation of uncertainty was accomplished by setting the fishing mortality rate associated with ABC (F_{ABC}) at specified fractions of the maximum allowable fishing mortality rate maximum F_{ABC}. This fraction varies directly with the uncertainty or variance of the survey biomass estimates. Specifically, this is accomplished by computing the average coefficient of variation for the survey biomass estimates in the time series and then computing the lower bound of the 90 percent confidence interval for a lognormal distribution with this coefficient of variation and a median of unity. This lower bound is the specified fraction by which to reduce maximum F_{ABC}. The specified fraction by which to reduce maximum F_{ABC} is provided as input to the model for FMP 4.1. All target species with biomass estimates were analyzed. Exceptions are made in the model projections for some species whose stock assessment F_{ABC} is below maximum F_{ABC}. These adjustment values, corresponding to the lower bound of the 90 percent confidence interval, are given in Table 4.1-24.

For FMP 4.1, the prohibited species cap for Pacific halibut mortality was reduced to 50 percent of the current level, causing a higher level of constraint.

FMP 4.2

No fishing was allowed for the 5 year-projection. We presume that under this example FMP, fisheries authorized following review would take the form of that regime being illustrated by FMP 4.1.

4.1.5.6 How Model Results Were Applied in Assessing Impacts of the Alternatives on Different Resources

Target, Forage, Prohibited, Other, and Non-Specified Species

For the target species, the multi-species, multi-fisheries simulation projection model provided fundamental dynamics to the model behavior. That is, as the biomass of an FMP species changed in the future, the constraint via ABC/TAC control also changed. The outputs from the model were primarily intended to reflect these dynamics and the interactions with the species composition of the different fisheries.

The significance of the impacts on target species were evaluated with respect to fishing mortality, change in biomass level, spatial/temporal concentration of the catch, prey availability, and habitat suitability.

The significance of the effects of the alternative fishing mortality levels are evaluated with respect to the overfishing mortality rates as set forth in Amendment 56/56. Fishing mortality rates that exceed the overfishing mortality rate are considered to jeopardize the capacity of the stock to produce MSY on a continuing basis and adversely impact the sustainability of the stock. A related measure of this potential is indicated by change in biomass levels. The significance of effects of the current spatial/temporal concentration of the catch and the level of prey availability and habitat suitability for target species are evaluated with respect to each stock's current size relative to its MSST. An action that jeopardizes the stock's ability to sustain itself at or above its MSST is considered to adversely affect the sustainability of the stock.

Species or species complexes that fall within Tiers 1 though 5 have estimates of the current fishing mortality rates, and are evaluated with respect to exceeding the overfishing mortality rate or fishing mortality effect. Species or species complexes that fall within Tiers 1, 2, or 3 have reliable estimates of MSST, and are evaluated for the effects of spatial/temporal concentration of the catch, prey availability, and habitat suitability. Species or species complexes that fall within Tiers 4, 5, or 6 do not have reliable estimates of MSST; therefore, we cannot evaluate the significance of these effects. This inability to evaluate the significance of the effects occurs for the forage, prohibited, and non-specified species. Since several species or species complexes do not have estimates of abundances-at-age, in this version of the model, their abundance levels simply reflect the most recent estimate. For these groups, analysis of the effects of the example FMPs were limited to catch projections and likely consequences given patterns in related fauna.

Habitat

A quantitative estimate of habitat impact under each example FMP requires an estimate of the fishing effort applied in areas remaining open under each scenario. The amount of effort should take into account the catch levels expected under the alternatives in each TAC management area and the amount of catch taken under the baseline that would have been taken inside and outside the area to be closed by the FMP. Because of the limitations in the multi-species bycatch model, not all species and their area-specific catches are easily explained by the stock dynamics. The impact of alternative-specific management practices on model outputs are also difficult to interpret on detailed area fishery and species scales. While stockwide projections of most major species are more easily understood, catch by TAC management area is required for the effort estimation. The time required to complete a rigorous analysis to validate, and in some cases correct, area-specific catch levels exceeds the time available to prepare this Programmatic SEIS. This necessitated a more qualitative evaluation in this Programmatic SEIS of the expected impacts on habitat based on known fishery characteristics.

Seabirds

The analysis of direct and indirect effects on seabirds relies on the projection model's estimates of fishing effort in mt by different gear types in the BSAI and GOA under the different FMP bookends. Hook-and-line or longline and trawl effort are particularly important for analysis of incidental take. For analysis of FMP 2.1, the projection model’s output essentially eliminates the BSAI longline cod fishery and triples the GOA longline cod fishery, and is based on small price differentials between gear types. This situation is considered an unrealistic artifact of the model's rules for allocating catch between gear types in lieu of specified allocations. For FMP 2.1, the BSAI longliners are assumed to take about the same volume of cod as they have under the baseline conditions, with the balance going to trawl and pot gear. For the GOA, longliners are assumed to take the same percentage of the cod TAC as they had under the baseline, which translated into a moderately higher catch because of the higher TAC. The implications of different spatial/temporal restrictions are also analyzed, especially as they relates to effects on prey availability for nearby seabird colonies and potential for trawling in critical habitat areas of eiders. Other factors that were not modeled, including implementation of seabird protection measures and the potential for a directed forage fish fishery, were also included in the analysis.

Marine Mammals

Results from the multi-species management model are used to analyze the effects of the example FMPs on marine mammal populations. Catch projections from the model are used to estimate incidental take of marine mammals and to evaluate harvest levels of marine mammal prey species. Total projected groundfish catch was averaged from 2003 to 2007 for each example FMP. This average projected catch is multiplied by the incidental take rate, calculated as marine mammal takes/mt of groundfish of each marine mammal species as derived from Angliss *et al.* (2001), to estimate changes in incidental take under each example FMP. The average annual fishing mortality rate (*F*) projected from 2003 to 2007 is compared to the baseline (2002) to determine the change in *F* expected under each alternative bookend for all key marine mammal prey species. Percent changes in *F* relative to the baseline were used to indicate changes in the prey field for affected marine mammal species. These analyses employ unmodified model results as they were reported and, therefore, incorporate all the assumptions that went into the model.

Socioeconomic

The output from the multi-species management model is used as the starting point for development of the socioeconomic impact model, referred to in the remainder of the document as the Sector Model. The Sector Model uses the multi-species management model output of catch of each species by gear in each area. The Sector Model distributes those catches and associated values, as well as income and employment, to the various fishing and processing sectors that depend on the groundfish resources, and to the geographic regions where the activities occur and where factor owners reside. A detailed description of the Sector Model is included in Section 4.1.7.

Ecosystem

The multi-species bycatch model is used to derive indicators for assessing the impacts of the alternatives on the ecosystem. The indicators chosen are ones that would characterize changes in predator/prey relationships, energy flow, and diversity. In predator/prey relationships, model outputs are used to obtain estimates of pelagic forage biomass of target species, such as the walleye pollock and Atka mackerel in the BSAI, and walleye pollock in the GOA. Total biomass of these species is used to derive this index. Bycatch estimates of squid, herring, and the managed forage species group from the model are used as another indicator of the magnitude of fishing impacts on these other forage species. Trophic level of the catch is an indicator of fishing down the food web, which is the sequential fishing down of species high in the food chain, such that over time the fisheries are left only with mid-trophic level species as targets. Model estimates of catch biomass for each target and nontarget species group are combined with estimates of trophic level of each species group, derived from food habits information to obtain estimates of the overall trophic level of the catch for each example FMP. Fishing effects on top predator species are evaluated through model estimates of bycatch of sharks and birds. Model estimates of total retained catch, and discards for target and nontarget species, are used as an indicator of the effects of the alternatives on energy cycling characteristics of the ecosystem through energy removal or total retained catch, and/or energy redirection discards. Finally, model estimates of bycatch of HAPC biota were used as an indicator of effects of fishing on functional structural habitat diversity.

Glossary of symbols used in description of the model

Dimensions

a_{max}	Maximum age used in the model (plus group)
a_{min}	Minimum age used in the model
n_{age}	Number of ages in the model
n_{gear}	Number of gear types for which separate selectivity schedules are used (as in the assessments)
n_{pro}	Number of years to project beyond the initial year in each simulation
n_{sims}	Number of simulations
n_G	Number of gears with allocation constraints
n_{Fsh}	Number of fisheries
n_{sp}	Number of species
n_{area}	Number of management areas defined for each species

Indices

a	Relative age index, $1 \leq a \leq n_{age}$
g	Fishery index, $1 \leq g \leq n_{Fsh}$
k	Sub-area
h	Fishing gear type
t	Projection year index, $1 \leq t \leq n_{pro}$
u	Simulation index, $1 \leq u \leq n_{sims}$
I	Alternative index
j	Species index

Life History and Fishery Parameters

d_h	Proportion of total instantaneous fishing mortality rate distributed to gear h
M_a	Natural mortality rate at age a
m_a	Proportion of age a fish that are mature
w_a	Weight-at-age a in the population
p	Proportion of females in the population
$s_{a,h}$	Selectivity of gear type h for fish of age a (scaled so that max(s)=1)
$w_{a,h}$	Weight of age a fish as sampled by gear h

Other Parameters and Expressions Used in Projections

SPR	Spawning biomass per recruit
ABC	Acceptable biological catch
TAC	Total allowable catch
OY	Optimum yield summed for the geographical area (e.g., BSAI) for all target (FMP) species
B_{ref}	A parameter of the control rules used to set the overfishing rate and to constrain F_{ABC}
$B_{t,u}$	Spawning biomass in projection year t of simulation u
C_{2002}	Actual catch observed in 2002 (or projected to be caught)

$C_{t,u}$	Catch in projection year t of simulation u for each population after the LP
$F_{t,u}$	Fishing mortality rate in projection year t of simulation u for each population
F_{lim}	A parameter of the control rule used to set the overfishing rate
F_{ref}	A parameter of the control rule used to constrain F_{ABC}
$X_{t,u}$	Fishing mortality rate in projection year t of simulation u for each population after the LP
$\phi_{a,t,u}$	Total mortality rate between the beginning of the year and the spawning period
$N_{a,t}$	Numbers at age a in projection year t
$N_{a,t,u}$	Numbers at age a in projection year t of simulation u
n_a	Numbers at age a in 2002
$O_{t,u}$	Rate of fishing mortality that constitutes overfishing in projection year t of simulation u
P	Probability of overfishing in at least one year of the projection period
R_{2003}	Recruitment for 2003 predicted in the 2002 stock assessment
$R_{t,u}$	Recruitment in projection year t of simulation u
$T_{t,u}$	Total biomass (between ages a_{min} and a_{max}) in projection year t of simulation u
TAC_{2002}	TAC actually specified for 2002
$X_{t,u}$	Fishing mortality rate that sets catch in projection year t of simulation u equal to C_{max}
A	Average age for each stock in the final projection year across all simulations
f_k	Proportion of the catch allocated to sub-area k for a particular species

Parameters and Expressions

Θ_t	Total objective function value
m_{ABC}	Number of ABC type of constraints (number of species that have TAC)
m_G	Number of gear type of constraints
m_{UL}	Number of upper limit constraints on relative catch of FMP species
m_{LL}	Number of lower limit constraints on relative catch of FMP species
m_{OY}	Number of optimum yield constraints (only one)
A_g	Objective function coefficients applied to each fishery
$C^{N}_{j,k,g}$	Catch data from the blend dataset by species, sub-area and fishery
$R_{j,g}$	Retained fraction of catch
$Y_{t,g}$	Relative total catch between fisheries within each year (main result returned from the constrained optimization)
$V_{j,g}$	Estimated ex-vessel value of each species within different fisheries

Computation of SPR values

SPR values are computed using species-specific demographic values (see www.fakr.noaa.gov/sustainablefisheries/seis/data), fishing mortality rates (e.g., $F^{j}_{40\%}$) that would reduce the female spawning stock (per recruit) to some fraction of the unfished level. The age-specific factors are selectivity, natural mortality, maturity, and weight or fecundity. For example, to compute $F^p_{40\%}$, an algorithm to solve the following set of implicit equations was used:

$$0.4B^p_{100\%} = \sum_{a=1}^{n^p_{age}-1}\left[w^p_a m^p_a \prod_{j=2}^{a} e^{-\left(M^p_{j-1}+F^p_{40\%}s^p_{j-1}\right)}\right] +$$
$$w^p_{n^p_{age}} m^p_{n^p_{age}} \prod_{j=2}^{n^p_{age}} e^{-\left(M^p_{j-1}+F^p_{40\%}s^p_{j-1}\right)}\left(1-e^{-M^p_{n^p_{age}}-F^p_{40\%}s^p_{n^p_{age}}}\right)^{-1}$$

where $B^p_{100\%}$ corresponds to the spawning stock per recruit of population p in an unfished equilibrium state. This information was used within the management rule that determines the quota. For some species and alternatives different F-spr rates were used.

4.1.6 Habitat Impacts Model

To evaluate the impacts of fishing on living habitat, the model developed by Fujioka (2002) is used. This model incorporates basic factors determining impacts of fishing on habitat. Given either estimated or assumed values of fishing intensity, where f equals the absolute effort in area swept per year divided by the area size, q_H equals sensitivity of habitat to fishing effort, ρ equals habitat recovery rate, the model predicts a value of equilibrium (i.e., long-term) habitat level, H_{eq}, as a proportion of the unfished level, H_0.

$H_{eq} = H_0 \cdot \rho\, S/(I + \rho\, S)$ where H_0 = unfished habitat level, $I = f\, q_H$, and $S = e^{-I}$.

Habitat impact or effect level, E, for the given effort, sensitivity, and recovery rates, would be 1-H_{eq}. Letting H_0 = 1.0, then

$E = I/(I + \rho\, S)$

Various habitat features could be impacted by fishing gear. Initially, this analysis focused on the impact to the biostructure habitat feature of living habitat composed of organisms such as soft corals, tunicates, and sponges with assumed recovery rates of 2 to 15 years. Where applicable, we attempted to address impacts to living habitat with slower recovery rates (i.e., 200 years), such as gorgonian corals (e.g., red tree coral, Primnoa). A widely accepted management policy has been to avoid impacting such long-lived organisms.

Habitat Sensitivity Rate (q_H)

The habitat sensitivity rate, q_h, is the proportion of habitat impacted by one pass of the fishing net. Organisms considered as indicators of habitat sensitivity range from relatively small and flexible (soft corals) to larger, more erect organisms (sea whips). Vulnerability of the organisms varies greatly depending on their physical characteristics and the characteristics of the trawl gear. The vulnerability may be difficult to determine. Certain features of the gear may make the gear more damaging to one type of organism than to another type. For biostructure sensitivity to bottom trawl gear, two values of q_H, 0.10 for less sensitive, and 0.25 for more sensitive, are proposed as plausible.

Habitat Recovery Rate (ρ)

Recovery rate, ρ , reflects the rate at which impacted habitat changes back into unimpacted habitat, H. In the absence of further impacts, impacted habitat would decrease exponentially with all habitat was in H the unimpacted condition. The recovery time, R, can be thought of as the average amount of time the impacted habitat stays in the impacted state, which would equal 1/ ρ in the absence of further impacts.

Little is known about the recovery rate of various benthic organisms that provide biostructure in waters off Alaska. The recovery rate as modeled includes any recruitment required to initiate recovery and the growth necessary to reach a size that can to provide habitat function. Recovery times as much as 15 (=1/ρ) years are within a plausible range. For this analysis, two biostructure recovery rates are used to cover a plausible range of impact. Scenario 1 is where $\rho = 0.5$ the 2-year or rapid recovery, and Scenario 2 is where $\rho =.0667$, the 15-year or long recovery. Table 4.1-25 shows the corresponding impact given levels of fishing intensities. For example, for $f = 0.25$, where the bottom area is swept once every four years, for $\rho = 0.50$, when habitat recovers in 2 years, and for a sensitivity rate $q_H = 0.10$, where one-tenth of the organisms are removed per sweep of the net, the long-term impact level, E, would be 0.049. That is, the habitat would be reduced slightly to 95.1 percent (H_{eq}) of its unfished level. If recovery rate $\rho = 0.067$, where habitat recovers in 15 years, and sensitivity q_H =0.25, where one-fourth of the organisms are removed per sweep of the net, the impact level would be 0.499, or 50.1 percent of its unfished level. This demonstrates that as f increases, impact level also increases, and the equilibrium level of habitat decreases.

Fishing Effort or Intensity (*f*)

Bottom trawl fishing effort has been estimated for each 5 kilometer (km) square block in the BSAI and GOA regions by Rose and Jorgenson (2002). Fishing intensity of a block is the fishing effort per year measured in area swept.High quality fishing effort data are available from the groundfish observer program. Individual sets were tallied for 5 x 5 km blocks for the years 1998 to 2002. This 5-year period was selected to represent the current level of fishing effects. Reported effort or duration for trawls was converted into swept areas. Trawl durations were multiplied by speed, trawl width, and proportion of effort on the bottom. Width and speed were estimated using a survey of trawlers on gear usage and from information collected by observers. The estimate for the proportion of pelagic trawl effort contacting the seafloor considered both the amount of time in which any part of the trawl contacted the seafloor and the width of trawl contact with the seafloor during different periods of the fishery (e.g., day/night, A and B seasons). Information for this estimate was provided by fishing organizations. As the vulnerability of pelagic trawls to damage precludes their operation on rough and hard substrates, bottom contact was set at zero for the hard bottom habitats of the GOA and Aleutians Islands.

Habitat Impact (*E*)

Impact is a function of sensitivity, recovery rate, and fishing intensity. For the given values of sensitivity q_h, recovery rate ρ, and bottom trawl fishing intensity *f* estimated for each 5 x 5 km block, habitat impact, $E_i = I_i/(I_i+\rho S_i)$, can be calculated for the 5 x 5 km block represented by the *I* parameter. Larger values of *E* equate with more impacts. Results for a region can be presented in a single value as a mean impact, as frequency distribution of impacts for each block, and as the geographic distribution of the impacts.

A draft report by Rose (2002) describes a proposed approach to quantifying impacts using the function = $(\sum E_i \cdot \text{Area}_i) / (\sum \text{Area}_i)$ summed over all area in waters less than 1,000 meters (m) deep (i.e, fishable EEZ waters). This is a single-valued metric which provides for simplified comparisons and evaluations. Ideally, any area summations would be weighted by habitat quantity and value as well, but such information is currently unknown and is set at 1.

In the analysis for this Programmatic SEIS, rather than summing the estimated impact block by block, the fishing intensity for each block is tabulated by intensity intervals, as shown in Table 4.1-26. For example, in the Bering Sea, 1,003 blocks were fished at an intensity level between 0.25 and 0.50, 822 blocks watershed at an intensity level between 0.50 and 1.00, and so forth. This information can be used to estimate the mean relative impact level for all the fished blocks, or for all fishable blocks (<1,000 m). This is approximated here by summing the frequency weighted midpoint impact levels and dividing by the number of fished blocks or number of fishable blocks. For example, for $\rho=0.50$ and $q_H=0.10$, the impact level for f=0.25 is 0.049, and for f = 0.50 is 0.095, with a midpoint of 0.072. The frequency weight of the interval 0.25 to 0.50 is 1,003. The interval midpoint impact levels are weighted and summed and divided for the Bering Sea by either 7,121 (number of fished blocks) or 31,995 (number of blocks <1,000 m in depth). For the more slow growing and more sensitive parameter scenario, the mean impact of fished areas is 0.419 and 0.093 for all fishable blocks.

This approximation should produce mean impact levels similar to the more exact computation method demonstrated in a report by Rose (2002). Ideally, any area summations would be weighted by habitat quantity and value as well, but such information is currently unknown and neither computation takes into account differences in the unfished level of biostructure habitat or habitat suitability that probably exist. This is a single-valued metric, which provides for simplified comparisons and evaluations. If all habitat over the fishable EEZ is of equal value to the productivity of the fisheries, then the simple mean impact estimates are indicative of the baseline fishing impacts. However, when summed over such broad categories of habitat, the mean impact value may not reflect effects if impacts are concentrated on specific habitat types, because not all habitat may be of equal value to stock productivity. Comparing impact expressed as a single value presumes that the value of different levels of impacts is additive. That is, two units of habitat each impacted to $H_{eq} = 0.75$ ($E = 0.25$) are equivalent to two units of habitat, one heavily impacted to $H_{eq}=0.50$ ($E = 0.50$) and one unimpacted at $H_{eq} = 1.0$ (E = 0.0). Thus, the average impacts are equal in both cases, but the actual effect on the ecosystem may not be equivalent. One could argue that all else being equal, the latter case provides a wider range of habitat type and greater diversity over the same amount of habitat and is preferred over a uniform distribution of impact. In contrast, if H_{eq} only needs to be greater than 0.5 to be effective EFH, the former case would be preferred. Whatever the case may be, comparison of the frequency distribution provides increased discernment of potential impact. Thus, the distribution of the impacts needs to be considered.

Mean impact levels were assessed in conjunction with the distribution information to further evaluate the baseline. While the mean impact values could be considered to indicate minor impacts, the distribution information shows that for the Bering Sea, for example, 552 + 277 = 829 blocks, or more than 8,000 sqare miles, are fished at an intensity of $f = 1.00$ or greater (Table 4.1-26). A map of the fishing distribution (Figure 4.1-10) shows that the heavily fished blocks are concentrated in a few large geographically extensive areas that are uninterrupted by any current fishing closures that might provide protection to or diversity in impact levels. The impact model estimates that those areas could have an impact level to bioshelter organisms of 18.1 percent or greater for the fast recovery rate parameter scenario, or as much as 82.8 percent for the slow recovery rate/more sensitive scenario. Concern for areas where such potential impact could be occurring is a major consideration in the evaluation of the baseline and comparison of the alternatives.

General results using the habitat model are used qualitatively to evaluate the closure strategies of the alternatives. The rates of relative change of catch and impact can be examined by combining the habitat impact model with standard fishery catch models. In general, closing large amounts of heavily fished areas may not result in significant reduction in net habitat impact, as large amounts of fishing effort are displaced. This results in increased impact levels in previously less heavily fished area. Such a large change in the system has high potential for unforeseen consequences. A strategy of closing only lightly fished habitat reduces further impact in those areas while displacing only moderate amounts of effort to heavier fished areas. An increase of effort in already heavily fished habitat increases habitat impact relatively less than an increase in lightly fished habitat. Such a strategy, however, does not address potential ongoing impacts in heavily fished areas. A strategy of closing only small proportions of heavily fished habitat and larger proportions of lightly fished areas can achieve similar or greater reductions in impact with only moderate increases in effort in the remaining open areas. With closures positioned appropriately, this strategy can protect a cross-section of habitat types and address the potential impacts of heavily fished habitat while minimizing economic effects and the chances of unforeseen consequences.

4.1.7 The Sector Model–An Adaptation of the Multi-Species Model To Estimate Socioeconomic Effects

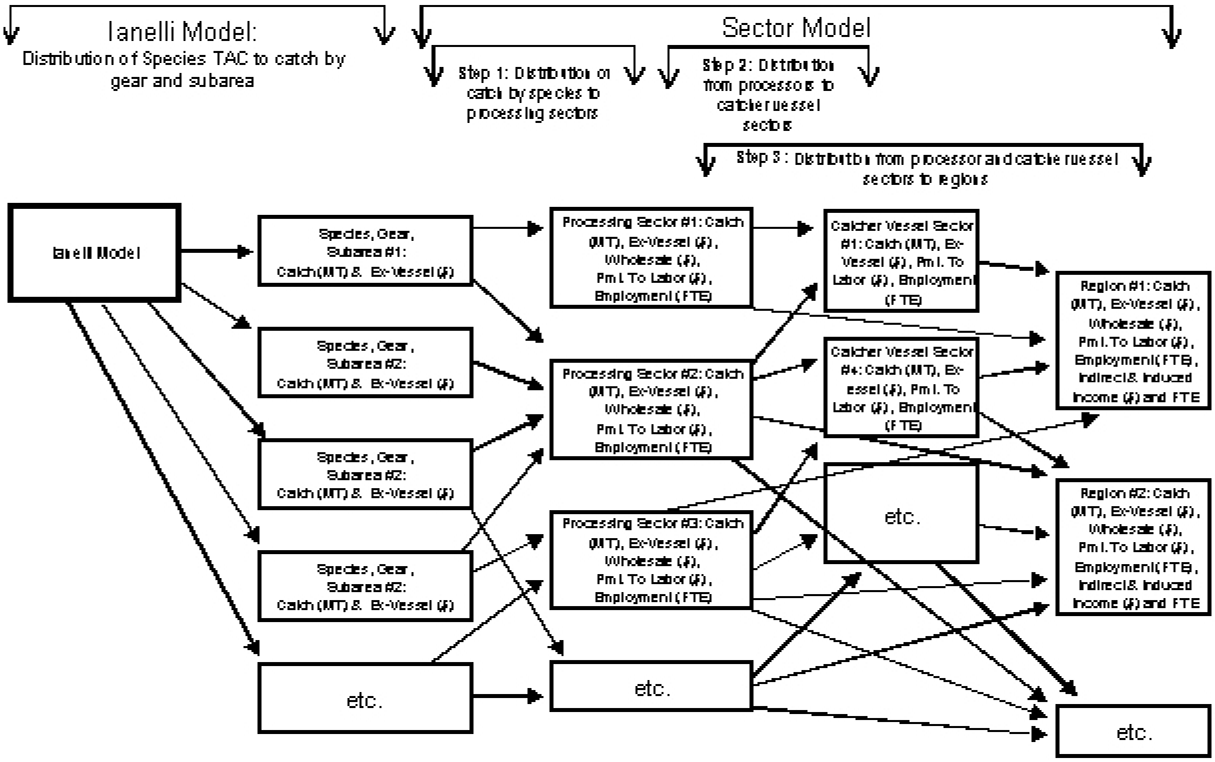
The socioeconomic impacts of the alternatives have been estimated using an extension of the multi-species model based on the harvesting and processing sectors and regions described in Sections 3.9 and 3.9.3. For the remainder of this discussion, the socioeconomic model extension is referred to as the sector model. The sector model applies 2001 harvest and processing proportions to the multi-species management (Ianelli) model output related to species catch by gear and subarea in order to estimate the distribution of catch and processing amounts among sectors and regions that rely on the groundfish fishery. A schematic representation of the linkages between the two models is shown below.

The sector model entails the following three-step process:

1. Estimate total catch and deliveries to processors.
2. Proportion out deliveries to specific catcher vessel sectors.
3. Distribute catches and processing amounts among the various regions where processors are located or vessel owners reside.

In each step of the sector model, the catch of each species by gear and subarea gets distributed to successive sectors based on the comparative baseline distribution in 2001.

The steps of the sector model can best be illustrated by providing a specific example. The multi-species management (Ianelli) model estimates that 1,472,600 mt of pollock will be harvested from the Bering Sea with trawl gear in 2003 under FMP 1. In step 1 of the sector model, this pollock is distributed to each processor sector according to the proportion of the total 2001 Bering Sea trawl pollock catch that the individual sector processed, including discards. In addition to total catch, the model uses 2001 information on each sector's retention percentage, wholesale value per round ton, payments to labor per dollar of wholesale product value, and full time equivalent (FTE) employment. These numbers are taken from the comparative baseline data presented in Section 3.9.9. Table 4.1-27 shows the 2001 conditions and how they are applied to generate the 2003 sector estimates for FMP 1. The results from Step 1of the sector model are used to estimate the direct economic impacts of the alternative FMP bookends on the various processing sectors.



As shown in the upper portion of the table, surimi trawl catcher processors caught 35.3 percent of the 2001 pollock trawl harvest from the Bering Sea and retained 99.8 percent of their catch. In the lower portion of the table, 35.3 percent of the 1,472,600 mt Bering Sea pollock trawl total under FMP 1 in 2003 is assigned to the surimi trawl catcher processor sector. The table also shows that 99.8 percent of the 519.3 mt of groundfish caught was retained. Assuming a wholesale product price of $604.4 per ton, the 2003 estimated wholesale product value for surimi trawl catcher processors is $313.8 million, with an estimated 35 percent ($109 million) of that be paid to labor. Employment generated by this sector is estimated to be 1342.8 FTEs, or 4.3 FTEs per million dollars of wholesale product value. A similar process is used to estimate the economic effects on other processing sectors.

Step 2 of the sector model distributes each processing sector's total retained catch amount back to the catcher vessels that delivered it, based on the proportion of each processing sector's deliveries from catcher vessel sectors in 2001. The analysis developed for each species, gear, and subarea, a processor sector/catcher vessel sector distribution matrix based on 2001 deliveries. The matrix for the Bering Sea trawl pollock sector is shown in Table 4.1-28. The table includes deliveries of catcher vessels to surimi and fillet catcher processors, inshore processors, and motherships. Although catcher vessels delivered only a relatively small amount of fish to surimi and fillet trawl catcher processors, they provided all the fish processed by other processing sectors. For example, the row for Bering Sea pollock shore plants indicates that 61.5 percent of their Bering Sea trawl pollock was delivered by Bering Sea pollock trawl catcher vessels greater than or equal to 125 ft, while Bering Sea pollock trawl catcher vessels 60 ft to 125 ft in length delivered 34.8 percent of the pollock catch. The remaining 3.6 percent was delivered by diversified AFA-eligible trawl catcher vessels greater than or equal to 60 ft and non-AFA trawl catcher vessels greater than or equal to 60 ft. The various catcher vessel sectors are defined and discussed in detail in Section 3.9.2.

The percentages, like those in Table 4.1-28, are multiplied by the total catch for the species gear and subarea for each processor to generate the total retained catch assigned to each catcher vessel sector for the FMP bookend and year. Ex-vessel prices and payments to labor and employment factors are applied to retained catches to generate the remaining catcher vessel sector indicators. Table 4.1-29 illustrates this process with numbers for the Bering Sea trawl pollock sector for FMP 1 in year 2003.

The third step of the sector model translates sector level activities to regional activities. This step is complex because the various sectors interact with regions in different ways, as described below:

- **Shore-Based Processors:** The sector model assumes that shore-based processors are closely related to the regions in which they are located. In fact, the shore-based processors are designated according to their associated region. Two exceptions are the Bering Sea Pollock Shore Plants, which are assigned to the Alaska Peninsula/Aleutian Islands region, and the Other States Shore Plants, which are assigned to the Washington inland waters region (most are located in Bellingham, Washington). The sector model assumes that ex-vessel values attributed to shore-based processors are directly linked to the region in which they are located through fish taxes. Further, the sector model assumes that all labor payments and employment generated by shore-based processors accrue within the region in which they are located.[1] This method of assigning employment to regions is similar to that used by state and federal agencies. Insufficient information exists to provide a more accurate account of regional employment patterns in the groundfish fisheries. Finally, the sector model assumes that the expenditures of shore-based processors for deliveries of raw fish and other supplies, as well as the expenditures of their employees, have indirect and induced impacts within the region in which they are located.[2]

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[1] The method of assigning employment to regions used in this analysis does not attempt to account for the formal or legal residency of workers in shore-based processors. For example, the labor force of many of the shore plants in Alaska, especially those in the Alaska Peninsula and Aleutian Islands region (defined in Section 3.9.2.4), have been traditionally dominated by persons considered non-residents or relatively short-term residents of Alaska communities or the state. In part, residency is a matter of definition, as community population count varies by information source. U.S. Census methodology, for instance, counts every person present at the time of enumeration as part of the official population of the community, with very few exceptions. Additional information on workforce demographics and the role that transient processing workers play in the groundfish fishing industry and communities can be found in Section 3.9.6.

[2] Another shortcoming of the sector model is that it is unable to track expenditures of processors and catcher vessels in other regions. For example, many of the shore-based processing plants have headquarter offices in Seattle, and clearly some of their expenditures are made in the location of their headquarters. Further, because many of the employees of shore-based plants are seasonal, they are likely to spend most of their earnings in their hometowns.

- **At-Sea Processors (Catcher Processors, Motherships, and Floating Processors):** The sector model assumes that an at-sea processor generates most of its regional impacts in the region represented by the vessel owner's address as listed in Commercial Fisheries Entry Commission vessel registration files or NOAA Fisheries Federal permit data. Typically, the location of the corporation that coordinates the operations of the vessel is listed. Consequently, the model assumes that crewmembers on a catcher processor or other at-sea processor are hired from the same region in which the vessel's operations are coordinated.[3] Although this method of assigning employment to regions is similar to that used by state and federal agencies, it is recognized that this is a simplification, as vessels (and corporations) may have complex ownership structures that influence various operational parameters, including point-of-hire employment decisions.[4] As noted above, insufficient information exists to provide a more accurate account of regional employment patterns in the groundfish fisheries. Other economic impacts, such as those resulting from purchases of equipment and supplies, are also assumed to accrue to the vessel owner's region.

- **Catcher Vessels:** In order to be consistent with the way in which at-sea processing employment is assigned, catcher vessel employment is assigned to the region represented by the vessel owner's address as listed in Commercial Fisheries Entry Commission vessel registration files or NOAA Fisheries Federal permit data.[5] catcher vessels affect regions by making deliveries to processors and providing earnings for their returning owners and crew to spend in the region. When these vessels make deliveries to processors located outside of the region, they bring their outside earnings into their home region when they return. However, when catcher vessels make deliveries to local processors, their earnings are already counted as expenditures by the local processors. Therefore, it is important to track not only the catcher vessels' home regions, but also the locations where they delivered fish. The sector model assumes that all vessel owner and crew income contributes to the regional economy, but, to avoid double counting, only the income from landings made outside the region is used to calculate indirect and induced income and employment.

A matrix showing the home regions of vessels participating in the pollock trawl fishery in 2001 in shown in Table 4.1-30. Similar matrices were developed for each species, gear, and area combination.

Multiplying the numbers in the regional matrix in Table 4.1-30 by the catches by sector (Table 4.1-27 for at-sea processors and Table 4.1-29 for catcher vessels) yields the regional apportionment of Bering Sea trawl

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[3] The method of assigning employment to regions used in this analysis does not attempt to account for the formal or legal residency of workers in the at-sea processing sector.

[4] As one example of this complexity, the western Alaska CDQ program has created many seasonal job opportunities for residents of eligible Alaska communities aboard catcher processors as a result of CDQ investment in this sector, among other factors. Beyond employment considerations, additional information regarding the importance of CDQ program-related investments and industry partnerships in increasing the participation of Alaska residents in the groundfish fisheries, especially those in Alaska Native communities, is provided in Section 3.9.4.

[5] The method of assigning employment to regions used in this analysis does not attempt to account for the formal or legal residency of workers aboard catcher vessels. For example, some of the catcher vessels owned by residents of the Washington Inland Waters Region (WAIW) region (defined in Section 3.9.2.4) that frequently berth in Alaska ports may hire residents of those ports. Moreover, as in the case of the at-sea processing sector, complex corporate ownership structures may influence vessel operational patterns, including crew employment decisions.

pollock catches for 2003 from FMP 1 (as shown in Table 4.1-31). A similar process is used to assign catches of other species, gears, and areas to regions for other years and for other FMP bookends.

The next step in estimating regional effects of catcher vessels involves distinguishing in-region deliveries and extra-regional deliveries. In-region deliveries are defined as deliveries to processing facilities assigned to the same region to which the catcher vessel is affiliated. For example, when a vessel owned by a resident of Kodiak makes a delivery to a Kodiak shore plant, it is considered an in-region delivery. When that same boat makes a delivery to an Alaska Peninsula/Aleutian Islands shore plant, it is considered an extra-regional delivery. It should be noted that at-sea deliveries are considered in-region ,if the both the owner of the catcher vessel and owner of the at-sea processor are from the same region. As indicated earlier, the regional effect of catcher vessels making an in-region delivery are counted as part of the regional shore-based processor effects, while the regional effects of extra-regional deliveries are assigned to the catcher vessels. Table 4.1-32 shows the 2003 value of in-regional and extra-regional deliveries of Bering Sea trawl pollock by the catcher vessel sectors for FMP 1.

The sector model's final step calculates and assigns income and employment multipliers for each region. The multipliers relate total output in dollars from the fishing sector in a region to the additional indirect and induced income and employment that are generated. Part of this additional income and employment occurs in the businesses whose goods and services are used as inputs in the groundfish fisheries, such as fuel suppliers, chandlers, gear manufacturers, boatyards, and insurance brokers. These firms are commonly referred to collectively as the support service sector of the fisheries. Moreover, people earning incomes directly or indirectly from the fisheries make expenditures within the economy as well, generating additional jobs and income. These indirect and induced economic benefits can be substantial, especially for regions such as the WAIN region. The multipliers used in this analysis are estimated with IMPLAN Version 2.[6] The IMPLAN software was used to create an input-output model for each region considered in the analysis. The input-output model is a mathematical representation of the inter-industry/institution transactions that occur within a defined economic region. The model traces how many times a dollar is re-spent within the regional economy before leaving the region, and the economic impact of each round of spending. The economic base concept was used to determine the level of aggregation of the more than 200 economic sectors that have backward linkages to the fishing sector in the regions considered. The multipliers for these economic base sectors or aggregated sectors were generated from IMPLAN, and were used to determine the additional income and employment effects, or secondary effects, that the fishing sector contributes to each region. Table 4.1-33 shows the regional multipliers used in the analysis.

It is important to note that the sector model does not directly estimate inter-regional linkages. For example, the model does not specifically include income and employment resulting from expenditures of at-sea processors in regions outside of a vessel owner's region. While it is recognized that there are inter-regional effects, the data necessary to reasonably estimate those effects are not available. It is also important to note that the lack of inter-regional effects is offset to some extent by the assumption that all of the employment and income effects of a shore-based processor occur within the region in which the processor is located.

An example of the tables used in the regional effects assessment is provided in Table 4.1-34. The example shows the effects of the Bering Sea pollock trawl fishery on the Alaska Peninsula/Aleutian Islands region for FMP 1 and 2003.

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[6] 1999 IMPLAN baseline data, which are the most current available, were used to estimate the multipliers.