Appendix B
Evaluation of Fishing Activities that May Adversely Affect Essential Fish Habitat

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National Marine Fisheries Service

April 2005

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ABL	Auke Bay Laboratory
ADF&G	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center
AI	Aleutian Islands
ANOVA	analysis of variance
B_{MSY}	biomass beneficial maximum sustainable yield
BS	Bering Sea
BSAI	Bering Sea/Aleutian Islands
C	centigrade
CFR	Code of Federal Regulations
cm	centimeter
Council	North Pacific Fishery Management Council
CPUE	catch per unit of effort
EBS	eastern Bering Sea
EFH	essential fish habitat
EIS	environmental impact statement
FMP	fishery management plan
F_{MSY}	fishing mortality rate at maximum sustainable yield
FOCI	fisheries oceanography coordinated investigations
GIS	geographic information system
GOA	Gulf of Alaska
HAPC	habitat area of particular concern
INPFC	International North Pacific Fisheries Commission (now the North Pacific Anadromous Fish Commission)
kg	kilogram
kg/cm^2	kilogram per square centimeter
km	kilometer
km^2	square kilometer
lb/in^2	pound per square inch
lbs	pounds
LEI	Long-term Effect Index
m	meter
mm	millimeter
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MMNT	more than minimal and not temporary
MSST	minimum stock size threshold
MSY	maximum sustainable yield
mt	metric ton

MT	minimal or temporary
nm	nautical mile
NMFS	National Marine Fisheries Service
N_{MSY}	equilibrium population size corresponding to MSY
NRC	National Research Council
ppm	parts per million
ppt	parts per thousand
PSEIS	Final Programmatic Groundfish SEIS
QS	quality scores
RACE	Resource Assessment and Conservation Engineering Division
ROV	Remote Operating Vehicle
SST	shortspine thornyheads
t	ton
U	unknown

B.1 Overview

This appendix addresses the requirement in Essential Fish Habitat (EFH) regulations (50 Code of Federal Regulations [CFR] 600.815(a)(2)(i)) that each FMP must contain an evaluation of the potential adverse effects of all regulated fishing activities on EFH. This evaluation must 1) describe each fishing activity, 2) review and discuss all available relevant information, and 3) provide conclusions regarding whether and how each fishing activity adversely affects EFH. Relevant information includes the intensity, extent, and frequency of any adverse effect on EFH; the type of habitat within EFH that may be affected adversely; and the habitat functions that may be disturbed.

In addition, the evaluation should 1) consider the cumulative effects of multiple fishing activities on EFH, 2) list and describe the benefits of any past management actions that minimize potential adverse effects on EFH, 3) give special attention to adverse effects on habitat areas of particular concern (HAPCs) and identify any EFH that is particularly vulnerable to fishing activities for possible designation as HAPCs, 4) consider the establishment of research closure areas or other measures to evaluate the impacts of fishing activities on EFH, 5) and use the best scientific information available, as well as other appropriate information sources.

This evaluation assesses whether fishing adversely affects EFH in a manner that is more than minimal and not temporary in nature (50 CFR 600.815(a)(2)(ii)). This standard determines whether Councils are required to act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable.

Much of the material responsive to this evaluation is located in other chapters of this environmental impact statement (EIS). These areas include the following:

- Descriptions of fishing activities (including gear, intensity, extent and frequency of effort) - Sections 3.4.1 and 3.4.2.
- Effects of fishing activities on fish habitat - Section 3.4.3.
- Past management actions that minimize potential adverse effects on EFH - Sections 2.2 and 4.3.
- Habitat requirements of managed species - Sections 3.2.1, 3.2.2, and Appendices D and F.
- Features of the habitat - Sections 3.1, 3.2.4 and 3.3.
- HAPCs - 2.2.2.7, 2.2.2.8, 2.3.2, and 4.2

Information from these sections is included by reference to avoid duplication. Specific information from these sections will be repeated in this appendix where it is applicable to the remainder of the evaluation.

Relevant rules and definitions from regulations and corresponding determinations

As defined in the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), “Essential fish habitat means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.”

For the purpose of interpreting the definition of EFH, “waters” include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; “substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” means the habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species’ full life cycle (50 CFR 600.10).

This definition differentiates EFH from all other fish habitat based on the extent that the habitat's support of a managed species affects that species' a) ability to support a sustainable fishery and b) ability to fulfill its role in a healthy ecosystem. While habitat functions support individual fish and are affected by fishing at local scales, the support of fisheries and ecosystem roles are accumulated across entire fish populations and ecosystems. Therefore, the appropriate scale for assessing the consequences of the effects of fishing on EFH is that of populations and ecosystems. The importance of habitat properties at specific sites depends on the role of local habitat functions in the full support of each managed species by all habitats. Negative effects to habitat function at specific sites may constitute adverse effects to EFH, but the relevant question is whether such site-specific effects cumulatively have adverse consequences for a stock of a managed species. In other words, do such effects impair the ability of a managed species to support a sustainable fishery or its role in a healthy ecosystem? This does not mean that site-specific effects are not assessed, rather that their cumulative consequences must be considered to evaluate effects on the EFH of each species.

The regulatory language guiding the assessment of effects in this evaluation is as follows:

> Each Fishery Management Plan (FMP) must minimize to the extent practicable adverse effects from fishing on EFH, including EFH designated under other Federal FMPs. Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature (50 CFR 600.815(a)(2)(ii)).

Numerical standards for minimal or temporary effects are not provided, although the preamble to the final rule (67 FR 2354) describes temporary impacts as those that are "limited in duration and that allow the particular environment to recover without measurable impact." No time scale was attached to the term 'limited duration.' The same commentary describes minimal impacts as those that "may result in relatively small changes in the affected environment and insignificant changes in ecological functions." In the EFH context, the terms 'environment' and 'function' refer to the features of the environment necessary for the spawning, breeding, feeding, and growth to maturity of the managed species and their function in providing that support.

As described in the EFH regulations, evaluation of the adverse effects of fishing on EFH is based upon the 'more than minimal and not temporary' standard. Fishing operations change the abundance or availability of certain habitat features (e.g., prey availability or the presence of living or non-living habitat structure) used by managed fish species to accomplish spawning, breeding, feeding, and growth to maturity. These changes can reduce or alter the abundance, distribution, or productivity of that species, which in turn can affect the species' ability to "support a sustainable fishery and the managed species' contribution to a healthy ecosystem" (50 CFR 600.10). The outcome of this chain of effects depends on characteristics of the fishing activities, the habitat, fish use of the habitat, and fish population dynamics. Conducting an analysis considering all relevant factors required that information from a wide range of sources and fields of study be consolidated in order to focus on the evaluation of the effects of fishing on EFH. Professional judgement had to be relied upon to address scientific uncertainty regarding information necessary for analysis.

The duration and degree of fishing's effects on habitat features depend on the intensity of fishing, the distribution of fishing with different gears across habitats, and the sensitivity and recovery rates of habitat features. A numeric model was developed as a tool to structure the relationships between available sources of information on these factors. This model was designed to estimate proportional effects on habitat features that would persist if current fishing levels were continued until affected habitat features reached an equilibrium with the fishing effects. At equilibrium, habitat features will neither further degrade nor improve if fishing effects persist at a constant level. Therefore, such effects would not be of limited duration and would meet the 'not temporary' test.

While subject to considerable limitations and uncertainties, model results consolidate the best available information on each factor determining fishing's effects on the properties (features) that allow the waters and substrates of Alaska to serve as fish habitat. These estimates only partially address the effects of fishing on the EFH of managed species, since the model does not consider the habitat requirements of those species or the distribution of their use of habitat features. Those considerations required qualitative assessments by experts on each species. In spite of its limitations, the model provided a consistent, reasonable perception of fishing's effects on features of the habitat at the smallest feasible spatial scale. This freed the species evaluators from making individual, subjective estimates of how and where fishing affects habitat features, allowing them to focus on what the effects estimated by the model mean for each managed species. Specifically, the evaluators were asked to use the model output in addressing whether the fisheries, as they are currently conducted, are affecting habitat that is essential to the welfare of each managed species. In other words, are continued fishing activities at the current rate and intensity likely to alter the ability of a managed species to sustain itself over the long term?

Evaluators were provided with the maps and habitat use information developed during the EFH designation analyses. Effect estimates from the model, displayed on charts and summed across habitat types and species EFH areas, were then evaluated as to how they impact the habitat's ability to support the spawning, breeding, feeding, or growth to maturity of a managed species. The evaluation considered which habitat features are used by each managed species, the overlap of that use with the effects of fishing on those features, and other evidence relevant to whether fishing affects the EFH of each species. The distribution of fishing effects on habitat features was portrayed to the smallest scale practicable to permit consideration of effects at any sites considered vital enough to have population-level effects. Indications from historical and current stock assessments of each species' ability to maintain productivity while subject to current or higher levels of fishing intensities were also considered. The standard for evaluation was whether the expected effect on the species' ability to support a sustainable fishery or its role in a healthy ecosystem is more than minimal.

The ability of the stock to produce its maximum sustainable yield (MSY) over the long term was used as a measure of its ability to "support a sustainable fishery."[1] Analysts familiar with the stock and the data available were instructed to determine whether there was evidence that habitat impacts due to fishing impaired the stocks' ability to produce MSY over the long term. No such standard was available for the species' "contribution to a healthy ecosystem." However, the stock level necessary to support a sustainable fishery does ensure that substantial numbers of fish are available to serve as prey or predators to other species, as well as fulfilling other ecosystem functions. For species where MSY could not be estimated with available data (e.g., recruitment estimates not available), assessing effects on EFH had to rely on other proxies or ratings of "unknown" were necessary.

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[1] The draft EIS used stock status relative to the minimum stock size threshold (MSST) as a reference point and addressed whether the effects of fishing on EFH would alter the ability of each stock to remain above its MSST over the long term. Given the apparent confusion some commenters expressed over how the National Marine Fisheries Service (NMFS) considered stock status in the analysis, NMFS modified the analytical approach in the final EIS to address whether stock status and trends indicate any potential influence of habitat disturbance due to fishing. Specifically, analysts addressed whether the temporal or spatial pattern of habitat disturbance on stock abundance is sufficient to alter the ability of the stock to produce MSY over the long term.

Substantial scientific uncertainties necessitate close consideration of the appropriate weighting of evidence. The preamble to the final EFH regulations provides the following guidance for these evaluations of fishing effects on EFH. First, Council action to minimize effects of fishing on EFH "is warranted to regulate fishing activities that reduce the capacity of EFH to support managed species, not fishing activities that result in inconsequential changes to the habitat." Therefore, there has to be evidence that such a reduction in capacity would occur. On the other hand, the preamble cautions against setting too high a standard for such evidence by stating the following:

> It is not appropriate to require definitive proof of a link between fishing impacts to EFH and reduced stock productivity before Councils can take action to minimize adverse fishing impacts to EFH to the extent practicable. Such a requirement would raise the threshold for action above that set by the Magnuson-Stevens Act.

Finally, the preamble gives this advice on how to weight different sources of information. "The final rule encourages Councils to use the best available science as well as other appropriate information sources when evaluating the impacts of fishing activities on EFH, and to consider different types of information according to its scientific rigor." Therefore, species evaluators had to consider the scientific basis, uncertainties, rigor of the estimates of effects on habitat features, knowledge of fish biology, distribution and use of the habitat, and the stock assessment information in determining whether effects on EFH were more than minimal and not temporary.

This evaluation does not address the direct effects of the fisheries on the fish themselves, such as catch or as bycatch. Those issues are the subject of other sections of the FMPs. The EFH regulations address adverse effects to species welfare resulting from habitat alterations. Therefore, changes in the abundance or productivity of a fish species due to direct mortalities by the fisheries are not considered adverse effects on EFH. An exception is the situation where a prey species is affected, and the habitat is essential for another managed fish species expressly because that prey species is present.

The remainder of this appendix describes the effects of fishing analysis (What effects on habitat features are not temporary?) and then the subsequent evaluation process (Do those effects on habitat have an effect on species welfare that is more than minimal?). The evaluations resulting from this process are then presented to satisfy the requirements of the EFH final rule.

B.2 Effects of Fishing Analysis

Fishing operations can adversely affect the availability of various habitat features for use by fish species. Habitat features are those parts of the habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. The literature regarding these effects has grown substantially over the last decade. Recent reviews include Johnson 2002, National Research Council (NRC) 2002, and Thrush and Dayton 2002. Literature most relevant to Alaska fisheries was reviewed in Section 3.2.3. A complex combination of factors influences the effects of fishing on habitat features, including the following:

1. Intensity of fishing effort
2. Sensitivity of habitat features to contact with fishing gear
3. Recovery rates of habitat features
4. Distribution of fishing effort relative to different types of habitat

The goal of this analysis was to combine available information on each of these factors into an index of the effects of fishing on features of fish habitat that is applicable to issues raised in the EFH regulations. This stage of the analysis embodied the risk assessment recommended in Chapter 5 of the National Academy of Sciences' review of the Effects of Trawling and Dredging on Seafloor Habitat (NRC 2002). It synthesized the available data and technical studies to describe the nature, severity, and distribution of the risk to features of the habitat relevant to the marine fish population of Alaska. This quantitative approach was considered preferable to more qualitative methods, such as subjective scoring and summing of factors, because it made the assumptions explicit, preserved the spatial detail of higher quality data sources (e.g., fishing distribution), and provided a consistent representation of the effects of fishing.

While at least some information was available on all of these factors, it varied in quality, spatial coverage, and applicability to Alaska fisheries. There was also no accepted model or analysis for relating this information to the questions posed by the EFH regulations. An initial approach was developed in April 2002 (Witherell 2002), which combined regional statistics into a gear factor, a habitat recovery factor, and a percent coverage factor for each fishery. These factors were then combined into two scores related to whether potential effects are minimal or temporary. A model (Fujioka 2002) was developed in May 2002 that combined this information into an estimate of the proportional reduction in a habitat feature, relative to an unfished state, if a fishery were continued at current intensity and distribution to equilibrium (effects neither increase nor decrease if continued longer). A preliminary analysis (Rose 2002), based on that model and applied on a 5-by-5-kilometer (km) spatial scale, was provided in August 2002 to aid the Council's EFH Committee in selecting potential alternative actions to minimize adverse effects of fishing. The current analysis follows the structure of that preliminary analysis, with improvements based on input from participants in the Council process and scientists inside and outside of NMFS. The analysis also benefits from an outside peer review by the Center for Independent Experts (Drinkwater 2004).

While this analysis provides a tool for bringing disparate sources of information to bear on the evaluation of EFH, numerous limitations arose of which users should remain mindful. Both the developing state of the model and the limited quality of available data to estimate input parameters prevent a robust evaluation of habitat effects. While quantitative output may provide an impression of rigor, the results are actually subject to considerable uncertainty. Notwithstanding, it is the best tool currently available for representing the relative risks to habitat features, but it is not necessarily a definitive predictor.

While some sources of input estimates are relatively good (fishing distribution), others have substantial uncertainty or come from indirect proxies. In many cases, results from other regions, with somewhat different habitats or fishing methods, were used to estimate parameters for Alaska. To facilitate evaluation of the input parameters, each table includes a column of quality scores (QS). These are subjective assessments of the quality of information available to estimate a specific parameter on a scale of 1 to 10. A QS of 10 indicates that NMFS has all the information needed to assess both the value and the variability of the parameter with confidence. A QS of 1 indicates that the provided parameter value has the highest uncertainty (or lowest confidence).

B.2.1 The Effect and Recovery Model

To use estimates of fishing intensity, sensitivity of habitat features, and feature recovery rates in a quantitative analysis required a model linking these factors into a unified measure of the resulting effects. This section describes the derivation of that model, followed by an explanation of how that model was applied to the available information.

Fishing reduces availability of a habitat feature at a rate I. I is the product of the proportion of the feature that the fishing gear contacts per time (f) and the proportion of the contacted elements that are made unavailable, due to damage, removal, or mortality (q):

$$(1)\ I = f \times q$$

Assuming elements of a habitat feature can be in only two conditions: let H = the portion of the feature unaffected by fishing, h = the portion of the feature not available to species as functioning habitat, I = rate at which fishing damages or removes the feature, ρ = rate at which the affected portion recovers to the unaffected condition, and e is a constant = 2.718:

$$(2)\ dH/dt = (- I \cdot H) + (\rho \cdot e^{-I} \cdot h)$$

so that there is no net loss of habitat, i.e., H + h = constant amount (H_0). This reflects that H is decreased at a rate I and increases as h survives further effects (e^{-I}) and recovers at a rate ρ.

Setting h = H_0-H and integrating, letting H = H_0 and h = 0 at time = 0, resulting in:

$$(3)\ \int dH/dt = \int(-I \cdot H + \rho \cdot e^{-I} \cdot (H_0 - H))$$

$$(4)\ H_t = H_0(I e^{-(I+\rho S)t} + \rho S)/(I + \rho S), \quad \text{where } S = e^{-I}$$

This gives the proportion of the original habitat remaining unaffected at any time t. To find the long-term result, when the rates of effect and recovery balance each other, t is set = ∞ (infinity), resulting in:

$$(5)\ H_{equil.} = H_0 \cdot \rho e^{-I}/(I + \rho e^{-I})$$

This is converted to a percentage reduction of H at equilibrium, which will be called the long-term effect index (LEI), by:

$$(6)\ LEI = 100 \cdot (1 - H_{equil})$$

From this, it can be seen that LEI increases as the effect rate I increases, while a high recovery rate, ρ, results in lower LEIs. Table B.2-1 shows LEI for a range of combinations of I and ρ (and 1/ρ = average recovery time). The balance of effect rate and recovery rate determines the proportion of habitat affected over the long term (equilibrium). Only features that recover very quickly (high ρ) could achieve a small LEI under any fishing intensity. Likewise, features that recover very slowly may have a high LEI even with small rates of fishing effects.

This use of q × f to estimate I assumes that habitat features are associated with particular locations and do not have substantial ability to move. Features contacted by fishing gear are reduced in the proportion available to species by the sensitivity proportion, (q). Habitat features that have been contacted recover through time and are vulnerable to subsequent contacts (reduction of the unrecovered remainder by [q]). Under this model, the fishing effort is distributed as very small sites of contact, placed randomly within the area being analyzed. Particularly over large scales, fishing effort distributions aggregate together, with small areas subject to heavy fishing and other areas subject to none. At finer scales, distributions tend to be more random and less patchy (Rijnsdorp et al. 1998). Therefore, this model is best applied separately to many small areas with the results summed to larger regions.

Recovery rate, ρ, reflects the rate of change of affected habitat, h, back to unaffected habitat, H. In the absence of further effects, h would decrease exponentially until all habitat was in H, the unaffected condition. The recovery time can be thought of as the average amount of time the affected habitat stays in the affected state and would equal $1/\rho$ (in the absence of further effects). Each habitat feature in each habitat may have different recovery times.

The results of this model (LEIs) are proportions of the original abundance of each habitat feature (H_0) remaining at equilibrium. Because this pristine amount is not known for the features and areas studied, the LEIs could not be used to calculate the actual amount of a feature remaining in an area. Instead, they represent the ability of fishing to reduce however much of each feature was present in an area as a proportional reduction. Summing of LEIs without feature distributions assumes that all locations in each habitat have equal value. Actual combined effects would be influenced by areas of high abundance more than by areas of low abundance. Therefore, accumulated LEIs will underestimate real effects for a feature that was originally more abundant in heavily fished areas than in those that were fished lightly or not fished. An overestimate of effects will occur if the reverse is true. Also, because initial feature abundance was not part of the LEI calculations, LEIs were calculated for all areas where fishing occurred, including some areas where the subject feature may never have existed. This particularly affects results for features with limited distributions.

B.2.2 Analysis Process

The model was developed to provide a quantitative tool for evaluating fishing effects based on fishing intensity, sensitivity of habitat features, and rate of habitat recovery. Numerous assumptions and simplifications were necessary to match model structure to the available data. These include assumptions about effect rates, habitat recovery rates, habitat distribution, and habitat utility. Another limitation of the model was the general nature of available information across relatively broad categories of habitats and features. These assumptions are described in each of the following sections, and their potential effects should be acknowledged in considering the results.

Table B.2-2 describes the actual calculations of fishing effects, including input data matrices, calculation steps, and output matrices. Final results appear in the $\text{LEI}_{\text{I (j}\bullet\text{k)}}$ matrix, which provides information on the spatial distribution of effects (by 5-by-5-km block and feature), and the $\text{LEI}_{\text{(j}\bullet\text{k)}}$ matrix, which summarizes effects to each habitat feature within each habitat.

To help assess the effect of parameter uncertainties and to demonstrate the potential range of plausible effects, LEIs were calculated using high, medium, and low input values for habitat sensitivity and recovery rates. The model was run three separate times: first with all parameter values that would yield high effect estimates, second with those for medium values, and, finally, with all values yielding low estimates combined. These upper and lower sets of estimates are not statistical confidence levels, but do provide a relative assessment of potential error in the central estimates.

The analysis initially assessed the cumulative effects of all fishing activities. The portion of those effects that could be attributed to individual fisheries was then calculated. The first analysis step ($f \times q = I$) was carried out for each fishery separately. The resulting *I* values were multiplied by the area of each block and summed for each feature/habitat combination, giving each fishery an area-weighted *I* value for each feature habitat combination. The original LEI for each feature/habitat combination (calculated for all fisheries combined) was then apportioned between fisheries according to the area-weighted *I* value for each fishery. The resulting fishery LEIs indicate the amount of the overall LEI attributed to that fishery.

B.2.3 Organizational Categories for Fishing Effects Analysis

B.2.3.1 Designation and Description of Habitats

Habitat information varies in quality between regions. McConnaughey and Smith (2000) and Smith and McConnaughey (1999) described available data on sediments for the Bering Sea (BS) shelf and the relationship of that data to the distribution of flatfish. The results from those studies were used to define five habitats for this analysis (Figure B.2-1). The first habitat, situated around the shallow eastern and southern perimeters of the eastern Bering Sea (EBS) and near the Pribilof Islands, has primarily sand substrates. The second, across the central shelf out to the 200-meter (m) contour, has mixtures of sand and mud. A third, west of a line between St. Matthew and St. Lawrence Islands, has primarily mud (silt and clay) substrates, with some sand. In addition to substrate, depth is an important determinant of species distributions and presumably their use of habitat. Therefore, the EBS slope (200 to 1,000 m), with primarily sand/mud substrates, was the fourth EBS habitat used in this analysis. The areas north and east of St. Lawrence Island, including Norton Sound, have a complex mixture of substrates, but were not included in this analysis because they are subject to almost no fishing effort.

Comprehensive substrate data sets do not exist for the Gulf of Alaska (GOA). Instead, there are only a few isolated pockets of observations. The GOA has a much more complex bathymetry than the EBS, so in this analysis, GOA habitats were defined using depth and slope criteria. The following combinations, based on strata used for Alaska Fisheries Science Center (AFSC) groundfish surveys, were used in this analysis: shallow waters (0 to 100 m), deeper waters on the shelf (100 to 300 m), and upper slope (200 to 1,000 m). Depths between 200 and 300 m were allocated to the slope only in areas where contours indicated a steep area immediately adjacent to the deeper slope depths.

The Aleutian Islands (AI) also have complex bathymetry and very limited available substrate information. Because the shelf is very narrow, AI habitats were separated into shallow (0 to 200 m) and deep (200 to 1,000 m) categories. Because its bathymetry more closely resembles the AI region than the EBS, the strip of the southern BS between 165 and 170º E longitude and south of 54º 30" N latitude (management areas 518 and 519) was considered part of the AI region for this analysis.

Designation of substrate types is useful since many of the recovery rate and fishing effect studies are specific to particular substrates. For the EBS shelf, substrate information was used directly in defining habitat areas, making the appropriate substrate apparent. However, both the GOA and the AI have complicated mixes of substrates, including a significant proportion of hard substrates (pebbles, cobbles, boulders, and rock). Insufficient data are available to describe their spatial distributions. Each of the strata in the GOA and AI were divided into two subhabitats, hard (pebble, cobble, and rock) and soft (silt, sand, and gravel) substrates.

Because distributional data are lacking, the same values for the proportions of hard and soft substrates were applied to each of the blocks in each habitat of the GOA and AI. Because better data or proxies were not available for these hard/soft proportions for the GOA habitat types, an estimate of hard/soft proportions was developed based upon the proportion of sites visited during NMFS groundfish surveys that was found to be appropriate for trawling with standard NMFS survey gear. Stations considered inappropriate for trawling for reasons unrelated to substrate hardness (steep or uneven bottoms, cable zones, or unnavigable waters) were not included. This proxy gives only a rough approximation of substrate as 1) the standard survey trawl may function on smoother pebble or cobble substrates that would otherwise be considered hard, 2) the trawl may be damaged by isolated boulders in predominantly soft substrates that may be mistakenly classified as hard, 3) a trawlable bottom may be found in areas of mostly hard substrate, and 4) soft bottom patches may exist in untrawlable areas, but these patches may not be continuous enough to achieve a minimum trawl tow. The data set also suffers from the inconsistency of reporting between years and lead survey scientists. The resulting proportions from the model were 19 percent hard substrate in the shallow stratum, 5 percent hard substrate in the deep shelf, and 10 percent hard substrate on the slope.

Trawl survey data were not similarly applicable for the AI because relatively few trawlable sites (with the standard survey trawl) have been located. It is likely that a large proportion of the AI seafloor is hard substrate. Therefore, a value of 80 percent hard substrates was used for both shallow and deep strata.

These proportional estimates of hard and soft substrates do not affect the results accumulated within habitats. LEI results reported for proportions of hard substrates are the same as those that would be calculated if the entire habitat area consisted of hard substrates and likewise for the soft substrate results. Proportion estimates do affect the values for individual blocks, where these estimates apportion the hard and soft LEI values for that block into a single value.

The insufficient amount of real data on the types, proportions, and distribution of substrates in the GOA and AI should engender great caution in the application of the analysis results for these regions. These are areas where an intensified search for relevant data and the collection of additional applicable data would significantly improve future analyses of fishing effects.

B.2.3.2 Selection of Habitat Features

The connection between fishing gear effects on habitat and on managed species will depend on which features of the habitats were selected for analysis. Features that are not affected by fishing or do not serve a habitat function for a managed species are not relevant to the EFH analysis. Except for prey, which will be discussed separately, no information was found indicating significant effects of fishing on features of pelagic waters serving a habitat function for a managed species. Therefore, pelagic effects were assessed as minimal and were not analyzed further.

In contrast, numerous studies (see EFH EIS Section 3.4.3) have identified effects of fishing on features of the benthic environment that may, in turn, affect the welfare of managed species. For each feature category used, estimates of sensitivity to fishing gears and recovery rates were derived from the literature. The limited number of relevant effect and recovery studies and the minimal amount of data pertaining to use of habitat features by managed species reduced the consideration of habitat features to broad categories.

Fishing effects have been demonstrated for a variety of organisms that are prey for managed species. These were divided into the categories of infaunal and epifaunal prey. Effects have also been documented for features providing seafloor structure that may be used by fish (particularly juveniles) for spawning/breeding purposes or as shelter from predators, particularly juveniles. These features were divided into the classes of living and non-living structure. A special category of living structure with very slow recovery rates, represented by hard corals, was analyzed separately. The organisms and structures making up infaunal prey, epifaunal prey, living structure, and non-living structure vary between different habitat types. Separate sensitivity and recovery rates were derived and applied to each. The analysis treated each habitat feature class separately for each habitat type, so substrate structure in rocky habitats was not compared directly to substrate structure in sandy habitats.

B.2.3.3 Definition of Fisheries and Description of Gear Used

Data from the NMFS observer program provided detailed information on the distribution and intensity of the effort by groundfish fisheries off of Alaska (Section 3.4.1). For each gear type, a vessel is assigned to a fishery based on the species making up the largest proportion of the total catch for the week. The fisheries of each region are listed in Table B.2-3. The groundfish fisheries use bottom trawls, pelagic trawls, longline gear, and pots. A NMFS workshop in March 2002 generated comprehensive descriptions of the gear used by each of the fisheries off of Alaska (see Section 3.4.1). These descriptions were very useful in deriving the areas covered by a unit of effort for each fishing gear type and in appropriately applying the available research on gear effects.

Groundfish vessels less than 60 feet long are not required to carry observers and are not represented in the observer data. The fleets of trawl and longline vessels under 60 feet each take less than 1 percent of the groundfish catch, so their exclusion from the analysis was not considered likely to significantly change the evaluation. Therefore, these fisheries were not considered.

An initial analysis, prepared by the North Pacific Fishery Management Council (Council) staff (Witherell 2002) and reviewed at the May 2002 EFH Committee meeting, indicated that groundfish fisheries represented all but a small fraction of the potential fishing effects on habitat. This analysis generated scores for each fishery similar to the LEI scores described above. Scallop, Bering Sea/Aleutian Islands (BSAI) crab, and salmon fisheries had negligible effects on EFH, with overall scores for each of these fisheries less than 0.1. For comparison, the analysis found that the groundfish fisheries had LEI scores for trawl fisheries ranging from 0.2 to 11.2. Based on the following evaluations, the non-groundfish fisheries were not included in the final detailed analysis.

For the scallop fishery, the Witherell analysis found that, although the effects of this gear on benthic habitats are greater than for other gear types, the fishery occurs in areas and habitat types with relatively fast recovery rates. Additionally, the overall footprint (area effected annually) of the scallop fishery is very small (149 square nautical miles [nm]), equating to about 0.1 percent of the total available benthic EFH area. The effects of this fishery are concentrated in a very small proportion of EFH; thus, these effects are considered minimal and temporary in nature.

For the BSAI crab fisheries, the analysis found that the fisheries have an extremely small overall footprint, totaling less than 1 square nm) per year, equating to less than 0.0007 percent of the total available benthic EFH area. The effects of this fishery are concentrated in an extremely small proportion of available EFH; thus, these effects are considered minimal and temporary in nature.

For the salmon fisheries, the analysis found that the effects on EFH are almost non-existent because the gear generally never touches benthic habitats. Only the drift gillnet fishery was found to have an overall coverage of more than 0.1 percent of available EFH, but, because the gear never touched the bottom, however, this fishery could not affect benthic EFH. Thus, the effects on benthic EFH of the Alaska salmon fisheries are considered minimal and temporary in nature.

B.2.4 Parameter Estimates

B.2.4.1 Fishing Intensity (f) (by 5-by-5-km blocks)

High-quality fishing effort data are available from the groundfish observer program (see Section 3.4.1). Individual sets were tallied for 5-by-5-km blocks from 1998 to 2002. This 5-year period was selected to represent the current level of fishing effects. Reported effort (duration for trawls, hooks for longlines, and pot drops for pots) was converted into swept areas. Trawl durations were multiplied by speed, trawl width, and proportion of effort on the bottom (Table B.2-4). 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 the AI.

For longline and pot fisheries, different methods were used. In reporting effort for the longline fishery, two factors were taken into account, the number of longline hooks multiplied by the length of line per hook and the side-to-side extent or movement of the line. Pot drops were multiplied by the width of the pot and an estimate of the average distance pots traveled across the seafloor. Effort values for vessels not subject to 100 percent observer coverage were extrapolated from an estimate of the proportion of effort that was observed for that fishery and vessel class. While extrapolations for unobserved effort accounted for the total quantity of effort, they could not account for any differences in the geographic distribution of observed and unobserved effort. The values used for each of these swept areas for trawl, longline, and pot fishing are presented in Table B.2-5, along with comments on the source and quality of the estimates. No direct observational data were available for longline effect width, pot movement distance, or the proportion of pelagic trawl effort contacting the bottom, so each value has some uncertainty.

Fishing effort data from the observer database were assigned to 5-by-5-km blocks based on the ending position of the tow, set, or string. The total area covered by the effort was assigned to each block (in square km [km^2]). This total area of effort was divided by the area of the block (25 km^2) and by the number of years (5) to derive an intensity index.

Consequences of assigning effort to blocks using this method include the following:

1) Some effort assigned to each block may actually extend into neighboring blocks because effort was assigned to blocks based on ending positions. In areas of similar intensity, most of such displacements will be nullified by offsetting exchanges of effort between neighboring blocks. More noticeable errors may occur along boundaries, or around isolated cells. However, large-scale patterns will not be substantially affected because no effort is moved farther than the length of a single tow. Averaging across years will also tend to mute the effects of these small-scale-effort displacements.

2) The raw average intensities do not account for uneven distribution of effort within blocks. While this simple ratio could be incorrectly interpreted as an equal number of contacts at every site in the block, actual fishing patterns are more likely to contact previously fished sites repeatedly (overlap) than to display such a simple uniform distribution. Overlapped effort has less total effect because habitat features removed by previous passes are no longer present. It also increases the likelihood that more of the area of a block will not be contacted. The analysis model treats all effort locations as independent, mimicking a random effort distribution. This accounts for the effects of overlap as long as no sites are preferentially targeted.

3) Even on scales smaller than 25 km^2, fishing effort would still be expected to focus on areas that produce higher catches of adult fish and leave some other areas untouched. Since fish, and hence the fisheries that harvest them, tend to aggregate, even at small scales, the random distribution probably

underestimates the proportion of effort overlap occurring in the fisheries and, hence, overestimates habitat effects. The localization of fishing effort and the habitat effect per contact determine the size of any such error.

4) Patchy distributions of fishing efforts, both within and between blocks, will produce different effects at different locations. Since the habitat features and their use by fish can also be patchy, the actual effects on habitat function are influenced by how fishing and habitat-use patterns correspond. High overlap of habitat use and fishing would produce underestimates of habitat effects, while separation between patterns would produce overestimates. Underestimates would be most likely for features used by adult fish that are targeted by the fisheries. Overestimates are more likely for features used by other age classes, where their distribution is different from adults, or for habitat features that occur in areas that are difficult to fish, such as those with very rough, hard seafloors.

B.2.4.2 Sensitivity (q)

As a recent National Academy of Sciences review stated, there have been numerous recent studies on the effects of fishing gear on seafloor habitats with the most studied gear type being bottom trawls. Estimates from those studies, using gear relevant to Alaska fisheries (see Section 3.4.3), were used to generate sensitivity parameters. Information on other Alaska gears, except scallop dredges, is extremely limited. Sensitivity parameters for these gears were assigned using professional judgement.

The most relevant studies were selected to estimate q, the proportion by which habitat function at a particular site is reduced by a single contact with each type of fishing gear. The results of the literature review were compared and combined, taking into account differences in methods, applicability to Alaska fisheries, and the habitats and habitat features studied. Where available, measurements of q from both statistically significant and non-significant results were considered. Thus, this summary analysis does not directly consider the variability from the individual studies. Instead, the sampling unit was defined as a single study result (i.e., one reduction estimate for one species from one study). While weighting by the variability of each estimate would have been preferable, this information was rarely available. Since the statistical distribution of these relatively sparse data was unknown, medians were used to represent the central tendencies of these data results. To allow consideration of the effects of variability on estimates, the 25th and 75th percentiles were also calculated and used to estimate the effects of fishing. Only studies where q could be directly estimated were used in the analysis. This requirement meant the number of gear contacts was known or could be estimated. Another requirement was that sufficient time for recovery to occur had not elapsed. Applicable studies where these requirements were not met were examined for consistency with the results of the studies used.

The gear effects model requires estimates of q and allows these estimates to be specified for each combination of fishing activity, habitat type, and habitat feature. To the extent that different effects can be identified for different components of a fishing gear, the effect rates were averaged after weighting the proportion of each gear component's contact with the seafloor.

While the goal of sensitivity estimation was to calculate changes in habitat function, this parameter is not directly measurable. A measurable property of the habitat features, such as the feature's abundance or condition, had to be used as a proxy for the level of function. Changes in the available biomass of different prey species were used as a proxy for feeding functions. Structure functions, the most important of which were those related to the survival of juveniles to maturity, were more difficult to assess. While the abundance of structure-providing species remaining after trawling was available as a proxy, the decrease in function of damaged organisms (clearly an important consideration) could not be quantitatively assessed with any confidence. A decrease in function of 50 percent was applied to estimate the decrease in function of damaged organisms for this analysis. Values available from studies that indicated mortality resulting from a portion of an organism being damaged were added to the estimates of decreased function for structure-providing organisms. Suitable proxies were less available for non-living substrates.

In estimating the effects of a single gear contact, as required for this analysis, it was necessary to extrapolate results from studies that combined the effects of several contacts. The analysis assumes that the effects of all gear contacts are independent; that is, a second contact decreases habitat function by the same proportion as the first contact. In reality, absolute reduction decreases with each subsequent contact because less habitat function is available for removal. The method to adjust for multiple contacts in a study followed that same assumption.

Therefore, the ratio of features present before n gear contacts (H_b) and after n gear contacts (H_a) is:

(7) $H_a/H_b = (1-q)^n$,

where q is the proportional reduction in habitat per gear contact, and n is the number of contacts. Solving for q gives:

(8) $q = 1- e^{(\ln(Ha/Hb)/n)}$,

which was used to adjust the total reduction estimates from studies using multiple contacts with the gear.

B.2.4.2.1 Bottom Trawls

Infaunal Prey

Infaunal organisms, such as polychaetes, other worms, and bivalves, are significant sources of prey for Alaska groundfish species. Because researchers were not able to determine which crustaceans cited in trawl effects studies were actually infauna, all crustaceans were categorized as epifaunal prey. Studies of the effects of representative trawl gear on infauna included Kenchington et al. (2001), Bergman and Santbrink (2000), Brown (2003), Brylinsky et al. (1994), and Gilkinson et al. (1998).

Kenchington et al. (2001) examined the effects on over 200 species of infauna from trawl gear that closely resembled the gear used off of Alaska. Three separate trawling events were conducted at intervals approximating 1 year. Each event included 12 tows through an experimental corridor, resulting in an average estimate of three to six contacts with the seafloor per event. Of the approximately 600 tests for species effects conducted, only 12 had statistically significant results. The statistical methods were biased toward a Type 1 error of incorrectly concluding an impact. Ten of the significant results are from a year when experimental trawling was more concentrated in the center of the corridors where the samples of infauna were taken. It is likely that more trawl contacts occurred at these sampled sites than the 4.5 estimate (average of three to six contacts) used to adjust the multiple contact results. As such, the results that were available from the study (non-significant values were not provided) represent a sample biased toward larger reductions when used to assess median reductions of infauna. The resulting median effect was 14 percent reduction in biomass.

Bergman and Santbrink (2000) studied effects on infauna (mostly bivalves) from an otter trawl equipped with 20-centimeter (cm) rollers in the North Sea. Because the study was conducted on fishing grounds with a long history of trawling, the infaunal community may already have been affected by fishing. Experimental trawling was conducted to achieve average coverage of 1.5 contacts within the experimental area over the course of the study. Results were provided for two substrate types: coarse sand with 1 to 5 percent of the area contacted, and silt and fine sand with 3 to 10 percent of the area contacted. The five infauna biomass reductions in the first area had a median of 8 percent. The ten infauna biomass reductions from the second area had a median of 5 percent.

In a recent master's thesis, Brown (2003) studied the effects of experimental trawling in an area of the nearshore EBS with sandy sediments. Trawling covered 57 percent of the experimental area. Several bivalves had lower abundance after trawling, while polychaetes were less affected. The median of the reduction in percentages for each species, after adjusting for coverage, was a 17 percent reduction in biomass per gear contact.

Brylinsky et al. (1994) investigated effects of trawling on infauna, mainly in trawl door tracks, at an intertidal estuary. Only three results were provided for infauna in roller gear tracks, but the results were so variable (-50 percent, +12 percent, +57 percent) that they were useless for the purpose of this analysis. Eight results on the effects of trawl doors on species biomass were available for polychaetes and nemerteans. These results had a median of 31 percent reduction in biomass and a 75th percentile of 42 percent reduction in biomass. Gilkinson et al. (1998) used a model trawl door on a prepared substrate to estimate that 64 percent of clams in the door's path were exposed after one pass, but only 5 percent were injured. Doors make up less than 4 percent of the area of the seafloor contacted by Alaska trawls.

The results of Kenchington et al. (2001), Bergman and Santbrink (2000), and Brown (2003) were combined for inclusion in the model, resulting in a median of 10 percent reduction in biomass per gear contact for infaunal species due to trawling, and 25th and 75th percentiles of 5 and 21 percent, respectively (Table B.2-5).

Epifaunal Prey

Epifaunal organisms, such as crustaceans, echinoderms, and gastropods, are significant prey of Alaska groundfish species. However, one of the most common classes of echinoderms, asteroids, are rarely found in fish stomachs. While some crustaceans may be infauna, an inability to consistently identify these species resulted in all crustaceans being categorized as epifaunal prey. Studies of the effects of representative trawl gear on epifauna included Prena et al. (1999), Brown (2003), Freese et al. (1999), McConnaughey et al. (2000), and Bergman and Santbrink (2000).

Prena et al. (1999), as a component of the Kenchington et al. (2001) study, measured the effects of trawling on seven species of epifauna. The median of these results was a 4 percent biomass reduction per gear contact. There appeared to be in-migration of scavenging crabs and snails in this and other studies. Removing crab and snails left only two measurements, 6 and 7 percent reductions in biomass. Bergman and Santbrink (2000) measured effects on four epifaunal species in the experimental coarse sand area (median reduction in biomass was 12 percent) and five epifaunal species in the experimental fine sand area (median reduction in biomass was 16 percent). When crabs and snails were removed, the coarse sand area was unchanged, and the median value for the fine sand area was 15 percent biomass reduction. Brown (2003) studied six epifaunal species, resulting in a median reduction in biomass per gear contact of 5 percent. Combining results from Prena et al. (1999), Brown (2003), and Bergman and Santbrink (2000), and removing crabs and snails, gives a median reduction in biomass of epifaunal species of 10 percent, and 25th and 75th percentiles of 4 and 17 percent, respectively. These are the q values used for the analysis of the effects of full trawls on epifaunal prey, except for those fisheries using tire gear (see below).

The study of McConnaughey et al. (2000) compared the effects of fishing on an area that received heavy fishing pressure between 4 and 8 years previously, using an adjacent unfished area as a control. Therefore, results included a combination of species reductions and recovery, were not adjusted for multiple contacts, and were not directly comparable to the results of the studies above. However, for comparison with previously discussed studies, the resulting median and 75th percentile reductions in biomass for six species of epifauna (excluding snails and crabs) were 12 and 28 percent, respectively. The median result was within the same range as those from the more direct studies, and the 75th percentile result was not sufficiently higher as to indicate substantial error in the direct estimates.

Freese et al. (1999) studied the effects of tire gear on the epifauna of a pebble and boulder substrate. Eight epifaunal species gave a median response of 17 percent reduction in biomass and a 75th percentile of 43 percent reduction in biomass. Before snails were removed, the 25th percentile indicated an increase in biomass of 82 percent due to colonization by snails. The resulting values when two snail taxa were removed were 38 and 43 percent medians and a 5 percent reduction in epifaunal biomass for the 75th and 25th percentiles. The authors noted a strong transition to apparently smaller effects outside of the direct path of the tire gear. For fisheries in hard-bottom areas, where tire gear is most common, epifaunal effects were adjusted for this increased effect within the path of the tire gear. Typical tire gear covers about 25 percent of the full trawl path (i.e., 14 m out of 55 m total), so the resulting q values are 17 percent reduction in epifaunal biomass for the median (0.25 times 38 plus 0.75 times 10), 23 percent reduction for epifaunal biomass for the 75th percentile (0.25 times 43 plus 0.75 times17), and 5 percent reduction for the 25th percentile.

Living Structure

Organisms that create habitat structure in Alaska waters include sponges, bryozoans, sea pens, soft and stony corals, anemones, and stalked tunicates. Studies of the effects of representative trawls on these groups include Van Dolah et al. (1987), Freese et al. (1999), Moran and Stephenson (2000), Prena et al. (1999), and McConnaughey et al. (2000). The first three studies examined the effects on epifauna on substrates such as pebble, cobble, and rock that support attached erect organisms, while the last two studies were located on sandy substrates. Effect estimates were available for only one type of structure-providing organism, the soft coral *Gersemia*, from Prena et al. (1999). After adjustment for multiple contacts, *Gersemia* had a q of 10 percent reduction in biomass per gear contact.

Both the Van Dolah et al. (1987) and Freese et al. (1999) studies identified removal rates and rates of damage to organisms remaining after contact, raising the question of how damage incurred from contact with gear reduces the structural function of organisms. In Freese et al. (1999), sponges were indicated as damaged if they had more than 10 percent of the colony removed, or if tears were present through more than 10 percent of the colony length. Van Dolah et al. (1987) classified organisms as heavily damaged (more than 50 percent damage or loss) or lightly damaged (less than 50 percent damage or loss). Lacking better information, the damaged organisms from Freese et al. (1999) were assigned a 50 percent loss of structural function, and the heavily and lightly damaged organisms from VanDolah et al. (1987) were assigned 75 and 25 percent losses of their function respectively.

Adjustments to the Freese et al.(1999) results were based on observations of a further decrease in vase sponge densities 1 year post-study. Freese (2001) indicates that some of the damaged sponges had suffered necrotization (decay of dead tissues) to the extent that they were no longer identifiable. This percentage was added to the category of removed organisms, resulting in q estimates for epifauna structures in the path of tire gear of a 35 percent median reduction in biomass per contact and a 75th percentile of 55 percent reduction in biomass per contact. Summary results of the VanDolah data show a median of 17 percent reduction in biomass per gear contact and a 75th percentile of 22 percent reduction in biomass per gear contact. Moran and Stephenson (2000) combined all erect epifauna taller than 20 cm and studied their reductions subsequent to each of a series of trawl contacts. They estimated a per contact reduction in biomass (q) of 15 percent. Combining the non-tire gear studies gives a full gear q median per contact reduction estimate of 15 percent and a 75th percentile per contact reduction estimate of 21 percent. Using the same methods as applied to epifauna for combining non-tire gear data with the tire gear data produced effect estimates for trawls employing tire gear of a median per contact reduction of 20 percent and a 75th percentile per contact reduction of 30 percent.

Data from McConnaughey et al. (2000) combining initial effects of high-intensity trawling and recovery had a median value for structure-forming epifauna per contact reduction of 23 percent and a 75th percentile reduction of 44 percent. While these results show greater reductions than the single pass estimates from the other studies, the effects of multiple years of high-intensity trawling can reasonably account for such a difference; thus, the above values for q were not altered.

Hard Corals

While numerous studies have documented damage to hard corals from trawls (e.g., Fossa 2002, Clark and O'Driscoll 2003), only one (Krieger 2001) was found that related damage to a known number of trawl encounters. Fortunately, this study occurred in the GOA with a common species of gorgonian coral (*Primnoa rubi*) and with gear not unlike that used in Alaska commercial fisheries. Krieger used a submersible to observe a site where large amounts of *Primnoa* were caught during a survey trawl. An estimated 27 percent of the original volume of coral was removed by the single trawl effort. The site was in an area closed to commercial trawling, so other trawling effects were absent. This value was used for coral sensitivity in the analysis bracketed by low and high values of 22 and 35 percent.

Non-living Structure

A variety of forms of the physical substrates in Alaska waters can provide structure to managed species, particularly juveniles. These physical structures range from boulder piles that provide crevices for hiding to sand ripples that may provide a resting area for organisms swimming against currents. Unfortunately, few of these interactions are understood well enough to assess the effects of substrate changes on habitat functions. A number of studies describe changes to the physical substrates resulting from the passage of trawls. However, there is no consistent metric available to relate the use of such structures by managed species to their abundance or condition. This lack of relationship effectively precludes a quantitative description of the effects of trawling on non-living structure. The following discussion describes such effects qualitatively and proposes preliminary values of q for the analysis.

Sand and Silt Substrates:
Schwinghamer et al. (1998) described physical changes to the fine sand habitats caused by trawling as part of the same study that produced Prena et al. (1999) and Kenchington et al. (2001). Door tracks, approximately 1 m wide and 5 cm deep, were detected with sidescan sonar, adding to the surface relief of the relatively featureless seafloor. Finer scale observations, made with video cameras, indicated that trawling replaced small hummocky features a few cm tall with linear alignments of organisms and shell hash. A dark organic floc that was present before trawling was absent afterwards. While no changes in sediment composition were detected, measurements of the internal structure of the top 4.5 cm of

sediment were interpreted to indicate loss of small biogenic sediment structures such as mounds, tubes, and burrows. Brylinsky et al. (1994) describe trawl tracks as the most apparent effect of trawls on a silty substrate and the tracks of rollers as resulting in much shallower lines of compressed sediment than tracks of trawls without rollers. A wide variety of papers describes trawl marks; these papers include Gilkinson et al. (1998), who describe the scouring process in detail as part of a model door study.

For effects on sedimentary forms, the action of roller gear trawls replaces one set of cm-scale forms, such as hummocks and sand ripples, with door and roller tracks of similar scales. In habitats with an abundance of such structures, this can represent a decrease in seabed complexity, while in relatively smooth areas, an increase in complexity will result (Smith et al. 2000). The effects on internal sediment structure are considered too small in scale to provide shelter directly to the juveniles of managed species. The extent to which they affect the availability of prey for managed species is better measured by directly considering the abundance or those prey species. This consideration was done by studies cited in the prey sections above. Since the observed effects of a single gear contact are relatively subtle, with ambiguous effects on function, the parameter selected for this analysis represents a small negative effect (-2 percent). This provides some effect size that can be scaled up or down if greater or lesser effects are hypothesized or measured.

Pebble to Boulder Substrates:

In substrates composed of larger particles (large pebbles to boulders), the interstitial structure of the substrate has a greater ability to provide shelter to juveniles and adults of managed species. The association of species aggregations with such substrates provides evidence of their function as structure (Krieger 1992, 1993). Freese et al. (1999) documented that the tire gear section of a trawl disturbed an average of 19 percent of the large boulders (more than 0.75-m longest axis) in its path. They noted that displaced boulders can still provide cover, while breaking up boulder piles can reduce the number and complexity of crevices.

In areas of smaller substrate particles (pebble to cobble), the track of the tire gear was distinguishable from the rest of the trawl path due to the removal of overlying silt from substrates with more cobble or the presence of a series of parallel furrows 1 to 8 cm deep from substrates with more pebble. Of the above effects, only breaking up boulder piles was hypothesized to decrease the amount of non-living functional structure for managed species. A key unknown is the proportional difference in functional structure between boulder piles and the same boulders, if separated. If that difference comprised 20 percent of the functional structure, and 19 percent of such piles were disturbed over one-third of the trawl paths (tire gear section), a single trawl pass would reduce non-living structure by only about 1 percent. Even if piles in the remaining trawl path were disturbed at half the rate of those in the path of the tire gear (likely an overestimate from descriptions in Freese et al. 1999), the effect would only increase to 2 percent. Lacking better information, this speculative value was applied in the analysis.

B.2.4.2.2 Pelagic Trawls

Studies using gear directly comparable to Alaska pelagic trawls, and thus identifying the resulting effect of such gear contact with the seafloor, are lacking. By regulation, these trawls must not use bobbins or other protective devices, so footropes are small in diameter (typically chain or sometimes cable or wrapped cable). Thus, their effects may be similar to other footropes with small diameters (i.e., shrimp or Nephrops trawls). However, these nets have a large enough mesh size in the forward sections that few, if any, benthic organisms that actively swim upward would be retained in the net. Thus, benthic animals that were found in other studies to be separated from the bottom and removed by trawls with small-diameter footropes would be returned to the seafloor immediately by the Alaska pelagic trawls.

Pelagic trawls are fished with doors that do not contact the seafloor, so any door effects are eliminated. Finally, because the pelagic trawl's unprotected footrope effectively precludes the use of these nets on rough or hard substrates, they do not affect the more complex habitats that occur on those substrates.

Two studies of small footrope trawls were used to represent the effects of pelagic trawl footropes on infaunal prey. Since most infaunal prey are too small to be effectively retained by bottom trawls, the large mesh size of pelagic trawls was not considered a relevant difference for the feature. Ball et al. (2000) investigated the effects of two tows of a Nephrops trawl in the Irish Sea on a muddy sand bottom in two different years. Eighteen taxonomic groups were measured in each year, including bivalves, gastropods, crustaceans, and annelids. For the 27 abundance reductions cited, the median effect was a 19 percent reduction abundance per gear contact, and the 75th percentile was a 40 percent reduction in abundance per gear contact, with the adjustment for multiple tows. Sparks-McConkey and Wating (2001) used four passes of a whiting trawl on a clay-silt bottom in the Bay of Maine. The infauna responses measured included three bivalves and seven polychaetes and nemerteans. The median response was a 24 percent reduction in abundance per gear contact, and the 75th percentile was a 31 percent reduction in abundance per gear contact, with the adjustment for multiple tows. Combining the two studies gave a median per contract reduction of 21 percent and a 75th percentile per contact reduction of 36 percent. These values were higher than those for roller gear trawls since there is continuous contact across the footrope and a greater ability of smaller footropes to penetrate the substrate.

Sessile organisms that create structural habitat may be uprooted or pass under pelagic trawl footropes, while those that are more mobile or attached to light substrates may pass over the footrope, with less resulting damage. Non-living structures may be more affected by pelagic trawl footropes than by bottom trawl footropes because of the continuous contact and smaller, more concentrated, surfaces over which weight and towing force are applied. In contrast, bottom trawls may capture and remove more of the large organisms that provide structural habitat than pelagic trawls because of their smaller mesh sizes. The bottom trawl doors and footropes could add complexity to sedimentary bedforms as mentioned previously, while pelagic trawls have an almost entirely smoothing effect. Based on these considerations, values of 20 percent reduction per gear contact and 30 percent reduction per gear contact were selected for both living and non-living structure.

B.2.4.2.3 Longlines

Studies that quantitatively assess the effects of longlines on seafloor habitat features were not found. Due to the light weight of the lines used with longline gear, effects on either infaunal or epifaunal prey organisms are considered to be limited to anchors and weights. Since these components make up less than 1/500th of the length of the gear, their effects are considered very limited (0.05 percent reduction per contact was the value used). Similarly, effects on the non-living structure of soft bottoms are also likely to be very limited.

Organisms providing structure may be hooked or otherwise affected by contact with the line. Observers have recorded anemones, corals, sea pens, sea whips, and sponges being brought to the surface hooked on longline gear (Stellar sea lion protection measures SEIS, 2001), indicating that the lines move some distance across the seafloor and can affect some of the benthic organisms. The effects on non-living structure in hard-bottom areas due to hang-ups on smaller boulder piles and other emergent structures are limited to what may occur at forces below those necessary to break the line. Similar arguments to those used for bottom trawl effects on hard non-living structure would justify an even lower effect than the value generated for bottom-trawling (1 percent). Unfortunately, there are no data to indicate what proportion the retained organisms represent of those contacted on the seafloor or the level of damage to any of the affected organisms. Values for reduction of living structure equal to one-half of those for bottom trawls were used for the area contacted by longlines.

B.2.4.2.4 Pots

The only studies on pots (Eno et al. 2001) have examined gear much smaller and lighter than that used in Alaska waters and are, thus, not directly applicable in estimating effects of pots on habitat. Alaska pots are approximately 110 times as heavy and cover 19 times the area as those used by Eno et al. (2001) (2.6 kilograms [kg], 0.25 m^2). The Eno et al. (2001) study did show that most sea pens recovered after being pressed flat against the bottom by a pot. Most Alaska pots have their mesh bottoms suspended 2.5 to 5 cm above their weight rails (lower perimeter and cross pieces that contact the substrate first); hence, the spatial extent to which the greater weight of those pots is applied to organisms located underneath the pots is limited, but more intense.

The area of seafloor disturbed by the weight rails is of the greatest concern, particularly to the extent that the pot is dragged across the seafloor by bad weather, currents, or during hauling. Based on the estimated weight of the pots in water, and the surface area of the bottom of these rails, the average pressure applied to the seafloor along the weight rails (about 1 pound per square inch [lb/in^2] [0.7 kilogram per square centimeter (kg/cm^2)]) is sufficient to penetrate into most substrates during lateral movement. The effects of pots as they move across the bottom were speculated to be most similar to those of pelagic trawls with smaller contact diameter and more weight concentrated on the contact surface. Therefore, structure reduction values 5 percent greater than those determined for pelagic trawls were used.

B.2.4.3 Recovery Rate

A small proportion of studies on the effects of fishing have looked at recovery periods for different features and habitat types. Most of these studies were summarized in Collie et al. (2000). This paper contained plots that combined results from studies that examined many gear types, including intertidal dredges, scallop dredges, beam trawls, and small footrope trawls. Nearly all of the organisms represented in the plots are from groups that are classified as infaunal or epifaunal prey. The only points in the plots representing living shelter are from the Van Dolah et al. (1987) study. The logarithmic time scale used for the figures in that paper makes it somewhat difficult to extract exact recovery periods. Careful measurements and known landmarks (i.e., there was generally a recognizable group of studies with 1 year in all plots) were used to achieve the following estimates. Fishing effects in sand habitats were reduced to very near zero effect within about 2 months, though a small amount of reduction in biomass remained until 1 year. Therefore, the estimated timeframe for recovery in sand habitats was 3 months or 0.25 year (Table B.2-6) to account for the small reduction over time. Mud/sand mixes and mud habitats were estimated to recover at 12 months and 6 months, respectively. Studies using roller trawls in those environments included Kenchington et al. (2001), which detected no remaining effects in a sand/mud mix after 1 year, and Brylinski et al. (1994) with polychaetes and nematodes in intertidal sand/mud mixes recovering in 1 to 2 months. The recovery period selected for sand/mud mixes was 0.75 year and 1 year for mud habitats.

To allow for evaluation of scientific uncertainty, the same data were considered to derive long and short recovery times for each habitat. The resulting values were 3 to 4 months for sand, 6 to 12 months for sand/mud, and 6 to 18 months for mud habitats. The inverses of all of these values were calculated to estimate the recovery rates needed for the effect model (Table B.2-6).

In general, very little data are available on the recovery periods for living structure. A literature review has undertaken to determine growth rates, recovery rates, fecundity values, and recruitment rates for major structuring invertebrate taxa (sponges, hard and soft corals, bivalves, hydroids, polychaetes, anemones, sea pens, and bryozoans) from previous studies. There was minimal information on most of these taxa from studies conducted in Alaska, and few studies were conducted in temperate or arctic waters in general. Preliminary data were available for EBS anemone populations, which indicated that the recovery rate of sea anemones from trawling effects may have been as great as 30 percent per year in soft bottom habitats (McConnaughey 2003). This finding was consistent with the Wahl (1985) study in temperate waters. In hard-bottom areas of the GOA, Freese (2001) returned to an area affected by tire gear and found no visible indications of healing or regrowth of vase sponges. A study gave a recovery rate for gorgonian corals of about 4 percent per year in a marine sanctuary in Florida (Gittings et al. 1988). In Alaska, gorgonian growth rates have been observed to be 0.2 and 0.58 cm per year (Stone et al. 2001, Andrews et al. 2002), indicating a 1-m-high coral could be more than 100 years old. An evaluation of maximum ages, growth rates, and recruitment rates for bivalves and polychaetes suggested their recovery times could be shorter than recovery times for corals, sponges, and anemones. VanDolah et al. (1987) found full recovery of sponges and octocorals in less than 1 year in a shallow water study off of North Carolina. Leys and Lauzon (1998) estimated that some sponges in a deepwater fjord averaged 35 years old with a maximum age of 220 years.

A meeting was scheduled with a panel of experts to discuss and estimate recovery rates of structure-forming invertebrates that would be acceptable to use in the fishing effects model. The participants included scientists who had previously studied invertebrate taxa. Attendees were Braxton Dew (RACE), Linc Freese (ABL), Bob McConnaughey (RACE), Chris Rooper (RACE), Craig Rose (RACE), Matt Wilson (FOCI), Bruce Wing (ABL), Cynthia Yeung (RACE), and Mark Zimmermann (RACE). The literature review of growth rates, recovery rates, fecundity values, and recruitment rates for “structuring invertebrate” taxa was circulated among the scientists before the meeting. This life history information served as background information for determining the potential recovery of these invertebrates. There was consensus that a reasonable range for recovery rates of structure-forming invertebrates associated with the soft bottom, based on their life history characteristics, was 10 to 30 percent per year with a mean of 20 percent per year. There was also consensus that hard-bottom recovery rates were slower, 1 to 9 percent per year, with a mean of 5 percent per year based on hard-bottom invertebrate life history characteristics. These were converted to exponential rates for use in the model by the following formula:

$$\rho = \ln(1+\text{annual percent increase}).$$

Resulting rho values were 0.26, 0.18, and 0.10 for soft substrate habitats and 0.09, 0.05, and 0.01 for hard substrate habitat.

Recovery rates of gorgonian corals are potentially much longer and, therefore, were evaluated separately in the analysis. Short, middle, and long recovery periods of 50, 100, and 200 years were the values used for gorgonian corals. Growth rates from Leys and Lauzon (1998) indicated that some sponges recover at rates between those of the other hard-bottom, living structure, and coral groups.

Recovery of non-living structures can occur from current and wave action or burrowing animals. Studies indicated that door marks had became undetectable within 2 to 4 months (Brylinski et al. 1994) or 1 year (Schwinghamer et al. 1998), and other marks dissipated more rapidly. Therefore, the recovery rate for soft substrates was determined to be 1 year for the purposes of the model. In hard substrates, the breaking up of boulder piles is not an effect that will recover on biological time scales, but disturbances of pebble-size substrates could be modified by biological action. The effect/recovery model is not a good fit for this type of habitat feature. While boulder pile habitat will not recover, the total effect possible is the difference between the habitat value of the piles and the habitat value of the same boulders when isolated. Past that point, no further degradation of that feature could occur, although the model continues to apply proportional reductions beyond that point. This is an area where more detailed information on habitat usage, description, and distribution is needed. For purposes of this analysis, a recovery period of 100 years, with a range of 50 to 200 years, was used to capture recovery of pebble site substrates.

B.2.4.4 Habitat Categorization

The habitat and regional boundaries (see B.2.3.1) were overlaid using geographic information systems (GIS) (ArcMap), resulting in the classification of each of the 5-by-5-km blocks by habitat type. Where a boundary passed through a block, the area within each habitat was calculated, and those areas were analyzed separately. For the GOA and AI habitats, the estimates of proportions of hard and soft substrate habitat types were entered into the classification matrix for each block.

B.2.4.5 Area (A)

The total area of each benthic habitat was calculated through GIS based on coastlines, regional boundaries, habitat boundaries, and depth contours (Table B.2-7).

B.2.5 Results of the Analysis of Effects of Fishing on Habitat Features

No fishing occurred in blocks covering a large proportion of the seafloor area shallower than 1,000 m from 1998 to 2002 (Table B.2-8), and even more blocks were unaffected by trawling. Most of the fished blocks experienced intensities less than 0.1, and only a small proportion of the area (2.5 percent BS, 0.8 percent AI, and 0.9 percent GOA) was in blocks with intensities above 1.0. These fishing intensities determined the spatial distribution of the indices of fishing effects estimated by the model.

The analysis estimated an LEI of the effects of fishing on infaunal prey, epifaunal prey, living structure (coral treated separately), and non-living structure across different habitats and between fisheries. The LEI estimated the percentage by which these habitat features would be reduced from a hypothetical unfished abundance if recent intensity and distribution of fishing effort were continued over a long enough term to achieve equilibrium. Equilibrium is defined as a point where the rate of loss of habitat features from fishing effects equal the gain from feature recovery. The spatial pattern of long-term effect indices largely reflects the distribution of fishing effort scaled by the sensitivity and recovery rates assigned to different features in different habitat types. Thus, patterns on the charts of LEI for each feature class were very similar, with higher overall LEIs for more sensitive or slower recovering features (Figures B.2-2 to B.2-5). Prey LEIs were substantially lower than structure LEIs, reflecting their lower sensitivity and faster recovery rates.

All habitats included substantially unfished and lightly fished areas that have low LEIs (less than 1 percent) as well as some areas of high fishing that resulted in high LEIs (more than 50 percent or even more than 75 percent). In the AI, GOA, and EBS slope, substantial LEIs were primarily concentrated into many small, discrete pockets. On the EBS shelf, there were two larger areas where high LEIs were concentrated: (1) an area of sand/mud habitat between Bristol Bay and the Pribilof Islands and (2) an area of sand habitat north of Unimak Island and Unimak Pass, mostly inside of the 100-m contour.

Some of the patterns in fishing effects can be related to areas closed to bottom trawl fishing. In the GOA, no bottom trawling is allowed east of 140ºE longitude, and fishing effects are light there. Bottom trawling has been substantially restricted within specified radii (10 and 20 nm) of Steller sea lion rookeries and haulouts. The effects of these actions on LEI values are most clearly seen in the AI, where high LEI values are concentrated in small patches where the narrow shelf does not intersect these closures. Two large EBS areas around the Pribilof Islands and in and adjacent to Bristol Bay both mostly in sand substrates, are closed to bottom trawling to protect red king crab habitat. These closures concentrate fishing in the southern part of the EBS into the remaining sand, sand/mud, and slope habitats, which likely increases the predicted LEI in those areas.

Aggregate LEIs for each of the habitats are shown in Table B.2-9. As discussed above, prey declined less than biostructure due to lower sensitivity and faster recovery rates. No prey feature was reduced by more than 3.5 percent (BS slope habitat). Biological structure features had LEIs between 7 and 9 percent in the hard substrate habitats where recovery rates were slow. LEIs above 10 percent were indicated for the biological structure of the sand/mud and slope habitats of the EBS where fishing effort is concentrated, and recovery rates are moderately slow.

Because of uncertainties in key input parameters, some evaluation was needed to determine how widely the resulting estimates might vary. In addition to the LEIs cited above, which were generated with median or central estimates for each input parameter (referred to below as central LEIs), LEI was estimated for both large and small values of sensitivity and recovery. High estimates of sensitivity were combined with low recovery rates to provide an upper LEI, and low estimates of sensitivity were combined with high recovery rates to produce a lower LEI. Lower LEIs for the habitat features (except for coral, which is discussed below) ranged from 8 to 50 percent of the original median estimates. Infaunal and epifaunal prey lower LEIs were all at or below 0.5 percent proportional reduction habitat, those for non-living structure were below 2 percent, and those for living structure were below 4 percent. The corresponding upper LEIs ranged from 1.5 to 3 times the original median estimate. The largest upper LEI values for infauna and epifauna prey were for the EBS sand/mud and slope habitats and ranged from 3.5 to 7 percent, with all other upper LEIs below 2 percent. Non-living structure upper LEIs were greatest on the GOA hard substrates, the AI shallow water habitat, and the EBS slope, ranging from 7 to 14 percent, with all other upper LEIs below 4 percent. In six habitats (the three GOA hard substrates, the AI shallow water habitats, and the EBS sand/mud and slope habitats), the upper LEI exceeded 10 percent, with the highest value (21 percent) on the GOA slope.

The analysis also calculated the proportion of each LEI attributable to each fishery. Fishery-specific LEI values for the habitat/feature combinations with the highest overall LEIs (all involving living structure) in each region are presented in Table B.2-10. While the pollock pelagic trawl fishery was the largest single component (4.6 percent) of the total effects on living structure in the EBS sand/mud habitat, the combined effects of the bottom trawl fisheries made up all of the remaining 6.3 percent (total LEI of 10.9 percent). This was not true for living structure on the EBS slope, where nearly all (7.2 percent out of 10.9 percent) of the LEI was due to the pollock pelagic trawl fishery. Living structure on hard bottom substrates of the GOA slope was affected by bottom trawling for both deepwater flatfish and rockfish. While the LEIs of these two fisheries were nearly equal, it is likely that much more of the rockfish effort occurred on hard substrates as compared with trawling for deepwater flatfish. [Because the spatial distribution of hard and soft substrate was unknown, such differences are not explicitly accounted for in the fishing effects analysis.] Therefore, most of the effects on this feature were attributed to the rockfish trawl fishery. In the shallow, hard substrate habitat of the AI, most of the effects (4.2 out of 7.3 percent) on living structure were attributable to the trawl fishery for Pacific cod. The remainder was attributed to Atka mackerel trawling at 2.5 percent. Living structure was the only habitat feature in which the effect of a passive gear fishery, longlining for Pacific cod, had an LEI above 0.1 percent. This fishery accounts for the consistent light blue (less than 1 percent LEI) coverage in Figure B.2-3 (a, b, and c) of many shallow areas of the AI not open to trawling.

Results for ultra-slow recovering structures, represented by hard corals, were different from those of other living structure in several ways. Corals had the highest LEI values of the fishing effects analyses. Because the very slow recovery rate of these organisms results in very high (more than 75 percent LEI) eventual effects with more than the most minimal amount of trawl fishing (annual trawl effort less than one tenth the area of the block), the distribution of high LEI values directly reflects the distribution of blocks subject to more than minimal trawl effort (Figure B.2-6 [a, b, and c]). The LEI values by habitat range from 6 to 20 percent with the highest values in the shallow AI and GOA slopes. These results mostly reflect the proportion of blocks in each habitat type subject to more than minimal trawl effort. Even though fairly wide ranges of both sensitivity and recovery rates were used for the upper and lower LEI estimates for coral, the range between upper and lower LEI was not as wide as for the other living structure organisms, ranging from plus 40 to -33 percent of the central value.

This analysis combined available information to assess the effects of Alaska fisheries on marine fish habitat. It estimated the effects (as measured by LEIs) of fisheries on habitat features that may be used by fish for spawning, breeding, feeding, or growth to maturity. These LEIs represent the proportion of feature abundances (relative to an unfished state) that would be lost if recent fishing patterns were continued indefinitely (to equilibrium). Therefore, all LEIs represent effects that are not limited in duration and satisfy the EFH regulation's definition of "not temporary." The magnitude and distribution of feature LEIs can, thus, be compared with the distribution of the use of that feature by fish species to assess whether the effects are "more than minimal" relative to that species' EFH (Section B.3). Effects meeting this second element would necessarily meet both elements (more than minimal and not temporary) due to the nature of the LEI estimates.

B.2.6 Effects on Habitat Features—Summary

Across broad habitats, LEIs were generally small (the largest central LEI was 11 percent). Living structure was the most vulnerable of the features, followed by non-living structure. Both infaunal and epifaunal prey were more resilient, with a maximum central LEI for a habitat of 3.5 percent.

As fishing efforts were the only data available on a small spatial scale, the details of the LEI maps represent distributions of fishing effort, weighted on a much broader scale for habitat vulnerability characteristics. Therefore, they only represent the potential for reduction of whatever habitat features may be present in each block, without discriminating differences in habitat function between blocks.

In particular locations, certain LEIs (particularly for living structure) were quite substantial. The area with the largest overall LEIs was a patch of sand habitat north of Unimak Island and Unimak Pass, where biological structure LEIs for most of the 5-by-5-km blocks were more than 75 percent. A larger area in the sand/mud habitat of the EBS between Bristol Bay and the Pribilof Islands had living structure LEIs mostly between 25 and 75 percent with a few above 75 percent. Areas with larger LEIs on the EBS slope and in the GOA and AI were much smaller and more scattered. The intensity of effects in these patches is likely affected by redistribution of fishing effort from existing fishing closures. The Unimak patch is the only sand habitat remaining open to trawling in the southern BS shelf after closures to protect red king crab habitat. The other EBS patch is directly between the two areas affected by those closures.

Hard coral LEIs represent animals with ultra-slow recovery rates, which make them very vulnerable to long-term effects from fishing. LEI calculations indicated that wherever these features encountered trawling effort above one-tenth of a block's area per year they had LEIs above 75 percent. The spatial distribution of coral LEIs (Figure B.2-6 [a, b, and c]) essentially identified all trawled areas. As described above, LEIs are estimated for all areas regardless of the abundance, or even the presence of a habitat feature. Because hard corals have particular habitat requirements, including hard substrate and significant currents, a large proportion of the blocks in Figure B.2-6 (a, b, and c) with high coral LEIs does not include suitable habitat for hard corals; hence, no coral reduction actually occurs. Therefore, consideration of coral LEIs focuses on the AI and the GOA slopes, areas of known hard coral abundance. Leys and Lauzon (1998) estimated that some sponges in a deepwater fjord averaged 35 years of age with a maximum age of 220 years. Therefore, effects for some sponges may be better represented by the hard coral LEIs than those for the general living-structure category.

Coral LEIs were also particularly subject to biases (described in Section B.2.2) due to interactions between the small-scale patchiness of the presence of these organisms with the patchiness of fishing effort. In hard-bottom areas, fishing location must consider seeking higher abundances of fish and avoiding structures (including rocks and rough bottom) that may damage fishing gear. This tends to move fishing effort toward smoother seafloors and away from rough, hard-bottom habitats. Higher concentrations of coral in rough, hard-bottom habitats would cause an overestimate of the actual LEI. Adding a seafloor constraint also concentrates fishing into known areas of fishable bottom, increasing overlap between tows. To the extent that such overlap exceeds what would occur if tows were randomly placed, LEIs overestimate actual effects because trawling encounters less undamaged structure. Therefore, the raw coral LEIs should not be taken at face value, and the above effects should be considered in their application.

In addition to the primary objective of assessing effects of fishing on habitat, another important function of this analysis was to identify weaknesses in the information base on which such an assessment must rely. Many of the parameters used in this analysis are speculative and only indirectly supported. These areas should be developed with further, or in some cases, initial, research. Areas of particular need include sensitivity of Alaska habitat species to fishing gear used in Alaska, the recovery rates of biological structure-forming organisms, the proportion and distribution of pelagic trawl effort in contact with the seafloor, the definition and characterization of habitat types and features relevant to managed species, the contact of longlines and pots with the seafloor and their effects, and methods for reducing the effects of fishing gears on habitats. Finally, a vital information gap is establishing linkages between changes in the availability of habitat features, the success of the life-history processes of fish species, and the subsequent effects on population abundances and structures.

Determining whether reductions of EFH are more than minimal and not temporary is conditioned on the premise that the habitat features being measured in some way affect the ability of managed species to feed, reproduce, and grow to maturity. Also considered is the extent to which a reduction in habitat limits a species' ability to support a fishery or participate in environmental linkages. Strong and specific dependencies on habitat would be necessary for the reductions in habitat features noted here to result in fish population reductions of similar magnitudes. Results of this analysis show reduction proportions well below the annual harvest rate for most of the managed species. On the other hand, much more specific knowledge of habitat dependencies would be needed to detect species-specific limitations that could create a population bottleneck. The following section will, to the extent possible with available information, assess the effects of the estimated reductions in habitat on the populations of managed species.

The results of the fishing effects analysis reflect the generalizations from the fishing-effects literature on which the model was based. The spatial pattern of effects primarily reflected the distribution of trawl fishing with some variation due to differences in habitat sensitivity and effort from other gears. The differences in LEI between habitat features (e.g., infauna prey versus living structure) indicated the potential for long-term changes in community composition and structure as seen in McConnaughey et al. (2000) and reviewed in Thrush and Dayton (2002). Since fishing effort has been at or above current levels for 30 years, most of the estimated effects may be reflected in current feature levels. For most of the parameters used in the analysis, 95 percent of the effects would be realized in less than 25 years (Fujioka, J., NMFS Lab, Auke Bay, personal communication). The exception is ultra-slow recovery species and low fishing rates (e.g., coral in the AI), where the effects would accumulate more slowly.

To test the validity of the model, catches of living-structure invertebrates by the annual groundfish survey of the EBS from 1990 to 2004 were analyzed to see if predicted changes due to varying fishing intensity could be detected. A year-to-year version of the model, based on Equation 4, was used instead of the equilibrium version that estimates LEIs. The survey structure of sampling at consistent sites every year at 85 stations with a range of fishing histories was well suited to such an analysis. Limiting the analysis were a sampling gear not optimized for these species (i.e., trawls are designed to catch fish, not corals or sponges) and a lack of information to independently estimate H_0, the unfished abundance. The requirement to estimate H_0 while fitting the model prevented a test of the model's ability to predict long-term trends. Instead, the analysis was limited to how well the model anticipated responses to year-to-year differences in fishing intensity.

Comparison of model results with abundance estimates from the survey indicated that little, if any, of the variation in the values from the survey could be attributed to fishing effects. Periods of high fishing effort were associated with both increases and decreases in the measured abundance, while drops in fishing effort did not usually result in the expected increases. The scale of abundance changes estimated from survey catches was much larger than that of the changes the fishing model predicted. Such large changes were prevalent at both fished and unfished stations. Much of the variation may be due to sampling error, including spatial variation between yearly survey sites, trawl performance variation, or catch sampling methods. However, many of the abundance patterns were large enough and showed enough consistency across years and between adjacent stations that they should have reflected significant changes in abundance. While the fishing effort data also had limitations, some of the indicated effort contrasts should have produced detectable effects if fishing effects were a substantial cause of variation in the abundance of these animals at the fishing intensities prevalent over those years. These results indicated that the model was not a powerful and robust predictor of year-to-year abundance changes under those conditions. It may be more useful for situations where fishing has a more dominant effect. The model's use as an LEI, which could not be directly tested without independent estimates of H_0, may be more robust than indicated for the short-term effects tested here.

While the model provides a tool for bringing disparate sources of information to bear on the evaluation of fishing effects on EFH, the validation results and data limitations indicate that LEI values only provide a coarse index of potential vulnerabilities. Both the developing state of the model and the limited quality of available data to estimate input parameters prevent this from providing a clear view of habitat effects. While output detail may provide an illusion of precision, the results are actually subject to considerable uncertainty. It is merely the best tool currently available for this assessment, not a definitive predictor.

B.3 Evaluation of Effects on Managed Species

The principal application of this document is to evaluate whether the fisheries, as they are currently conducted off of Alaska, will affect habitat that is essential to the welfare of the managed fish populations in a way that is more than minimal and not temporary. The previous statement describes the standard set in the EFH regulations which, if met, requires Councils to act to minimize such effects. The above analysis has identified changes to habitat features that are not expected to be temporary. The habitat features were selected as those which a) can be affected by fishing and b) may be important to fish in spawning, breeding, feeding, and growth to maturity. This section evaluates the extent that these changes relate to the EFH of each managed species and whether they constitute an effect to EFH that is more than minimal.

Two conclusions are necessary for this evaluation: (1) the definition of EFH draws a distinction between the amount of habitat necessary for a species to "support a sustainable fishery and the managed species' contribution to a healthy ecosystem" (50 CFR 600.10) and all habitat features used by any individuals of a species; (2) this distinction applies to both the designation of EFH and the evaluation of fishing effects on EFH. If these conclusions are valid, the "more than minimal" standard relates to impacts that potentially affect the ability of the species to fulfill its fishery and ecosystem roles, not just impacts on a local scale. The forgoing analysis has indicated substantial effects to some habitat features in some locations, many of which are within the spatial boundaries of the EFH of a species that may use them in a life-history function. These habitat changes may or may not affect the welfare of that species (a term used to represent "the ability of a species to support a sustainable fishery and its role in a healthy ecosystem").

B.3.1 Evaluation Methods

The following evaluation assesses whether the fisheries, as they are currently conducted off of Alaska, are affecting habitat that is essential to the welfare of the managed fish populations in a way that is more than minimal and not temporary. The following resources were used:

1. The results of the effects of fishing analysis (Section B.2).

2. Literature and other sources of knowledge regarding what each species requires to accomplish spawning, breeding, feeding, and growth to maturity.

3. Knowledge of the responses of the recruitment, biomass, and growth of these species during periods with similar fishing intensities.

4. Spatial and temporal length, weight, age, diet, and catch-per-unit-of-effort (CPUE) data from the NMFS surveys, as well as fishing effort time series estimates. [Note: CPUE distribution maps are available on the following website: http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm.]

5. The knowledge and professional judgement of scientists who manage and study these species.

For each species, a knowledgeable scientist was designated to perform the evaluation; the analyst was someone who was familiar with the biology and population dynamics of the stock, as well as the data available for the species. The initial step was identification of any known linkages between the life stages of the species and the habitat features in each habitat used in the effects-of-fishing analysis. These linkages are summarized in Table B.3-1. Scientists then reviewed these linkages and other knowledge to describe the known habitat connections between the species and/or species group and the three life history processes of spawning/breeding (combined), feeding, and growth to maturity (including feeding, growth, and survival before maturity). The texts of these reviews, labeled Habitat Connections, are found in Sections B.3.2 to B.3.4.

The scientists were then asked to evaluate the following question: Is there evidence that fishing adversely affects EFH in a manner that is more than minimal and not temporary in nature? To conduct this evaluation, the analysts first reviewed the LEI output from the fishing effects model to assess overlap with the distribution of each stock. The analysts then focused on habitat impacts relative to the three life-history processes of spawning/breeding, feeding, and growth to maturity (the evaluation criteria are provided in Table B.3-2). Finally, the analysts assessed whether available information on the stock status and trends indicated any potential influence of habitat disturbance due to fishing. More specifics regarding this evaluation process are provided below.

Because EFH comprises the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem, a consistent, existing benchmark was useful to represent these concepts in the EFH evaluations. The ability of the stock to produce MSY over the long term was used as a measure of its ability to support a sustainable fishery. No similar benchmark was available for the role of each species in a healthy ecosystem. However, population levels sufficient to support a sustainable fishery would ensure that substantial numbers of fish are available to serve as prey or predators to other species, as well as fulfilling other ecosystem functions. For species where MSY could not be estimated with available data (e.g., recruitment estimates were not available), scientists assessing the effects on EFH had to rely on other proxies, or ratings of "unknown" were necessary.

Given the LEIs from the effects-of-fishing analysis and the linkages identified in the habitat connections exercise, the analysts assessed whether the expected effects on species welfare were more than minimal. Evaluators considered which life history functions could be affected by changes in available habitat, the role of those functions in species welfare, and the spatial overlap of habitat use with the estimated fishing effects. For many species, limited information was available for one or all of these factors. Therefore, the professional knowledge and judgement of the evaluator were important. Because LEIs are inherently not temporary, any such effects assessed as more than minimal met both elements of the test for effects requiring Council action to minimize the effects of fishing on EFH.

To aid in the evaluations, LEI charts and all three LEI values (lower, central, and upper) for each habitat were provided. The LEI charts provided effect information at the finest feasible scale, allowing evaluators to focus on any specific sites considered important to their species. To assist evaluators in considering the cumulative effects on habitats across the distribution of each species, LEIs were aggregated for the intersections of each habitat and two geographical EFH areas for each species, the general distribution and the known concentration. Derivation and charts of these areas are in Section B.2.3.1 and Appendix D. This process also provided the proportion of each species' EFH within each habitat. The resulting LEIs and habitat proportions are displayed in Table B.3-3.

To assess the levels of habitat impact on the spawning/breeding, feeding, and growth to maturity of managed species, the analysts were provided with a trigger question to help focus their evaluations: Is the temporal or spatial pattern of habitat disturbance on spawning/breeding, feeding, or growth to maturity sufficient to impact the ability of the stock to produce MSY over the long term in a manner that is more than minimal and not temporary? The analysts were provided with spatial and temporal information on length, weight, age, diet and CPUE data from the NMFS surveys, as well as fishing effort time series estimates (this information is provided on the following website: http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). It was up to the analysts to determine if any of this information was comprehensive enough to be useful in their evaluations. For some species, this information was either too sparse to evaluate, or simply did not exist.

The final evaluation consideration was an assessment of the stock status and trends. For at least 30 years, fishing effort and, presumably, its habitat effects have been at similar or higher levels than the recent levels evaluated here. The condition of fish populations through this period is, therefore, one indicator of their response to all effects of fishing, including those on EFH. The EFH of species that maintained a favorable stock condition through this period, while supporting a fishery, was considered resistant to habitat effects caused by this level of fishing. While poor stock performance could result from a number of factors, including the direct effects of fishing and environmental change, consistently favorable stock conditions indicate that none of these, including fishing's effect on habitat, has jeopardized stock productivity. Again, the knowledge and expertise of each evaluator were required to assess the effect of any special circumstances for each species that made this a stronger or weaker form of evidence.

For fish stocks where information was available to estimate recruitment, recruitments from the late 1970s to the present were used in assessing stock condition relative to its MSY. These estimated recruitments, as well as other stock characteristics such as growth rates, represent a range of recent history when impacts to the stock from fishing practices would have been expected. As part of the Final Programmatic Groundfish SEIS (PSEIS) (NMFS 2004), 10-year projections were made to assess whether the stocks would be likely to fall below their MSST level under the status quo harvesting policy, as well as a broad range of alternative policies. These projections combine the current stock status and historical distributions of population parameters, both of which reflect any effects of historic levels of fishing that have been similar to or greater than current levels.

The analysts considered not only whether the temporal or spatial pattern of habitat disturbance on stock abundance was sufficient to adversely affect the ability of the stock to remain above MSST, but also whether the temporal or spatial pattern of habitat disturbance on stock abundance was sufficient to adversely affect the ability of the stock to produce MSY over the long term. Evaluators knew of potential peculiarities in their species' history that would make these indicators more or less relevant. No BSAI or GOA groundfish stocks have a current population biomass below the level necessary to produce MSY (Figure B.3.1-1).

Under this analytical approach, either of the two lines of consideration (habitat connections or sustainability analysis) could be sufficient to indicate a potential effect of fishing on EFH that is more than minimal, depending on the available information. Definitive proof of a population level effect was not required to rate effects as more than minimal and not temporary. Instead, the authors were expected to weigh the specific evidence for any consequences of habitat effects. For example, a strong stock history could be overcome by a clear connection between LEIs and species requirements. Given the current state of knowledge, uncertainties were expected, and evaluators indicated where these might be important or raised concerns.

B.3.2 Effects of Fishing on Essential Fish Habitat of Salmon, Scallops, and Crab

The following evaluations were made to answer the question: "Is there evidence that fishing adversely affects EFH in a manner that is more than minimal and not temporary in nature?"

B.3.2.1 Salmon Species

Habitat Connections

Five species of Pacific salmon (chinook, chum, pink, coho, and sockeye) are managed under the Alaska salmon FMP. Because all of these species use similar types of habitat, including habitats where fishing activities may occur, fishing effects on EFH were evaluated for all species together.

Spawning/Breeding—Salmon spawn and deposit their eggs in gravel areas of freshwater rivers and streams. Successful spawning depends upon the numbers of spawners, available habitat for spawning and nursery areas, and environmental conditions. Impacts to spawning and breeding of salmon occur when these habitat areas are disturbed, spawning biomass is reduced, or spawners are unable to reach suitable spawning areas.

Feeding—Once salmon smolts begin to enter the ocean, they feed on copepods. As they get larger, they add squid, juvenile herring, smelt, and other forage fish and invertebrate species to their diets. Salmon smolts use the nearshore area after entering the ocean, moving offshore as they get older, using pelagic habitats when at sea.

Growth to Maturity—Salmon feed throughout the open ocean of the North Pacific for up to 6 years (depending upon species) before maturing and returning to their natal rivers to spawn. Growth and mortality of juveniles depend on food availability, predation, bycatch in fisheries, and environmental conditions.

Evaluation of Effects

Issue	Evaluation
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—No commercial fisheries in Alaska are thought to adversely affect salmon spawning habitat given almost no effort (except recreational and subsistence fisheries) in freshwater spawning and rearing areas. Thus, the effects of the fisheries on spawning of salmon are considered minimal and temporary in nature.

Fisheries are considered not to have any impact on freshwater or pelagic habitats used by juvenile salmon. However, fisheries do catch some species eaten by piscivorus species of salmon in the ocean, including squid, capelin, and juvenile herring. Currently, the catch of these prey species is very small relative to overall population size of these species, so fishing activities are considered to have minimal and temporary effects on feeding of all salmon species.

As stated above, fisheries are considered to have minimal effects on prey availability of salmon, including juveniles. Fisheries impacts on juvenile salmon at sea are due to incidental catches in groundfish fisheries. Bycatch in groundfish fisheries is almost nonexistent for pink salmon, coho salmon, and sockeye salmon, but does occur in measurable numbers for chum salmon and chinook salmon taken in trawl fisheries, particularly the pollock trawl fisheries (Witherell et al. 2002). The bycatch amounts are considered to be a small proportion of the stocks and do not cause a substantial impact on salmon populations (Witherell et al. 2002). Thus, fishing activities are considered to have minimal and temporary effects on growth to maturity of salmon.

Fishing activities are considered to have overall minimal and temporary effects on the EFH for all salmon species. Fishing activities only interact with salmon habitat to any degree in the ocean habitats, and the concerns about these interactions center on effects on prey availability and bycatch. Prey of salmon (from copepods up to squid and forage fish) are not subject to directed fisheries removals, and bycatch is not a significant factor in total mortality. Professional judgement led to the conclusion that fisheries do not adversely affect the EFH of salmon species.

B.3.2.2 Weathervane Scallops

Habitat Connections

Weathervane scallops are found from shallow intertidal waters to depths of 300 m, but abundance tends to be greatest between depths of 40 to 130 m on beds of mud, clay, sand, and gravel (Hennick 1973, Turk 2000). Scallop beds tend to be elongated along the direction of current flow. A combination of large-scale processes (overall spawning population size and oceanographic conditions) and small-scale processes (site suitability for settlement) influence the recruitment of scallops to beds.

Spawning/Breeding—Successful scallop recruitment depends upon high egg-fertilization rate, transport of spat to nursery areas, environmental conditions, and survival to the adult stage. Scallop gametes are broadcast into the water and rely on currents to mix sperm and eggs. If males and females are not close together, the dilution of sperm can limit fertilization. Thus, spatial distribution is thought to be a critical component of the spawning/breeding success of scallops (Stokesbury 2000, Alaska Department of Fish and Game [ADF&G] 2000). Indicators of potential effects on spatial distribution are changes in population biomass and fishing mortality.

Feeding—Scallops are filter feeders. Successful feeding depends on the concentration and quality of suspended food particles, particularly phytoplankton. Prey availability depends on localized plankton blooms. Fishing activity can impact feeding of scallops through introduction of particles low in nutrient quality or organic content, thus diluting the naturally occurring nutritional particles (MacDonald 2000). More fishing activity by trawl or dredge gear could potentially introduce additional inorganic particulate matter that could negatively affect scallop feeding success, or conversely, introduce organic matter that could be beneficial to scallops.

Growth to Maturity—Growth to maturity is measured in terms of survival to maturity (which occurs at sizes smaller than those commercially harvested). The consequences of fishing activities on scallop survival depend upon habitat alteration and gear-induced damage and mortality (Grant 2000). The effects of habitat alternation may depend primarily on sediment resuspension and the potential for siltation, which would increase mortality.

Evaluation of Effects

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	U (Unknown effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—Because scallops have limited mobility, scallop settlement generally occurs on substrates and in locations where adults are already found (Turk 2000). Thus, the nursery areas are the same areas occupied by adults. These are also the areas where the directed scallop fisheries occur. However, there is no evidence that scallop recruitment has decreased with the current level of scallop fishing effort.

The overall footprint (area effected annually) of the scallop fishery was small (149 square nm), equating to about 0.1 percent of the total available amount of those habitat types (sand, mud, and gravel) (Witherell 2002). Although the effects of scallop dredge gear on the bottom are thought to be higher than other gear types, the fishery occurs in areas and habitat types that have relatively fast recovery rates. Thus, the effects of the fishery are concentrated in a relatively small proportion of benthic habitats. The effects on spawning and breeding of scallops are considered minimal and temporary in nature.

Sediment resuspension by dredges can have positive or negative effects on scallop feeding. The current fishing effort intensity of the Alaska scallop fishery does not appear to affect scallop growth, so one may surmise that feeding is not disturbed. However, there is not enough information to evaluate this issue.

The weathervane scallop resource is considered to be at sustainable biomass levels and has maintained relatively high recruitment in most areas over the past 10 years (Barnhart, J., ADF&G, personal communication). This species does not depend upon any habitat feature vulnerable to fishing activities. Based on the overlap of fisheries with juvenile and adult scallop stock distribution, there appear to be minimal effects on the weathervane scallop habitat.

B.3.2.3 Red King Crab

Habitat Connections

Habitat effects on crab concern effects on prey and on living and non-living structures on and in the ocean bottom. Effects on the population due to bycatch in trawl fisheries are not included as a habitat effect. Direct effects due to bycatch mortality in trawl fisheries on crab populations were addressed in the PSEIS (NMFS 2004). The focus of this report is on the linkages to fishing-induced impacts on habitat and their subsequent effects on spawning/breeding, growth to maturity, or adult feeding of red king crab.

Spawning/Breeding
Spawning and breeding success of crab species depends upon high egg-fertilization rate, successful transport of pelagic larvae to nursery areas, good environmental conditions, and survival to the adult stage. Egg fertilization success depends upon the size and number of mature male crabs (and hence the amount of sperm) available. The eggs are attached to the underside of females and carried for nearly a year before hatching. Transport of larvae depends upon environmental conditions, and survival depends upon the quantity and quality of nursery habitat and the presence of predators.

Settlement and nursery areas are important components of spawning success for crab species. In the southeastern BS, females remain in relatively shallow nearshore waters most of the year, whereas males move offshore into deeper water during the summer and fall, then return to shallower water for breeding in the winter and early spring (Loher 2001). The location of females hatching eggs and prevailing currents determine the general area where larvae settle. Settling larvae have moderate swimming capability and have some ability to choose the micro-habitat where they settle (Loher 2000). Suitable substrates for survival of settling larvae appear to be largely rock or cobble bottoms, mussel beds, or other areas with a variety of epifauna such as hydroids or epiflora (i.e., kelp hold fasts) (Loher 2000, Stevens and Kittaka 1998).

Adult Feeding

From settling larvae to senescence, crabs dwell on the bottom and depend on benthic feeding. Red king crab are omnivorous. Bivalves, barnacles, polychaetes, snails, Tanner crab, echinoids, and hydroids have been found in stomachs of red king crab from shallow waters near Kodiak during May and June (Feder and Jewett 1981). Juvenile red king crab near Kodiak have been observed to eat sea stars, kelp, sea lettuce, red king crab molt exuvia, lettleneck clams, mussels, nudibranch egg masses, and barnacles (Dew 1990).

Growth to Maturity

Early stage red king crabs seek out biological cover in which to hide. Survival at this stage depends upon availability of cover. After they reach a size exceeding 25-millimeter (mm) carapace length, red king crabs form pods, which consist of similar sized crabs of both sexes, and may contain hundreds to thousands of crabs. Pods of juvenile crabs form during the daytime, but disperse at night for feeding. As crabs grow, they move to deeper water in Bristol Bay where the substrate is mostly sand, silt, and mud.

Evaluation of Effects

LEI Values Relative to Species Distribution

The Japanese established a trawl closure known as the pot sanctuary that remained in effect from 1959 to 1977 (Figure B.3.2.3-1). The pot sanctuary encompassed an area from the western end of Unimak Island to 160º W in Bristol Bay; however, the areas changed somewhat over that time. Within the pot sanctuary, a special area was established beginning in 1964. The area was established for a directed pot fishing only. The area expanded over time, however, and consisted generally of the area north of Unimak Island (Dew and McConnaughey in press).

The United States established trawl closure areas beginning in 1995 with the Pribilof Islands Conservation Area, the Red King Crab Savings Area, and the nearshore Bristol Bay Closure Area (waters east of 162º W) (Witherell and Pautzke 1997). Bycatch caps for groundfish trawl fisheries were also established for red king, Tanner, and snow crab.

Spatial overlap exists between current female red king crab distribution and fishing effects only in the areas near 162 to 163º W and about 55.5º N and 56.5º N (Figure B.3.2.3-2). Male red king crab may migrate through this area in the spring when mating occurs; however, when the survey occurs (June) in Bristol Bay, most males are farther offshore and are protected by existing trawl closure areas (Figure B.3.2.3-3). During the 1970s, female distribution extended farther west and south than the distribution from current surveys (Dew and McConnaughey 2003). The change in distribution of female red king crab from the 1970s to the current distribution farther east could have been affected by bycatch in trawl fisheries in the late 1970s and early 1980s (Dew and McConnaughey 2003). At present, however, most of the female red king crab distribution is protected by trawl closure areas.

The importance of the high fishing effects area north of Unimak pass for spawning/breeding is unknown. Larval drift would tend to be along the Alaska Peninsula from females hatching eggs nearshore from Unimak Island westward (Loher 2001). If larvae are carried offshore into the middle of Bristol Bay, however, survival may be less likely. The distribution of females hatching eggs may be an important factor in future recruitment strength. Recruitment from eggs hatched in the late 1960s resulted in the high biomass levels in the 1970s (Figures B.3.2.3-4 and B.3.2.3-5). Recruitment resulting from eggs hatched from the 1970s to the present has been relatively low.

The distribution of female red king crab in the area north of Unimak Island during the increasing abundance of the 1970s could have been an expansion of their range rather than a requirement for good recruitment. There is scant information on the distribution of red king crab prior to the 1970s. The Bureau of Commercial Fisheries conducted surveys in Bristol Bay in 1959 and annually from 1963 to the present; however, data from the surveys in the 1960s are unavailable for analysis, except for tables of catch per tow in 1968 (International North Pacific Fisheries Commission [INPFC] [now the North Pacific Anadromous Fish Commission] 1968). A survey of Bristol Bay was conducted in spring (May) and in fall during 1968. The highest densities of female red king crab in the spring survey were found from about 163 to 160º W (Figure B.3.2.3-1).

Catch of female red king crab per tow from the 1959 survey indicates that high densities occurred at about 163º W and at about 161.5º W, similar to the 1968 survey (Figure B.3.2.3-6) (INPFC 1959). Some crab were caught as far west as about 165º W in the area north of Unimak Island, however in lower numbers than to the east.

Japanese exploratory fishing during the 1960s was conducted using tangle nets and reported in INPFC document 765 (Figures B.3.2.3-7 through B.3.2.3-10). The area north of Unimak Island as far west as about 165º W was fished only in 1963 and 1964 during the spring. The reports do not define the extent of the exploratory fishing areas or the exact dates when fishing occurred. The 1963 and 1964 catch per tan (a Japanese unit of fishing effort for tangle nets) indicates that the large male distribution was widespread and extended from about 165 to about 160º W (Figures B.3.2.3-9 and B.3.2.3-10). Female red king crab distribution was similar to large males in 1964; however, it did not extend as far west in 1963 (Figures B.3.2.3-7 and B.3.2.3-8).

The limited data presented above indicate that the distribution of red king crab varied over time and to some extent included the area north of Unimak Island; however, it was mostly east of 163 to 164º W, except in the 1970s. Habitats effects in mud and sand were up to 35 percent on living structure and less than 5 percent for other effects (Table B.3-3).

Habitat Impacts Relative to Spawning/Breeding

As discussed in the previous section, there is only a small area of overlap between current female red king crab distribution and areas where trawling occurs. This overlap would only occur in the areas between about 162 and 163º W where fishing effects are generally low. Male and female red king crab migrate to nearshore waters generally less than 50 m deep to hatch their eggs and mate. North of Unimak Island, some of the high fishing effects area extends into waters less than 50 m deep; however, to the east, trawling generally occurs more than 50 m deep. The mating areas would experience little impact; however, trawling in deeper waters somewhat overlaps the migration route to mating areas.

Habitat Impacts Relative to Growth to Maturity

There are essentially no fishing effects in areas important to juvenile red king crab. All known juvenile rearing areas are currently protected by trawl closure areas (Figure B.3.2.3-11). Growth per molt for BS red king crab showed no change between the late 1950s and the 1990s based on tag data (Council 2004). Molting probability during different time periods has been estimated in a stock assessment model; however, parameters are confounded by change with natural mortality, and it is difficult to assess the age of crab. Molting probability was estimated as higher in the 1950s and lower in the 1960s from tag data

(Balsiger 1974). Model estimates of molting probability were higher in the 1970s than those from the 1960s tag data and have been lower since then (Council 2004).

Habitat Impacts Relative to Feeding
Changes in growth for Bristol Bay red king crab are unknown. Most of the distribution of red king crab is to the north and east of the high fishing effects areas.

Stocks Status and Trends
Mature biomass of red king crab estimated from NMFS surveys declined from a high in the late 1970s to relatively low levels from 1983 to 2004 (Figure B.3.2.3-12). The reason for the sharp decline in abundance in the early 1980s is unknown; however, it was probably due to a combination of factors including reduced recruitment due to environmental conditions and predation, directed fishing, and bycatch. Mature biomass has fluctuated during the last 20 years around a level lower than the pre-1983 biomass. The stock is currently considered to be above B_{MSY} due to prevailing environmental conditions, where B_{MSY} is estimated as the average of the survey mature biomass from 1983 to 1997 (BSAI Crab FMP).

Calibrated fishery CPUE from Japanese and United States fleets indicate that biomass was higher in the 1950s, then declined to a low near 1970 (Figure B.3.2.3-4) (Balsiger 1970). Fishery CPUE data may not accurately represent changes in abundance due to areas and times fished and gear changes; however, these data generally indicate that biomass levels previous to the early 1970s were higher than current biomass, but lower than biomass in the late 1970s.

Overall trawl effort in the BS was highest from 1981 to 1985 then declined (Figure B.3.2.3-13). Trawl effort in the EBS high effects area was high from 1981 to 1983, generally lower from 1984 to 1992, increased from 1993 to 1998, then declined. Estimated recruitment was highest in the late 1960s (approximate year eggs were fertilized) and peaked in 1970, then declined throughout the 1970s and has stayed at low levels to the present. Recruitment was already low when the time series of trawl effort began in 1981.

The increased recruitment to the mature crab biomass in the 1970s would have resulted from eggs hatching in the mid- to late 1960s. The declining biomass in the 1960s resulted from lower recruitment of eggs hatching in the 1950s. Recruitment strength may depend on the distribution of red king crab mature females where eggs are hatched, which, along with current environmental conditions, would determine the general area where larvae will settle.

Mechanisms determining recruitment strength are unknown for red king crab. The lack of increased recruitment from high mature biomass in the 1970s could have been due to unobserved bycatch (Dew and McConnaughey 2003) or poor environmental conditions for larval and juvenile survival.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

B.3.2.4 Blue King Crab

Habitat Connections

Spawning/Breeding
Spawning and breeding success of crab species depends upon a high egg-fertilization rate, successful transport of pelagic larvae to nursery areas, and survival to the adult stage. Egg fertilization success depends upon the size and number of mature male crabs (and hence the amount of sperm) available. The eggs are attached to the underside of females and carried for many months prior to hatching. Transport of larvae depends on environmental conditions, and survival depends upon the quantity and quality of nursery habitat and the presence of predators.

Settlement and nursery areas are important components of spawning success for crab species. For king crabs, selection of benthic habitat by glaucothoe appears to be an important mechanism leading to increased probability of larvae settling on an appropriate substrate. Such substrates appear to be largely rock or cobble bottoms, mussel beds, or other areas with a variety of epifauna such as hydroids or epiflora (i.e., kelp hold-fasts).

Review of the LEI maps reveals that the overlap of groundfish trawl effort with mature female blue king crabs is very limited, and the expected fishing-induced reductions in living and non-living structure are small (Table B.3-3, Figure B.2-2a). The existing trawl closure area in the Pribilof Islands encompasses nearly the entire Pribilof Islands stock, and there is virtually no overlap of trawl fisheries with the St. Matthew blue king crab stock. There is some bycatch of St. Matthew blue king crab that occurs in groundfish fisheries in the vicinity of St. Matthew Island. However, the amount of habitat impact associated with groundfish fisheries in the vicinity of St. Matthew Island area is low. See Section 3.2.1.2.2 for further discussion and references.

Adult Feeding
From settling larvae to senescence, crabs dwell on the bottom and depend upon benthic feeding (Table B.3-1). Changes in diet due to habitat disturbance caused by fishing may impact crab survival and production. However, the magnitude of habitat disturbance is expected to be low, and the effects of these changes will be difficult to assess given the limited information on feeding requirements of crab species.

Growth to Maturity
Early stage blue king crabs probably seek out biological structure in which to hide similar to red king crab, although no studies have been conducted for blue king crab (Table B.3-3). Survival at this stage probably depends upon availability of cover. The Pribilof Islands habitat conservation area was established in 1995 to eliminate potential effects of trawling on this habitat feature and to reduce bycatch (Council 1995).

No information on changes in growth is available for blue king crab stocks.

Recruitment trends are generally similar for the Pribilof Island and St. Matthew Island stocks because biomass trends are similar. Since there have been low levels of trawling near St. Matthew Island, this would indicate that habitat effects were not a major factor in recruitment strength (Figure B.3.2.4-1). Also, the area has been protected from trawling since 1995, and the biomass has declined since that time (Figure B.3.2.4-2).

Stock Status and Trends

Both the Pribilof Islands stock and the St. Matthew blue king crab stocks increased in abundance from the mid 1980s to the late 1990s, then they declined(Figures B.3.2.4-1 and B.3.2.4-2). Both stocks are currently below their MSST and have been declared overfished. Rebuilding plans have been developed and implemented. The similarity in trends in biomass and the small amount of trawling that has occurred near St. Matthew Island indicate that habitat effects were probably not a major factor in declines in abundance.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Fishing activities are considered to have overall minimal and temporary effects on the EFH for blue king crab, although both the Pribilof Islands stock and the St. Matthew stock of blue king crabs are considered to be below MSST. Habitat loss or degradation by fishing activities probably did not play any role in the decline of these stocks. For the Pribilof Islands blue king crab, any fishing activities thought to have adverse consequences have previously been mitigated by establishment of the Pribilof Islands trawl closure area. For St. Matthew blue king crab, there has never been a groundfish bottom trawl fishery in the area. Given the current very small overlap and fishing intensity in areas with blue king crab of all life stages, professional judgement indicates that fisheries do not currently adversely affect the EFH of blue king crab.

B.3.2.5 Golden King Crab

Habitat Connections

Spawning/Breeding

Spawning and breeding requirements for golden king crab are unknown. It is likely that settlement and nursery areas are important components of spawning success. For other species of king crabs, selection of benthic habitat by glaucothoe appears to be an important mechanism leading to the increased probability of larvae settling on an appropriate substrate.

The overlap of groundfish trawl effort with mature female golden king crabs is very limited. Trawl fishing intensity does overlap with crab distribution on the EBS slope to some extent, but not in the AI slope area.

Adult Feeding

From settling larvae to senescence, crabs dwell on the bottom and depend on benthic feeding. The importance of habitat quality to crab diet seems intuitive, but it is not quantified for benthic life stages. Changes in diet due to habitat disturbance and alternative may impact crab survival and production. The effects of these changes will, however, be difficult to assess given the limited information on feeding requirements of crab species.

Growth to Maturity

Early stage king crabs may seek out biological structure in which to hide. It is not known how the fisheries affect habitat used by juvenile golden king crabs.

Stocks Status and Trends
Stock status and trends are unknown as this stock is not regularly surveyed, and no stock assessment model has been developed.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Fishing activities are considered to have overall minimal and temporary effects on the EFH for golden king crab. Groundfish trawl fishing in the EBS slope is of some concern; however, any effects are thought to be minimal. Professional judgement indicates that fisheries do not adversely affect the EFH of golden king crab.

B.3.2.6 Scarlet King Crab

Habitat Connections

Spawning/Breeding
Spawning, breeding, and habitat requirements for scarlet king crab are unknown. Nevertheless, the overlap of groundfish trawl effort with mature female crabs is likely very limited, given the deep-water nature of this species. There is virtually no directed pot fishery for this species. A few landings were made in 1995 (2,600 pounds [lbs]) and 1996.

Adult Feeding
Nothing is known about the feeding requirements for this species.

Growth to Maturity
Factors affecting growth and survival of this species are not known. Almost none is taken as bycatch in groundfish or crab fisheries.

Stocks Status and Trends
This stock is not surveyed, so stock status and trends are unknown.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Fishing activities are considered to have overall minimal and temporary effects on the EFH for scarlet king crab. This is a deepwater species with almost no overlap with commercial fisheries, so habitat effects are unlikely. Professional judgement indicates that fisheries are unlikely to adversely affect the EFH of scarlet king crab.

B.3.2.7 Tanner Crab

Habitat Connections

Spawning/Breeding
Spawning and breeding success of crab species depends upon a high egg-fertilization rate, successful transport of pelagic larvae to nursery areas, and survival to the adult stage. Egg fertilization success depends on the size and number of mature male crabs (and hence the amount of sperm) available. The eggs are attached to the underside of females and carried for nearly a year prior to hatching. Transport of larvae depends on environmental conditions. Tanner crabs settle on mud habitats to the north and in shallower water than adult crab distribution, depending on environmental conditions. See Section 3.2.1.3.5 for further discussion and references.

Adult Feeding
Tanner crabs feed on an extensive variety of benthic organisms, including bivalves, brittle stars, crustaceans (including other snow crabs), polychaetes and other worms, gastropods, and fish.

Growth to Maturity
No studies indicate a direct dependence of juvenile Tanner crabs on any vulnerable habitat feature. They are believed to settle and grow on mud habitat. Recruitment strength depends on transport to suitable habitat towards the north and west.

Evaluation of Effects

LEI Values Relative to Species Distribution
Current adult male and female Tanner crab and juvenile Tanner crab distributions overlap high fishing effects areas north of Unimak Island and high fishing effects areas east of the Pribilof Islands (Figures B.3.2.7-1, B.3.2.7-2, and B.3.2.7-3). The distribution of mature male and female Tanner crab is mainly in the area just north of Unimak Island; however, it extends northward as well. Juvenile crab distribution is generally to the north of mature crab habitat; and also to the west, extending north of the Pribilof Islands. The juvenile crab distribution overlaps the mature distribution in the area east of the Pribilof Islands in the high fishing effects area.

The distribution of large male Tanner crab in the 1980s and early 1990s was centered farther east and north towards Bristol Bay mostly outside the areas of high fishing effects compared to the current distribution (Figures B.3.2.7-4 through B.3.2.7-8). As abundance declined in the 1990s, the distribution of large male Tanner crab shifted from Bristol Bay (mostly east of 164º W) to the south and east into the area of high fishing effects north of Unimak Island (Figure B.3.2.7-2).

Groundfish trawl bycatch caps were established for BS Tanner crab to limit the effect of trawling. The caps began in 1982 for foreign fisheries and in 1987 for joint-venture fisheries (Witherell and Pautzke 1997). The bycatch limits have been reduced several times since their inception. The existing BS trawl closure areas in Bristol Bay that were established in 1995 do not include the majority of the current Tanner crab distribution. They do, however, encompass a large fraction of the historical range of this species. Tanner crab are also caught as bycatch in the red king crab and snow crab pot fisheries. Tanner crab live mostly on mud and sand habitats, which are the least affected habitat in the BS (from 11 to 20 percent for living structure and less than 5 percent for other effects) (Table B.3-3).

Habitat Impacts Relative to Spawning/Breeding

NMFS survey data indicate that the large female tanner crab distribution was farther west and south of the large male distribution in the early 1990s, overlapping the areas of high fishing effects (Figures B.3.2.7-1 and B.3.2.7-2) (e.g., NMFS 2002). The current distribution of large females based on summer survey data shows high density around the Pribilof Islands. The current distribution of large females outside the Pribilof Islands overlaps the regions where fishing is expected to have the greatest impact on habitat.

Review of historical survey data reveals a long-term westward shift in male tanner crab distribution. The distribution of large males in 1979 (Figure B.3.2.7-4) was similar to the 1980s, except that the three largest catches were near the Alaska Peninsula between about 164 and 162.5º W (Figures B.3.2.7-5, B.3.2.7-6, and B.3.2.7-7). During these years, the most dense concentrations of male crabs more than 5.5 inches in carapace width (138 mm) were located east of 165º longitude. By 1994, male crabs more than 5.5 inches in carapace width (138 mm) began to shift into in the middle shelf of the southern EBS (Figure B.3.2.7-8). By 2004, large male crabs were concentrated along the outer shelf of the southern EBS and in regions surrounding the Pribilof Islands. This analysis of the spatial distribution of tanner crabs relative to expected habitat impacts indicates that tanner crabs have not demonstrated shifts away from regions heavily impacted by fishing. The closure of the Bristol Bay region and its associated reduction in habitat impacts did not attract crabs to the region.

Recruitment was high in the late 1960s and early 1980s (fertilization year) (Figure B.3.2.7-9). Recruitment was low in the 1970s and from 1985 to the present. In the early 1980s, the distribution of large females overlapped the areas of high fishing effects somewhat, with less overlap for large males. Fishing effort was higher during periods of highest recruitment in the early 1980s than currently.

Habitat Impacts Relative to Growth to Maturity

Tanner crab settle and grow on mud habitat, which was the least affected habitat in the EBS (Table B.3-3). Some areas of high abundance of small Tanner crabs (Figure B.3.2.7-3) are protected by trawl closure areas around the Pribilof Islands. There are no tagging data to compare growth per molt or molting probability over time for BS Tanner crab.

Habitat Impacts Relative to Feeding

The effects of fishing activities on Tanner crab feeding activities is minimal. Relative to the distribution of fisheries and the intensity of fisheries effects, only a small reduction of the infauna and epifauna prey occurs on mud habitats (Table B.3-3).

Stocks Status and Trends

Mature biomass declined in the late 1970s to a low level in the early 1980s, then increased to a peak in 1991, then declined to below MSST in 1996 (Figure B.3.2.7-9). The fishery was closed in 1997 and has remained closed through 2004. The BS Tanner crab stock was declared overfished in 1999, and a rebuilding plan was put into place in 2000 (Council 2000a).

Overall trawl effort in the low effects area was highest in 1981 to 1983. Trawl effort declined gradually from 1984 to 2002 (Figure B.3.2.7-10). Trawl effort in the high effects area was high in 1981 to 1983, generally lower in 1984 to 1992, increased in 1993 to 1998, then declined. The biomass of Tanner crab decreased as trawl effort declined in the 1980s, then biomass increased in the late 1990s, then declined as trawl effort increased in the mid-1990s. In the late 1990s, when Tanner crab were at low abundance, however, the distribution shifted more into the high trawling effects area.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Fishing activities are considered to have overall minimal and temporary effects on the EFH for Tanner crabs.

B.3.2.8 Snow Crab

Habitat Connections, Evaluation of Effects

Spawning/Breeding
Spawning and breeding success of crab species depends upon high egg-fertilization rate, transport of pelagic larvae to nursery areas, and survival to the adult stage. Egg fertilization success depends upon the size and number of mature male crabs (and hence the amount of sperm) available. The eggs are attached to the underside of females and carried for nearly a year prior to hatching. Transport of larvae depends on environmental conditions. Snow crabs settle on mud habitats. See Section 3.2.1.3.6 for further discussion and references.

Adult Feeding
Snow crabs feed on an extensive variety of benthic organisms including bivalves, brittle stars, crustaceans (including other snow crabs), polychaetes and other worms, gastropods, and fish.

Growth to Maturity
No studies indicate a direct dependence of juvenile snow crabs on any vulnerable habitat feature. They are believed to settle and grow on mud habitats, which was the least affected habitat in the EBS.

Evaluation of Effects

LEI Values Relative to Species Distribution
The centers of distribution of male snow crab were located in the middle shelf in 1978. During the early 1980s, distributions shifted north and west, with centers located on the outer shelf. Between 1984 and 1994, the distribution shifted between the shelf break and the middle shelf at latitudes north of those observed in the early 1980s. After 1994, the distribution returned to the shelf break, but the centers of distribution remained located at higher latitudes (Figure B.3.2.8-1) (Orensanz et al. 2005).

In the late 1970s, the center of the distribution of mature female snow crab overlapped the area of high fishing effects to the east of the Pribilof Islands. The current center of distribution is in the area of low fishing effects, north of the Pribilof Islands to St. Matthews Island. Juvenile crab are distributed to the north and east of mature crab areas and migrate to the south and west into deeper water as they age (Orensanz et al. 2005).

Trawl effort declined in the 1980s as snow crab biomass was increasing to a high in 1992. The distribution of mature snow crab shifted over time to the north and west, away from the high fishing effects areas. However, recruitment was highest from the period of high trawl effects in 1980, when the center of distribution of female snow crab was in the northern edge of the high effects area east of the

Pribilof Islands (Figures B.3.2.8-2 and B.3.2.8-3). In 1986, a recruitment event of lesser magnitude occurred when the center of distribution of mature snow crab was still close to the northern edge of the high effects area. Recruitment has been low since the 1986 year class.

Snow crab occur on mud and sand habitats which are the least effected habitat in the BS (Table B.3-3). Habitat effects are less than 10 percent on living structure in mud and sand habitats and less than 3 percent on other components.

Habitat Impacts Relative to Spawning/Breeding

From 1978 to 1999, the distribution of snow crab shifted away from the areas of high trawling effects. It is not known, however, if habitat degradation contributed to this shift or whether climate-change-directed fishing taking place mostly in the southern portion of the snow crab's range and trawl bycatch occurring mostly in the southern portion of the range were more important factors.

Female snow crab shift to a biennial spawning cycle when waters are colder than about 1.5º centigrade (C), which occurs in the northern part of their range. Current recruitment strength may be affected by the location of the mature female stock. The shift in distribution of snow crab may be due to the combined influences of warmer waters in the BS after 1976, and directed fishing that occurred mainly in the southern part of the snow crab distribution, and bycatch in trawl fisheries. The current distribution of snow crab does not overlap the high trawl effects area to any extent (Figures B.3.2.8-2 and B.3.2.8-4).

Habitat Impacts Relative to Growth to Maturity

Juvenile snow crab distribution does not overlap areas of high trawling effects. It occurs on mud substrate, which is the least affected substrate.

Habitat Impacts Relative to Feeding

Snow crabs feed on an extensive variety of benthic organisms, including bivalves, brittle stars, crustaceans (including other snow crabs), polychaetes and other worms, gastropods, and fish. The LEI table indicates that the reduction in epifauna and infauna prey is quite low (less than 3 percent), but may be as high as 9 percent for living structures in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Considering the distribution of fisheries and the intensity of fisheries effects, only a small reduction in the infaunal and epifaunal prey is projected for mud habitats. Based on this information, fishing effects on snow crab habitat and the subsequent impacts on snow crab feeding are expected to be minimal.

No information is available to evaluate growth changes over time.

Stocks Status and Trends

The mature biomass of snow crab was high in the late 1970s, declined to a low level in the mid-1980s, then increased to a high in 1991 (Figure 3.2.8-3). Snow crab declined in the early 1990s, increased again in the mid-1990s, then declined to below the MSST in 1999. The stock was declared overfished in 1999. A rebuilding plan was developed in 2000 and is currently in effect (Council 2000b).

Summary

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

B.3.2.9 Deepwater Tanner Crabs

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Spawning/Breeding—The spawning, breeding, and habitat requirements for grooved Tanner crab and triangle crab are unknown. Nevertheless, the overlap of groundfish trawl effort with mature female crabs is likely very limited, given the deep water nature of these species. There has been virtually no directed pot fishery for this species in recent years. Only a few landings of deepwater Tanner crab have been made in the EBS: 49,000 lbs of triangle crab in 1995 and minor confidential landings in 1996 and 2000, as well as 106,000 lbs of grooved crab in 1996 and minor confidential landings in 2000. Also, 145,000 lbs of grooved crabs were harvested in the AI in 1995.

Feeding—Nothing is known about the feeding requirements for these species.

Growth to Maturity—Factors affecting growth and survival of this species are not known. Almost none are taken as bycatch in groundfish or crab fisheries.

Summary of Effects—Fishing activities are considered to have overall minimal and temporary effects on the EFH for deepwater Tanner crabs. These are deepwater species with almost no overlap with commercial fisheries, so habitat effects are unlikely. Professional judgement led to the conclusion that fisheries are unlikely to adversely affect the EFH of deepwater Tanner crabs.

B.3.3 Effects of Fishing on Essential Fish Habitat of Groundfish Species

The following evaluations were made to answer the question: "Is there evidence that fishing adversely affects EFH in a manner that is more than minimal and not temporary in nature?"

B.3.3.1 Walleye Pollock (BSAI and GOA)

Habitat Connections

Spawning/Breeding
Peak pollock spawning occurs on the southeastern BS and eastern AI along the outer continental shelf around mid-March. North of the Pribilof Islands spawning occurs later (April and May) in smaller spawning aggregations. The pollock of the Aleutian Basin spawn in deep water and appear to spawn slightly earlier, late February to early March. In the GOA, peak spawning occurs in late March in Shelikof Strait. Peak spawning in the Shumagin area occurs 2 to 3 weeks earlier than in Shelikof Strait.

Spawning occurs in the pelagic zone, and egg development occurs throughout the water column (70 to 80 m in the EBS shelf; 150 to 200 m in Shelikof Strait). The rate of development depends on water temperature. In the EBS, eggs take about 17 to 20 days to develop at 4º C in the Bogoslof area and 25 days at 2º C on the continental shelf. In the GOA, development takes approximately 14 days at ambient temperature (5º C). Larvae are also distributed in the upper water column. In the EBS, the larval period lasts approximately 60 days. The larvae eat progressively larger naupliar stages of copepods as they grow, then small euphausiids as they metamorphose to juveniles (approximately 25 mm standard length). In the GOA, larvae are distributed in the upper 40 m of the water column, and diet is similar to EBS larvae. FOCI survey data indicate larval pollock may use the stratified warmer upper waters of the mid-shelf to avoid predation by adult pollock which tend to prefer deeper water. See Section 3.2.1.2.1 for further discussion and references.

Feeding

Adults feed mainly on pelagic zooplankton. Major prey species are euphausiids, followed by calanoid copepods. Benthic zooplankton and shrimp make up 7 percent of pollock diet in the EBS, 11 percent of pollock diet in the AI, and 25 percent of pollock diet in the GOA. Pollock consumption is primarily in the pelagic pathway of the food web, so affected habitat features of the seafloor are not directly linked to pollock diet, though indirect links may exist.

Growth to Maturity

Pollock larvae are pelagic. Carlson (1994) reported observations of age-zero pollock forming "shoals of hundreds to a few thousand loosely aggregated individuals within 1 m above the bottom or off rock ledges at 20 to 30 m" at a study site in Auke Bay, Alaska. Juvenile pollock are faced with mortality risks due to predation by surface diving seabirds and marine mammals, from other groundfish species, and cannibalism. These risks vary both seasonally and on an interannual basis. For example, the risk of cannibalism for age-zero and age-1 pollock would increase in the presence of a strong year class of age-2 pollock. Juvenile pollock may have various mechanisms to avoid predation risk, but their behavior is likely an adaptive interplay between multiple influences such as thermal preferences and food availability, as well as predation risk (Duffy-Anderson et al. 2003). Juveniles (in particular, 1-year olds) are common near the bottom based on the summer bottom trawl surveys. The degree that this association is due to refuge value of benthic habitat structure (living or non-living) is unknown. There is some evidence that pollock associate with living structure. In the pelagic zone, juvenile pollock have been found with jellyfish in the EBS (Brodeur 1998). However, the importance of jellyfish as refuge from predation is unclear since jellyfish appear to feed significantly on larval (age-zero) pollock (Brodeur et al. 2002). Sogard and Olla (1993) evaluated association with seagrass beds in a laboratory experiment using juveniles collected in Port Townsend, Washington. In the absence of predators, juvenile pollock avoided artificial seagrass plots. In the presence of an artificial predator, pollock sought refuge and remained in the artificial seagrass plots. Utilization of seagrass beds by pollock has not been observed in Alaska.

Adults are semipelagic, are demersal at times, and are associated with a variety of habitats. They exhibit strong diel vertical migrations with nightly movements away from the bottom up into the water column. See Section 3.2.1.2.1 for further discussion and references.

Evaluation of Effects

LEI Values Relative to Species Distribution

In the BS, spatial overlap exists between the areas with high fishing effects and the extent of pollock distribution observed during June, July, and August (Figure B.2-2a, Table B.3-3). The benthic habitat in this area is primarily sand and a sand/mud composite (Table B.3-1). Estimated reductions of epifaunal and infaunal prey due to fishing are quite low (approximately 2 percent). However, reduction may be as high as 13 percent for living structure in this habitat across the entire BS. Substantial areas to the north of Unimak Island and on the middle shelf within pollock EFH show LEI impacts in excess of 50 percent for living structure.

In the GOA, estimated reductions of epifaunal and infaunal prey due to fishing are less than 1 percent for all substrate types. For living structure, LEI impacts ranged between 3 and 7 percent depending on the substrate. Local areas with LEI values in excess of 50 percent occur to the east of Kodiak Island in Barnabus, Chiniak, and Marmot Gullies. These are areas that support high densities of pollock.

The impacts that areas with high LEI effects have on the availability of prey for individual pollock or their ability to find refuge are unknown. The high LEI effects for living structure in areas that support high pollock densities may be a concern due the unknown role that these habitat features play in pollock survival to maturity. Nevertheless, pollock remain abundant in areas with high fishing effort. For example, trends in CPUE data from surveys in the EBS, AI, and GOA indicate similar patterns between the highly fished areas and areas that have had little or no fishing effort (Figure B.3.3.1-1). In addition, analysis of survey CPUE in the EBS shows that the spatial pattern of habitat use during summer months does not shift away from, or into, regions of high LEIs. See the following Website: http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm.

To address the concern that classification of 5-by-5-km^2 blocks into high effort and low effort areas was based only on fishing effort from 1998 to 2002, a more extensive data set of fishing effort extending back to 1981 was examined. This data set contains effort measured as the number of tows (not area swept) and is more uncertain due to lower observer coverage. Density of non-pollock tows has been consistently high in the high effort areas since the late 1980s or early 1990s, depending on the region (Figure B.3.3.1-2). The shifts in effort in the late 1980s reflect the development of the domestic groundfish fishery. These shifts suggest that detecting fishing effects on EFH that occur on decadal scales would be difficult using differential growth and relative abundance patterns in areas where current effort is high or low. This is because the level of effort changed (spatially) after the 1990s.

Habitat Impacts Relative to Spawning/Breeding

The areas of Shelikof Strait in the GOA and north of Unimak Island in the EBS are the main spawning regions for pollock. Spawning is thought to peak from February to April and occurs in the pelagic zone. In Shelikof Strait, there has been a decline in spawning stock biomass. However, the spatial overlap between spawning areas and high levels of fishing impact is minor. In the EBS, fishing impacts are concentrated in areas of spawning. Echo-integration trawl surveys conducted at the time of spawning in these areas have not detected a shift in the spatial component of spawning since surveys began in 1979. The small-scale spatial distribution of pollock spawning shows considerable year-to-year variation. This variation is likely due to a number of factors unrelated to seafloor habitat, such as the age structure of the population, water temperature, extent of ice cover, and speed of ice retreat.

Since recruitment in both the GOA and EBS varies highly (while fishing effort and catch have been relatively stable), the magnitude of recruitment is unlikely to be driven primarily by fishing impacts on habitat. As with the spatial distribution of spawning pollock, environmental factors are thought to play an important role in determining year-class strengths (i.e., during years when favorable bio-physical factors exist, pollock survival through egg and larval stages improves, which results in higher recruitment levels). However, high recruitment variability makes it unlikely that relatively subtle habitat effects can be detected.

There is no evidence that the existing level of habitat disturbance due to fishing is impacting pollock spawning/breeding. The precautionary measures for overall exploitation rates (which explicitly consider spawning population conservation) in these areas are intended to ensure that the pollock stocks will approach B_{MSY} on average (Ianelli et al. 2004a, Dorn et al. 2004, Barbeaux et al. 2004).

Habitat Impacts Relative to Growth to Maturity
Patterns in high or low relative pollock weight (given length and sex from summer bottom trawl survey data) indicate significant year and fishing effort effects. Relative weights are slightly higher in the high fishing effort areas in the GOA and EBS, but not in the AI. This may simply indicate that the fishery tends to concentrate in areas of high pollock abundance, where conditions would expected to be favorable for pollock growth. The difference in relative weight between high and low impact areas shows no trend over time that would indicate of gradual degradation in habitat quality (Figure B.3.3.1-3). These patterns suggest that the impact of fishing on habitat has not adversely affected pollock growth.

Habitat Impacts Relative to Feeding
Since pollock feed primarily on zooplankton and pelagic organisms, the fishing impact on habitat features of the seafloor would not be expected to show a correlation to their feeding success. Analysis of feeding distributions in the BS show that pollock are broadly distributed over the shelf region and in the pelagic zone and that this distribution does not appear to have shifted over time. In the GOA, there has been a trend towards a broader spatial distribution of pollock at the same time that mean abundance has been decreasing (Shima et al. 2002). This pattern is contrary to the expected range contraction with declining abundance, suggesting that other factors may be influencing spatial pattern. Shima et al. (2002) noted the possibility of both fishing disturbance and environmental factors, but fishing effects on habitat could also result in a broader spatial distribution if the best habitats are reduced in quality.

Stock Status and Trends
Stock information for pollock in these regions has been available from fisheries catch and catch at age since 1964. Survey and other abundance index data are available through major parts of these time series and allow reasonable calibrations of age-structured stock assessment models. Model estimates indicate that the pollock spawning biomass in the GOA began at low levels and reached peaks in the 1980s after a period of high recruitment, then subsequently declined (Figure B.3.3.1-4). Spawning stock dropped below the B_{MSY} proxy of B35 percent in 1999, but is projected to increase to above B_{MSY} in 2005. Estimates of pollock biomass in the EBS also began at relatively low levels and grew to high levels in the mid-1980s and have remained relatively high and variable (due to recruitment fluctuations) at around 10 million tons (mt) of age 3 and older total biomass (Figure B.3.3.1-5).

The female spawning biomass has produced strong recruitment in both areas and has maintained levels above or near B_{MSY} estimates for the past 20 years. Annual fishing mortality rates have been below F_{MSY} levels during this period. There is no evidence at the stock level that the cumulative effects of fishing activity on habitat have impaired the stocks' ability to produce MSY over this time.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—Pollock is a generalist species that occupies a broad geographic niche and can use a wide variety of different habitats (Bailey et al. 1999). The ability of pollock to invade and adapt to marginal habitats has been suggested as a possible reason for the rapid increases in abundance during the environmental changes that occurred in the North Pacific in the 1970s (Bailey 2000). Pollock's ecological plasticity may allow adaption to habitats that have been modified by fishing impacts. Fishing impacts might even be beneficial, particularly if there are significant adverse impacts on predators or competitors more dependent on seafloor habitat features.

The overall evaluation of fishing impacts on pollock EFH is based primarily on extensive life history information that shows that pollock eggs, larvae, juveniles, and adults are not associated with seafloor habitat features affected by fishing. Some pollock life history stages are more demersal (i.e., age-1 juveniles), but even here the association is more likely related to temperature tolerances and avoidance of predators higher up in the water column than any characteristic of the bottom that can be impacted by trawling. The rating for fishing impacts on spawning/breeding for BSAI/GOA pollock is MT because pollock are pelagic spawners, as are their eggs and larvae. The rating for fishing impacts on feeding for BSAI/GOA pollock is MT because adults feed mainly on pelagic euphausiids followed by calanoid copepods.

The primary concern for pollock is the reduction in living structure in areas that support high pollock densities and its potential importance to juvenile pollock in providing refuge from predation. Changes in predation (or cannibalism) on juveniles have been proposed as a mechanism for population control in both the BSAI (Hunt et al. 2002) and the GOA (Bailey 2000). An increase in juvenile mortality will reduce spawning output per individual and, if large enough, could impair the ability of the stock to produce MSY over the long term (Dorn 2004). In the GOA, there is evidence of an increase in pollock mortality due to increases in the abundance of the dominant piscivores (Bailey 2000, Hollowed et al. 2000). However, evidence is weak that living structure plays a significant role in mediating mortality risk for juvenile pollock in the BSAI and the GOA, and it appears more likely that juveniles avoid predation risk through behavioral mechanisms such as shoaling and position in the water column. In addition, the overall reduction in living substrate for pollock EFH is relatively small (7 percent). Therefore, the rating for fishing impacts on growth to maturity for BSAI/GOA pollock is MT.

B.3.3.2 Pacific Cod (BSAI and GOA)

Habitat Connections

Spawning/Breeding

Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3 to 6° C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 parts per million (ppm) to saturation. Little is known about the optimal substrate type for egg incubation. See Sections 3.2.1.1.2 and 3.2.1.2.2 for further discussion and references.

Feeding

Pacific cod are omnivorous. In terms of percent occurrence, the most important items in the diet of Pacific cod in the BSAI and GOA are polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important dietary items are euphausiids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important dietary items are walleye pollock, fishery discards, and yellowfin sole. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. See Sections 3.2.1.1.2 and 3.2.1.2.2 for further discussion and references.

Growth to Maturity

Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow. Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shallow water of the shoreline to 500 m. Average depth of occurrence tends to vary directly with age for at least the first few years of life, with mature fish concentrated on the outer continental shelf. Preferred substrate is soft sediment, from mud and clay to sand. See Sections 3.2.1.1.2 and 3.2.1.2.2 for further discussion and references.

Evaluation of Effects

LEI Values Relative to Species Distribution

Long-term effect indices are shown in Table B.3-3. Figures B.2-1 through B.2-6c provide a more spatially explicit summary of the long-term effect indices. As this table and these figures show, there are overlaps between habitat features for which long-term effects are expected and areas of habitat use by Pacific cod. A rough estimate of the potential significance of the overlap between Pacific cod habitat and fishing's long-term effect on a given habitat feature can be obtained by weighting the long-term effect indices by the proportion of Pacific cod habitat made up of each habitat type and summing across habitat types. This results in the following set of weighted average LEIs (these are based on the 75 percent concentration; the weighted averages based on the 95 percent concentration are all lower):

Habitat Feature	BSAI	GOA
Infauna Prey	0.02	0.01
Epifauna Prey	0.01	0.01
Living Structure	0.10	0.06
Non-living Structure	0.02	0.01
Hard Coral	0.02	0.19

Only three habitat features have weighted average LEIs exceeding 2 percent: living structure in the BSAI (10 percent) and GOA (6 percent) and hard coral in the GOA (19 percent).

These weighted averages are only approximate estimates of potential significance for two reasons:
1) In order for the weighted averages to apply to the Pacific cod stock (as opposed to the Pacific cod *habitat*), fish would have to be evenly distributed across the area of 75 percent concentration (i.e., the proportion of fish in a given habitat type would have to equal the proportion of that habitat type in the area of 75 percent concentration). For example, the most significant impacts on several habitat features in the BSAI occur just north of Unimak Island (Figures B.2-2a through B.2-6c), where a major spawning aggregation of Pacific cod occurs, in which case the weighted averages may tend to underestimate the impacts on spawning fish. 2) The weighted averages say nothing about any particular habitat feature's importance to Pacific cod. For example, a 19 percent reduction in GOA hard coral may mean very little if hard coral is not a limiting factor in the population dynamics of GOA Pacific cod.

Because the areas of hard coral abundance are very small compared to the area of 75 percent Pacific cod concentration, it seems unlikely that hard coral is a limiting factor. The most important habitat features from the perspective of Pacific cod are probably infaunal and epifaunal prey, where the weighted average LEIs are only 1 to 2 percent for both the BSAI and GOA.

Given that the habitat features most important to Pacific cod are expected to be reduced by only 1 to 2 percent relative to their unfished condition (the above caveats notwithstanding) and given that the spawning biomass of Pacific cod at MSY is likely to be less than half the spawning biomass in the unfished condition (therefore requiring substantially fewer resources than in the unfished condition), it is reasonable to conclude that the relationships between the LEI values and the distribution of Pacific cod do not provide substantial evidence that fishing's effects on habitat features will significantly impair the stocks' ability to sustain itself at or near the MSY level.

Habitat Impacts Relative to Spawning/Breeding

When Figures B.2.2a through 2.6c are compared with annual maps showing the distribution of fishery and survey CPUE, no linkage between habitat disturbance and spawning/breeding success is obvious. For example, within the heavily fished area north of Unimak Island, which is an area traditionally associated with high concentrations of spawning Pacific cod, the survey almost invariably achieves a high CPUE in at least some stations.

It is possible, however, that such examinations miss subtle tendencies. Therefore, survey CPUE was compared and contrasted statistically between three treatments, defined by those areas in which fishing was high, low, or nonexistent. For the times covered by the respective surveys (AI, BS, and GOA), eight regulatory areas contain Pacific cod CPUE observations in all years and all three treatments: Area 541 in the AI; Areas 509, 513, 516, and 517 in the BS; and Areas 610, 620, and 630 in the GOA. These data were examined as follows: First, average CPUE of adult Pacific cod was computed across the time series for each area and treatment. Second, the average CPUE values were compared on a pairwise basis between treatments in each area. Third, the number of areas in which a given treatment had the higher CPUE in each pairwise comparison was tabulated. The results are shown below:

Comparison:	High versus Low		High versus None		Low versus None	
Treatment:	High	Low	High	None	Low	None
Number of regulatory areas in which average CPUE was higher:	4	4	4	4	5	3

If fishing were the primary determinant of adult biomass, one might expect areas of high fishing to have a lower average CPUE than areas of low fishing or no fishing. Areas of low fishing would be expected to have lower average CPUE than areas of no fishing. However, such tendencies are not apparent. High fishing was just as likely to achieve a higher CPUE than either low fishing or no fishing, and low fishing was slightly more likely to achieve a higher CPUE than no fishing. None of the differences between average CPUE was significant at the 5 percent level.

The above analysis was repeated using two alternative measures of relative biomass: average proportion CPUE and average logit proportion CPUE. The results in both cases were broadly similar to the above, except that three comparisons were significant at the 5 percent level when average proportion CPUE was used. In one area (541), high fishing was associated with significantly lower average proportion CPUE than no fishing, and in two areas (509 and 517), high fishing was associated with a significantly higher average proportion CPUE than no fishing.

Comparisons of long-term averages such as those described above may miss trends over time (e.g., two time series may have the same average, but one may be increasing while the other is decreasing). Therefore, the trend in relative adult biomass was examined for each time series in the high fishing treatment. Regardless of whether relative adult biomass was measured by average CPUE, average proportion CPUE, or average logit proportion CPUE, the results showed more negative than positive trends. Only two of the trends were significant at the 5 percent level, however: Area 513 showed a significant negative trend using either average proportion CPUE or average logit proportion CPUE, and Area 517 showed a significant negative trend using average CPUE.

Data are insufficient to determine whether Pacific cod maturity at age has changed over time.

Given the above, it is reasonable to conclude that the available information regarding the spatio-temporal distributions of the fishery and the adult portion of the Pacific cod stock does not provide substantial evidence that fishing's effects on habitat features will significantly impair the stocks' ability to sustain itself at or near the MSY level.

Habitat Impacts Relative to Growth to Maturity

In terms of survival to maturity, several studies have shown that early life stages of other *Gadus* species exhibit higher survival in the presence of habitat structure (e.g., Cote et al. 2001, Gregory and Anderson 1997, Laurel et al. 2003). The extent to which the results of these studies can be transferred to Pacific cod is unclear, however. For example, some of these studies focus only on very nearshore areas (depths of 1 to 2 m, or within 50 m of shore), whereas most Pacific cod spawning occurs in much deeper water. Also, it is possible for results to differ significantly between closely related species. For example, the study by Laurel et al. (2003) showed different responses between Atlantic cod (*Gadus morhua*) and Greenland cod (*Gadus ogac*). While it is probably safe to assume that habitat structure confers some amount of benefit to early life stages of Pacific cod, it would probably be a mistake to assume that early life stages of Pacific cod depend on habitat structure, given the fact that much Pacific cod spawning takes place in habitat with relatively little structure. In habitat types such as sand or sand/mud, the net impact of trawling on habitat structure is unclear.

In terms of growth to maturity, the available evidence does suggest a possible effect of fishing. The following weight-length relationship was fit separately to data from the EBS, AI, and GOA, distinguishing in each case between areas of high fishing and low fishing:

$$W(I) = \exp(\ \theta + \rho \times \ln(L(I))\ )$$

where $W(I)$ represents weight of the *i*th fish, $L(I)$ represents length of the *i*th fish, and θ and ρ are parameters to be estimated. In the EBS, the 95 percent confidence intervals for the high fishing and low fishing parameter estimates did not overlap. The same was true in the AI. However, in the GOA, there were very few data from high fishing areas, so the 95 percent confidence ellipse for the low fishing parameter estimates was entirely subsumed by the 95 percent confidence ellipse for the high fishing parameter estimates. The length ranges within which high fishing had negative/positive effects on predicted weight at length are summarized below:

Area	W@L is lower under high fishing at:	W@L is higher under high fishing at:
EBS	L < 59 cm	L > 58 cm
AI	all lengths	no lengths
GOA	L > 56 cm	L < 57 cm

Although statistically significant effects can be identified, at least in the EBS and AI, they are not very large. In the EBS, the maximum expected decrease in weight at length is never more than 6 percent, and there is a less than 5 percent chance of a decrease more than 10 percent except at lengths less than 21 cm. In the AI, the maximum expected decrease in weight at length is never more than 3 percent, and there is less than a 5 percent chance of a decrease more than 10 percent, except at lengths less than 25 cm. In the GOA, the maximum expected decrease in weight at length is never more than 1 percent, and there is a less than 5 percent chance of a decrease more than 10 percent at all lengths.

Sample sizes are probably too small to detect significant temporal trends in weight at length.

Given that the point estimates of change in weight at length are all very small and that there is only a small length range within which the probability of even a 10 percent change exceeds 5 percent, it is reasonable to conclude that the available information regarding the relationship between fishing and growth to maturity does not provide substantial evidence that fishing's effects on habitat features will significantly impair the stocks' ability to sustain itself at or near the MSY level.

Habitat Impacts Relative to Feeding

Overall, there is little reason to suspect a link between habitat disturbance and feeding success of Pacific cod. As noted in the preceding subsection, fishing seems to have little effect on the weight-length relationship, which would not be the case if fishing resulted in a chronic inability of Pacific cod to find sufficient food.

Survey CPUE distributions over time do not reveal any obvious changes that might be attributable to decreased feeding success in heavily fished areas. On the contrary, areas of sustained heavy fishing are often associated with areas of sustained high survey CPUE.

Data are insufficient to determine whether there has been a detectable change in the diet of Pacific cod attributable to fishing.

Given the above, it is reasonable to conclude that the available information regarding the relationship between fishing and feeding success does not provide substantial evidence that fishing's effects on habitat features will significantly impair the stocks' ability to sustain itself at or near the MSY level.

Stock Status and Trends

In both the EBS and GOA, spawning biomass of Pacific cod has been above the MSY level throughout the history of management under the Magnuson-Stevens Act. Depending on the endpoints used to compute a trend; however, negative trends in spawning biomass can be identified in both the EBS and GOA. In the EBS, any time period beginning in the interval from 1980 to 1997 and ending in 2004 has a negative slope that is significant at the 5 percent level. In the GOA, any time period beginning in the interval from 1980 to 2001 and ending in 2004 has a negative slope that is significant at the 5 percent level.

As with spawning biomass, recruitment of Pacific cod in both the EBS and GOA has tended to fluctuate around the levels associated with MSY. Depending on the endpoints used to compute a trend; however, negative trends in recruitment can be identified in both the EBS and GOA. In the EBS, the periods from 1978 to 2004, 1979 to 2004, and 1982 to 2004 all have negative slopes that are significant at the 5 percent level. In the GOA, any period beginning in the interval from 1978 to 1992 and ending in 2003 has a negative slope that is significant at the 5 percent level.

Fishing is expected to affect future recruitment because fishing has effects on spawning biomass, to which recruitment is presumably related, at least on average. Unfortunately, it is typically difficult to estimate the relationship between spawning biomass and recruitment (Thompson and Dorn 2004). If, in addition to biomass-mediated effects on future recruitment, fishing also imposes habitat-mediated effects on future recruitment, these will be hard to detect. In an effort to estimate some of the uncertainty surrounding both biomass-mediated and habitat-mediated effects of fishing on future recruitment, the following stock-recruitment relationship was examined in a Bayesian framework:

$$R(t+1) = S(t) \times \exp(-\alpha - \beta \times S(t) - \gamma \times F(t))$$

where R(t+1) represents age 1 recruits at time t+1; S(t) represents spawning biomass at time t; F(t) represents fishing mortality at time t; and α, β, and γ represent parameters to be estimated. The parameter γ represents all non-biomass-mediated effects of fishing on recruitment. To be precautionary, it was assumed that all such effects are mediated through fishing's effect on habitat.

The time series of age-1 recruits, spawning biomass, and fishing mortality were taken from the most recent stock assessments (Thompson and Dorn 2004 and Thompson et al. 2004 for the EBS and GOA stocks, respectively). The fishing mortality rates represent all fishing mortality on Pacific cod, regardless of target, season, or gear type.

Normal prior distributions were specified for each of the three parameters. The mean of the prior for α was set equal to -1 minus the average log (recruits-per-unit-spawning-biomass), the mean of the prior for β was set equal to 1 over the average spawning biomass, and the mean of the prior for γ was set equal to zero. When the stock-recruitment relationship is estimated using the means of the three prior distributions, the stock achieves equilibrium at the average spawning biomass and the geometric mean replacement rate.

The standard deviations for all three prior distributions were set such that there was a 1 percent probability that the parameter had a sign opposite that of the mean, except in the case of γ, where the slope of a least-squares regression of log (recruits-per-unit-spawning-biomass) against annual fishing mortality was substituted for the mean.

A lognormal likelihood was assumed, and the maximum likelihood estimate of variance was assumed to be the true value of this parameter in subsequent computations.

The marginal posterior distribution of γ was obtained for the EBS and GOA stocks. For the EBS stock, the probability that γ is positive was 71 percent. For the GOA stock, the probability that γ is positive was nearly 100 percent. Therefore, in both areas, this analysis suggests that fishing probably has some level of habitat-mediated effect on recruitment.

However, it is important to consider not only the existence but the magnitude of any habitat-mediated effect on recruitment, specifically with regard to the stocks' ability to sustain itself at or near the MSY level. To examine this question, it was assumed that the biomass associated with maximum recruitment is equal to the MSY level. This is a conservative assumption, because MSY biomass is typically somewhat lower than the biomass associated with maximum recruitment. It was also assumed that the stocks' ability to sustain itself at or near the MSY level would not be impaired unless equilibrium biomass under average fishing mortality (computed over the available time series, 1978 to 2003) was less than MSST. The average fishing mortality rate was used to focus the analysis on the expected long-term effects of the overall management regime. To simplify the analysis, MSST was assumed to equal half the

MSY level (this is a special case of the full, official definition of MSST). In the EBS, the point estimate of equilibrium biomass under average fishing mortality is 155 percent above MSST. In the GOA, the point estimate of equilibrium biomass under average fishing mortality is 23 percent above MSST. However, the results from the GOA analysis depend heavily on the strengths of the two most recent year classes. These year classes are the least precisely estimated in the time series. If they are removed, the point estimate of equilibrium biomass in the GOA is 91 percent above MSST.

Although the point estimates of equilibrium biomass are above MSST in both the EBS and GOA, uncertainty remains as to whether habitat-related effects could drive the stock below MSST. Could habitat-related effects of fishing cause the stock to fall below MSST, given that the biomass-related effects would not cause the stock to fall below MSST? In the EBS, this conditional probability is nearly zero. In the GOA, this conditional probability is 27 percent. As noted above, however, the results of the GOA analysis are heavily dependent on the strengths of the two most recent (and least precisely estimated) year classes. If these two year classes are removed, the conditional probability is only 1 percent.

Caveats

1. The model described above was completed late in the process of preparing this FEIS. Little time was available for reviewing the model or applying it to other species prior to the deadline for completion of the FEIS.

2. The model described above may not be useful for all species. In particular, it would probably be difficult to identify any non-biomass-mediated effect of fishing in the case of a species characterized by highly variable recruitment or highly stable fishing mortality.

3. Estimation of stock-recruitment relationships is a difficult exercise in the field of stock assessment for two reasons: 1) the spawning biomass values and the recruitment values are invariably measured with error, and 2) because the errors in the recruitment measurements are necessarily autocorrelated (Walters and Ludwig 1981). In contrast, most estimation methods, including the approach used above, are based on the assumptions that the spawning biomass values are measured without error and that the errors in the recruitment measurements are uncorrelated. Furthermore, the approach used above is based on the assumption that the standard deviations of the error terms (on a log scale) are all equal; it is likely, however, that the error terms for the more recent year classes are larger than for earlier, more fully observed, year classes. To date, the Scientific and Statistical Committee has not viewed existing estimates of the standard two-parameter (α and β) Ricker stock-recruitment relationship as being reliable enough to use in setting acceptable biological catch levels for Pacific cod. Addition of a third parameter (γ) would be expected to further decrease the reliability of the estimates.

4. Generally speaking, statistical significance does not necessarily imply biological significance. Statistical significance deals with the question, “Do the data indicate that an effect exists?” Biological significance deals with the question, “Is the effect of sufficient magnitude to be important to the organism (or population, or ecosystem, etc.)?” Therefore, results pertaining to the probable existence of habitat-mediated fishing effects should not be viewed in isolation from results describing the biological significance of those effects.

5. While it was assumed above that all non-biomass-mediated effects of fishing are a result of fishing's effect on habitat, other interpretations are possible (e.g., fishing could disrupt spawning aggregations directly).

6. In the above analysis, the total annual fishing mortality impacting the Pacific cod stock was used as a proxy for the total annual fishing mortality impacting Pacific cod habitat. This assumption could be problematic to some extent if either of the following conditions holds:

   A. The distribution of the fishery between seasons or gear types has changed substantially, and substantial differences exist in any habitat-mediated impacts of the fishery between seasons or gear types.
   B. Pacific cod vacate a substantial portion of their habitat during some part of the year, and a substantial fishery takes place for other species in that portion of the habitat during the same time of year.

7. It is possible that the habitat-mediated effects attributed above to fishing were actually caused by some other variable that is highly correlated (either causally or coincidentally) with fishing mortality.

8. The above analysis was based on a single modeling approach. Many other modeling approaches are possible. Two examples are discussed below.

Alternative Models

The model described above has some similarities to a model proposed by Shester (2004). Shester's model assumes logistic growth in population numbers and a constant catch harvest policy. Fishing's effects on carrying capacity are assumed to be proportional to catch. These effects are subtracted from the pristine carrying capacity (i.e., the long-term average population size that would be expected in the absence of fishing). In equation form, Shester's model can be written as follows:

$$dN/dt = r \times N \times (1 - N/(K - \Omega \times h)) - h$$

where N represents population size in numbers, r represents the intrinsic rate of increase, K represents pristine carrying capacity, h represents catch, and Ω represents the rate at which catch affects carrying capacity. If Ω is greater than zero, and if the values of r and K are known, Shester's model indicates that both MSY and the equilibrium population size corresponding to MSY (N_{MSY}) will be lower than would be predicted if Ω were assumed to equal zero.

As originally configured, Shester's model has limited applicability to management of North Pacific groundfish fisheries because management of those fisheries is not based on a constant catch policy. However, it is easy to reconfigure Shester's model to reflect a constant rate policy, which would be closer to the policy actually used in managing the North Pacific groundfish fisheries:

$$dN/dt = r \times N \times (1 - N/(K - \Omega \times F \times N)) - F \times N$$

In the above reconfiguration of Shester's model, it can be shown that the effect of Ω on N_{MSY} is exactly the same as in Shester's original configuration. However, it can also be shown that fishing mortality sustainable yield (F_{MSY}), the fishing mortality rate corresponding to MSY, is completely independent of Ω. That is, equilibrium yield is maximized by fishing at the same value of F (specifically, r/2), regardless of fishing's effects on carrying capacity.

The model used here is more precautionary than Shester's model because F_{MSY} in this model varies inversely with the rate of habitat impacts, while N_{MSY} varies directly with the rate of habitat impacts. In other words, if fishing imposes a habitat-mediated impact on recruitment, F_{MSY} will be lower, and N_{MSY} will be higher than would be the case if fishing did not impose a habitat-mediated impact on recruitment.

Conclusions with Respect to Stock Status and Trends

Given the above, it is reasonable to conclude that the available information regarding the relationship between fishing and stock status and trends does not provide substantial evidence that fishing's effects on habitat features will significantly impair the stocks' ability to sustain itself at or near the MSY level.

Summary

Issue	Evaluation
Spawning/Breeding	MT (Minimal or temporary effect)
Growth to Maturity	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)

Summary of Effects—Fishing's effects on the habitat of Pacific cod in the BSAI and GOA do not appear to have impaired either stocks' ability to sustain itself at or near the MSY level. When weighted by the proportions of habitat types used by Pacific cod, the long-term effect indices are low, particularly those of the habitat features most likely to be important to Pacific cod (infaunal and epifaunal prey). The fishery appears to have had minimal effects on the distribution of adult Pacific cod. Effects of fishing on weight at length, while statistically significant in some cases, are uniformly small and sometimes positive. While the fishery may impose some habitat-mediated effects on recruitment, these fall below the standard necessary to justify a rating of anything other than minimal or temporary.

B.3.3.3 Sablefish (GOA and BSAI)

Habitat Connections

Spawning/Breeding

Spawning occurs from 300 to 500 m deep near the edges of the continental slope (McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 290 km (Wing 1997). The average spawning date based on otolith analysis is March 30 (Sigler et al. 2001). Sablefish are not thought to have any particular spawning grounds like halibut, so spawning likely is widespread along the upper continental slope. During surveys of the outer continental shelf, most young-of-the-year sablefish are caught in the central and eastern GOA (Sigler et al. 2001), implying that spawning is more likely to be successful in these areas. Particular habitat affiliation within broad habitat categories of gully and slope have not been noted for sablefish. They are distributed throughout these hydrographic features and occur in a wide range of habitats. They do not demonstrate any exclusivity to particular habitat features like some rockfish species that use primarily rocky habitat.

Feeding

Larval sablefish feed on a variety of small zooplankton, ranging from copepod nauplii to small amphipods. Young-of-the-year are epipelagic and feed primarily on macrozooplankton and micronekton (e.g., euphausiids) (Sigler et al. 2002). Juveniles less than 60 cm feed primarily on euphausiids, shrimp, and cephalopods (Yang and Nelson 2000), while sablefish more than 60 cm feed more on fish. Both juvenile and adult sablefish are considered opportunistic feeders. Fish most important to the sablefish diet include pollock, eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish, with pollock being the most predominant (10 to 26 percent of prey weight, depending on year). Squid, euphausiids, and jellyfish were also found, squid being the most important of the invertebrates (Yang and Nelson 2000). Feeding studies conducted in Oregon and California found that fish made up 76 percent of the diet (Laidig et al. 1997). Off the southwest coast of Vancouver Island, euphausiids dominated sablefish diet (Tanasichuk 1997). The diet of sablefish is similar to that of the large flatfish such as arrowtooth flounder and Pacific halibut (Yang and Nelson 2000).

Growth to Maturity
Juveniles are pelagic and move into comparatively shallow nearshore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). After their second summer, juveniles begin moving offshore, eventually reaching the upper continental slope as adults. Fish first appear on the upper continental slope, where the longline survey and longline fishery primarily occur, as early as age 2 and fork length about 50 to 53 cm, although only 10 percent are estimated to reach the slope at that young age. Fish are susceptible to trawl gear at an earlier age than to longline gear because trawl fisheries usually occur on the continental shelf and shelf break areas that are inhabited by younger fish. Sablefish grow rapidly in early life, gaining 1.2 mm per day during their first spring and summer (Sigler et al. 2001). Within 100 days after first increment formation, they average 120 mm. They reach average maximum lengths and weights of 69 cm and 3.4 kg for males and 83 cm and 6.2 kg for females. Fifty percent of females mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.5 years for females and 5 years for males.

No specific connections to habitat features are known for sablefish, although in general one would expect a demersal roundfish such as sablefish to be adapted to habitat with benthic biostructure rather than to habitat without or with greatly reduced biological structure. Moore (1999) indicates that unlike roundfish, flatfish do not require a complex structured habitat and notes that Rijnsdorp and van Leeuwen (1996) found an increase in growth rate of flatfish in intensely fished areas of the North Sea.

Evaluation of Effects

LEI Values Relative to Species Distribution
A number of areas experience high fishing intensity on the continental shelf and are distributed in a few large areas on the BS shelf and in smaller localized areas on the GOA shelf. While Table B.3-3 indicates that only a small percentage of total sablefish EFH is on the continental shelf, total sablefish EFH, as estimated in the table, is biomass based and primarily determines the adult distribution. Because of their small size and intermittent abundance, EFH for juvenile sablefish may not be well determined, and the importance of shelf habitat for juvenile sablefish may be underestimated. While the areas of importance to juvenile sablefish may not be well represented in Table B.3-3, it does indicate that high LEIs do occur in the sablefish EFH detected on the southwest BS shelf.

Habitat Impacts Relative to Spawning/Breeding
While there are areas of high bottom trawling intensity along the continental slope, and sablefish are believed to spawn along the slope, there is little information to determine the spawning distribution or detect shifts in distribution. Changes in the maturity of age for sablefish have not been detected.

Habitat Impacts Relative to Growth to Maturity
There has been a downward trend in sablefish recruitment over the last 25 years. Years of strong young-of-the-year survival have occurred from 1980 to the 1990s, so the failure of strong recruitment to the mature stage suggests a decreased survival of juveniles during their residence as 2- to 4-year-olds on the

continental shelf. While no specific link can be established, areas of the continental shelf may be more important to juvenile sablefish than indicated in Table B.3-3. Intense bottom trawling on the continental shelf may have reduced both benthic biostructure and the ability of juvenile sablefish to compete or otherwise survive to maturity. A lack of spatial and temporal distribution information of historical bottom trawling effort limits the ability to establish a link to decreased recruitment should one exist.

Habitat Impacts Relative to Feeding

The length-to-weight relationship of sablefish sampled from areas defined as high and low fishing intensity was compared. No significant differences were found. Limitations such as insufficient sample size, the lack of contrast between high and low areas within similar habitat and geographic areas, and the likelihood that fish did not confine themselves to the respective treatment areas preclude determining if possible effects exist. The lack of such finding is not proof that habitat impacts have no effects on the feeding success of sablefish.

Stock Status and Trends

There has been a negative trend in sablefish recruitment estimates since the late 1970s (see Figure 3.11 in Sigler et al. 2004). This negative trend in recruitment has resulted in a downward trend in the estimates of biomass reference points such as $B_{40\%}$, $B_{35\%}$, and MSST. These values are directly related to the stock's average recruitment. Figure B.3.3.3-1 shows retrospective estimates of $B_{40\%}$ using three variations of estimating sablefish average recruitment.

After strong year classes in the late 1970s and early 1980s peaked in biomass, sablefish spawning stock biomass decreased steadily and has since remained below target biomass levels ($B_{40\%}$) (see Figure 3.10 in Sigler et al 2004). The spawning stock has remained below target levels in spite of fishing rates being adjusted below the level ($F_{40\%}$) that should have allowed recovery to $B_{40\%}$ and the long-term attainment of $B_{40\%}$.

There is no direct evidence to attribute these trends to fishing impacts on habitat. Whether the decreasing trend in recruitment is the result of climate conditions or altered benthic habitat is unclear. However, juvenile sablefish reside in the demersal habitat of the continental shelf for 2 to 4 years before they recruit to deeper waters as adults. Areas of the continental shelf have been bottom trawled intensively. In one area in particular in the BS north of Unimak Island, juvenile sablefish from the strong 1977 year class were observed at high levels from 1978 to 1980 (Umeda et al. 1983). Even though indications of high egg-larval-young of the year survival have occurred since the 1977 year class, 2- to 4-year-old sablefish abundance has been uncommon in this area. This area north of the Alaska Peninsula was closed to trawling by Japan in 1959 and apparently was untrawled until it was opened to United States trawling in 1983 (Witherell 1997, Fredin 1987). This area is currently one of the most intensely bottom trawled areas in Alaska. Bioshelter LEI values for much of this area are high.

A plausible indirect linkage attributing these trends to fishing impacts on habitat is suggested by the increase of arrowtooth flounder on the shelf of the GOA and BS. Arrowtooth flounder in the area north of Unimak Island has increased significantly since the mid 1980s while the abundance of sablefish has been minimal since then (Connors et al. 2004, Umeda et al. 1983). Moore (1999) indicates that, unlike roundfish, flatfish do not require a complex structured habitat and notes that Rijnsdorp and van Leeuwen (1996) found an increase in growth rate of flatfish in intensely trawled areas of the North Sea. This suggests intensive trawling has the potential to improve conditions for flatfish.

Whether sablefish are linked to arrowtooth flounder as prey or through competition is unknown. Food studies by the AFSC do not indicate sablefish as a prominent prey item; however, juvenile sablefish are available only intermittently and at lower numbers than more abundant prey such as pollock and cod. Therefore, it is not inconceivable that sablefish are preyed upon by arrowtooth to the detriment of sablefish without them being detected as prominent prey compared to other more numerous species. The diet of sablefish is similar to that of the large flatfish, arrowtooth flounder, and Pacific halibut (Yang and Nelson 2000), so competition may be a factor.

The decreasing trend in recruitment and resulting estimates of biomass reference points and their corresponding yield levels indicate that the level of MSY has been impaired. The decreasing estimate of a target biomass, $B_{40\%}$, has led to a lowering of the expectation of the long-term catch level. Biomass reference points such as $B_{35\%}$ or $B_{40\%}$ are one form of estimate or surrogate for MSY. It is likely that any other estimate of MSY would have decreased over the same time period.

While the stock is currently above the latest estimate of a biomass of 35 percent, this should not be taken as proof that the sablefish stock productivity is unimpaired. Considerations should include the following points:

1. The biomass is projected to decrease again in the near future.
2. The biomass has been below $B_{35\%}$ in the recent past.
3. Given the harvest control rules and the resultant fishing rates, the biomass should have been fluctuating around $B_{40\%}$.
4. Estimates of $B_{35\%}$ have decreased over time.
5. The current biomass is below what $B_{35\%}$ would have been estimated at 10 years ago.

Summary

Issue	**Evaluation**
Spawning/Breeding	MT
Growth to Maturity	U (Unknown)
Feeding	U (Unknown)

Summary of Effects—The estimated productivity and sustainable yield of sablefish have declined steadily since the late 1970s. This is demonstrated by a decreasing trend in recruitment and subsequent estimates of biomass reference points and the inability of the stock to rebuild to target biomass levels despite of the decreasing level of the targets and fishing rates below the target fishing rate. While years of strong young-of-the-year survival have occurred in the 1980s and 1990s, the failure of strong recruitment to the mature stage suggests a decreased survival of juveniles during their residence as 2- to 4-year-olds on the continental shelf. While climate-related changes are a possible cause for reduced productivity, the observations noted above are consistent with possible effects of fishing on habitat and resulting changes in the juvenile ecology of sablefish, possibly through increased competition for food and space. Given the concern for the decline in the sustainable yield of sablefish, the possibility of the role of fishing effects on juvenile sablefish habitat, and the need for a better understanding of the possible causes, an MT rating is not merited, and sablefish growth to maturity and feeding is rated unknown.

B.3.3.4 Atka Mackerel (BSAI and GOA)

Habitat Connections

Habitat preferences for the early life stages of Atka mackerel, particularly the larval and early juvenile stages, are poorly known in comparison to the adult stage. The available information is summarized in Table B.3-1. Spawning is demersal in moderately shallow waters; observations extend to approximately 100 m, but the lower depth limit for spawning and nesting of Atka mackerel in the AI is unknown. Female Atka mackerel deposit eggs in nests built and guarded by males on rocky substrates or on kelp in shallow water. The egg stage is noted to occur in AI shallow habitat, which extends to 200 m (Table B.3-1). Although Atka mackerel nests with eggs have not been observed in the GOA, the assumption is made that eggs would be found in the same substrate as observed in the AI (GOA shallow habitat, Table B.3-1). Eggs develop and hatch at depth, releasing planktonic larvae, which have been found up to 800 km from shore. It is presumed that the larval and early juvenile stages are pelagic. Little is known of the distribution and habitat preferences of young Atka mackerel prior to their appearance in trawl surveys and the fishery at about 2 to 3 years of age. At some point, they are assumed to migrate to the bottom and take up a demersal existence, but catches of juveniles less than 20-cm fork length is relatively rare in the fishery and bottom trawl surveys. Older juveniles have been taken only infrequently in the trawl surveys and fishery.

Adult Atka mackerel occur in large localized aggregations, usually at depths less than 200 m, and generally over rough, rocky, and uneven bottom near areas where tidal currents are swift. Associations with corals and sponges have been observed for AI Atka mackerel (NMFS 2004, Stone 2004). Adults are semi-demersal, displaying strong diel behavior with vertical movements away from the bottom occurring almost exclusively during the daylight hours, presumably for feeding, and little to no movement at night (Nichol and Somerton 2002).

Spawning/Breeding
Females deposit adhesive eggs in benthic nests in rocky crevices and hollows and among stones or on kelp in shallow water at depths less than 100 m.

Feeding
The adults feed mainly on pelagic euphausiids followed by calanoid copepods, which are not one of the affected habitat features (Yang 1999). As euphausiids and copepods are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal or temporary effect on the availability of prey to Atka mackerel.

Growth to Maturity
Larvae and young juveniles are presumed to be pelagic. As noted above, habitat requirements for the larval and young juvenile life stages of Atka mackerel are mostly unknown. Younger juveniles (less than 20-cm fork length) are rarely caught on groundfish fishing gear, so it is likely that fishing does not occur (and thus has no direct effect) on whatever habitat they do occupy. However, older juveniles and adults are demersal at times and are associated with rough, rocky habitat generally less than 200 m deep and are the target of a bottom trawl fishery. Adult Atka mackerel have been observed in association with corals and sponges (NMFS 2004, Stone 2004), and they may prefer the rocky substrate inhabited by such epifauna. Although the importance of these associations is uncertain, bottom trawling is known to damage such living substrates, which could have an impact on Atka mackerel.

Evaluation of Effects

LEI Values Relative to Species Distribution

The center of abundance for Atka mackerel is in the AI, and currently there is no directed fishery for GOA Atka mackerel. Historically, a fishery had occurred in the GOA as far as Kodiak Island through the mid-1980s; catches in the GOA peaked at about 28,000 mt in 1975 (Lowe and Lauth 2003). Subsequently, recruitment to the AI population was low from 1980 to 1985, and catches in the GOA dropped to almost zero in 1986. In 1988, GOA Atka mackerel were combined in the other species category due to low abundance and the absence of a directed fishery for the previous several years. After a series of large year classes recruited to the AI region in the late 1980s, the population and the fishery re-established (at a much lower level) in the early 1990s in the western GOA. The Council separated Atka mackerel from the other species category in 1994. Catches again declined after the mid-1990s, and the GOA Atka mackerel fishery has been managed as a bycatch-only fishery since 1997, with catch quotas of 1,000 mt in 1997 and 600 mt from 1998 to 2004. Just before to 2003, the catch of GOA Atka mackerel had been less than 100 mt but jumped dramatically in 2003 to nearly 600 mt. Two strong back-to-back year classes (1998 and 1999) have shown up prominently in the AI, and the GOA Atka mackerel have been determined to largely comprise the 1999 year class, as indicated by fish sampled from the 2003 GOA survey and fisheries. Observations of small catches of Atka mackerel in 2003 from the fishery and the survey extended well into the Kodiak regulatory area. The recent increase in observations of Atka mackerel in the GOA, which largely comprise a single cohort (1999 year class), do not appear to indicate an expanded population with a broad distribution of age classes.

The evaluation of fishing effects on habitat for Atka mackerel focuses on AI Atka mackerel, which are the main source of the population and have a long history of exploitation. The significant decline of the GOA Atka mackerel fishery (and population) after the mid-1980s suggests that this area may be the edge of the species' range. During periods of high recruitment in the AI, it is thought that juvenile Atka mackerel may move into the GOA under favorable conditions (Kimura and Ronholt 1988). In addition, it is presumed that there is some limited spawning activity in the GOA and larval settlement in the area, perhaps enhanced by the same favorable environmental conditions contributing to good recruitment in the AI. The history of the GOA fishery and population seems to indicate that GOA Atka mackerel may be at the margin of their distribution, where they are more patchily distributed than in the AI. Hence, they exhibit a greater vulnerability to the direct effects of fishing (Lowe and Lauth 2003). There are no studies that link habitat disturbance with the ability of the stock to maintain itself in the GOA. Environmental conditions and the direct effects of fishing (fishing mortality) likely have the greatest impacts on GOA Atka mackerel.

The habitat information that is available for Atka mackerel indicates that they are associated with living structure, non-living structure, and hard corals (Table B.3-1). Atka mackerel are found in the AI deep and shallow habitats, but predominantly in the AI shallow habitat; 50 percent of the concentrated Atka mackerel distribution (75 percent column) is estimated to be within the designated AI shallow habitat (Table B.3-3). The LEI table estimates a 20 percent reduction in living structure within the AI shallow habitat that overlaps with the 75 percent concentration of Atka mackerel distribution (Table B.3-3). However, the LEI map indicates quite a broad range in the potential reduction in living structure features of habitat areas where AI Atka mackerel are found (1 to 50 percent, Figure B.2-3c). The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Furthermore, the LEI maps are difficult to interpret because of the irregularity and patchiness in the distribution of habitat features. This is especially true for living substrate features such as sponges and corals, which are likely to be patchily distributed and occur on a finer scale than presented in this analysis. What these maps do indicate is that Atka mackerel are found over a broad range of low to high fished areas within the AI (Figures B.2-3c, B.2-4c, and B.2-6c).

The estimated reduction in non-living structure within AI Atka mackerel habitat is lower relative to estimates for living structure, ranging from 1 to 25 percent according to the LEI map (Figure B.2-4c). The LEI table estimates a 13 percent reduction in non-living structure within the AI shallow habitat that overlaps with the 75 percent concentration of Atka mackerel distribution (Table B.3-3). The LEI index for hard corals in the AI where Atka mackerel occur is much higher relative to the estimates for living and non-living structure. The LEI table estimates a 40 percent reduction in hard corals within the AI shallow habitat that overlaps with the 75 percent concentration of Atka mackerel distribution (Table B.3-3). The LEI map indicates many areas with less than 1 percent estimated reduction for hard corals, but it also indicates many areas with more than 50 percent estimated reductions within the AI (Figure B.2-6c). As noted above, the LEI maps are difficult to interpret, and this is particularly true for the distribution of LEI of fishing effects on coral. The LEIs were, however, calculated wherever fishing occurred. The actual distribution of coral is much more restricted and is not specifically known. Therefore, the maps indicate reductions in many areas where no coral, and hence no actual coral loss, occurs (Figures B.2-6a-c).

The extent and nature of the associations between AI Atka mackerel and living and non-living substrate and hard corals are unknown. However, if these are desirable habitat features for Atka mackerel and there is a significant dependance on these features, the potential large reduction (more than 50 percent) in hard corals in many areas of the AI could be of concern. It is unclear what the impact of the estimated reductions for living, non-living, and hard coral habitat features would be for Atka mackerel. Overall, the Atka mackerel stock is in relatively good condition and is currently at a high abundance level. There are no indications that the affected habitat areas that overlap with the distribution of Atka mackerel would impair the ability of the stock to produce MSY over the long term. This is not to say that affected habitat areas have no impact on Atka mackerel, but environmental conditions may be such that they are favorable for Atka mackerel and override impacts due to the effects of fishing on habitat features important to Atka mackerel. Also, while the maps indicate areas of relatively high LEIs, particularly for coral, there are also many areas of very low LEIs (less than 1 percent) in the AI.

GOA Atka mackerel eggs are presumed to be associated with shallow benthic habitats based on observations in the AI (Table B.3-3). Juveniles and adults are also associated with benthic habitats, specifically hard, non-living substrate on the GOA deep shelf (Table B.3-3). Overall, the GOA shallow and deep shelf habitats comprise 4 and 5 percent, respectively, of the areas designated as the Atka mackerel 75 percent concentration distribution within the AI/GOA (Table B.3-3). It is assumed that the impact of the estimated reductions for living, non-living, and hard coral habitat features would be negligible or minimal for GOA Atka mackerel.

Habitat Impacts Relative to Spawning/Breeding

Spawning is demersal in moderately shallow waters; observations extend to approximately 100 m, but the lower depth limit for spawning and nesting of Atka mackerel in the AI is unknown. Female Atka mackerel deposit eggs in nests built and guarded by males on rocky substrates or on kelp in shallow water. Figure D-94 (Appendix D) shows the general distribution of adult Atka mackerel in the BSAI, but the distribution of specific locations of nesting sites throughout the AI is unknown. Specific spawning and nesting sites have been observed off Seguam Island and on offshore reefs and in and around island passes from Stalemate Bank to Akutan Pass (Lowe et al. 2004). Just based on depth considerations, there is likely some overlap of the fishery with the distribution of nesting sites (Table B.3-3), but the extent of the overlap with the spatial distribution of fishing impacted areas is unknown. However, overlap with spawning areas is likely to be low due to the following factors: 1) Atka mackerel are summer spawners, and the directed fishery is conducted during two seasons that run from January 20 to April 15 (A season) and from September 1 to November (B season); 2) observations to date indicate that at least some spawning and nesting grounds occur in areas too shallow and rough for the fishery to operate; 3) there are trawl exclusion zones within 10 nm of all sea lion rookeries in the AI and within 20 nm of the rookeries on Seguam and Agligadak Islands (in area 541); and 4) there are maximum seasonal catch percentage limits in place for sea lion critical habitat areas in the central (542) and western (543) AI. These sea lion protection measures likely afford protection to several spawning grounds, and other spawning grounds that are not in closed areas but that occur in untrawlable habitat are also afforded protection.

Summer resource assessment trawl surveys conducted biennially in the AI at the time of spawning provide a relative measure of abundance of the spawning biomass and have not detected a shift in the spatial distribution of biomass (Lowe et al. 2004, refer to http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm for survey CPUE maps). The distribution of survey catch per unit effort data indicates a relatively consistent occurrence in the spatial distribution of Atka mackerel catches (Lowe et al. 2004). What is evident in recent surveys is an increase in the occurrence of Atka mackerel catches due to increased abundance levels. In summary, the impacts of fishing due to habitat disturbance have not reached a level that has resulted in the movement of fish out of the impacted region or the failure of continued recruitment to the region.

Only one study has estimated age at maturity for Atka mackerel from the GOA and AI with data collected from 1992 to 1994 (McDermott and Lowe 1997). Efforts are currently underway to look at inter-annual variability in maturity-at-age (Cooper, D., AFSC, personal communication). To date, there is no evidence to suggest a link between habitat disturbance and the spawning/breeding success of AI Atka mackerel.

Habitat Impacts Relative to Growth to Maturity

As noted above, habitat preferences for the early life stages of Atka mackerel, particularly the larval and early juvenile stages, are poorly known in comparison to the adult stage. Younger juveniles (less than 20-cm fork length) are rarely caught on groundfish fishing gear, so it is likely that fishing does not occur on whatever habitat they do occupy and, thus, has no direct effect. However, older juveniles and adults are demersal at times, are associated with rough, rocky habitat at depths generally less than 200 m, and are the target of a bottom trawl fishery. Adult Atka mackerel have also been observed in association with corals and sponges (NMFS 2004, Stone 2004) and may prefer the rocky substrate inhabited by such epifauna. Although the importance of these associations is uncertain, bottom trawling is known to damage such living substrates, which could have an impact on Atka mackerel. At present, however, review of time trends in size at age do not indicate that past and current levels of habitat disturbance of these substrates is affecting the growth to maturity for Atka mackerel.

Growth analyses of length at age, weight at age, and weight at length of AI Atka mackerel caught in low trawl intensity areas versus high trawl intensity areas have been computed, but are uninformative. The statistical power of these tests is expected to be low due to very small sample sizes in the high trawl intensity areas. Atka mackerel samples from the high effort areas in the AI were collected over 3 years (1994, 2002, and 2004), with sample sizes of 9, 25, and 23 fish, respectively. Data from the years 2002 and 2004 were analyzed, and results indicated statistically significant differences in weight and length-at-age and weight-at-length for both years, where the higher values were found in the high fishing effort treatment group. Although these results seem counter-intuitive and the sample sizes are questionable, they do corroborate previous growth studies for Atka mackerel. Kimura and Ronholt (1988) and Lowe et al. (1998) documented a longitudinal trend in growth in three sub-areas of the AI and the western

GOA. Results showed length-at-age was smallest in the western AI (a region lightly fished) and largest in the eastern AI and western GOA (regions of relatively heavy fishing impacts).

A large and sustained Atka mackerel fishery has been conducted throughout the AI since the early 1970s. Catches fluctuated with the demise of the foreign fishery and the development of the domestic fishery. In subsequent years, the fishery was concentrated in the eastern AI where the largest fish reside (Lowe et al. 1998). The fish in the western AI have not been heavily exploited since 1980 after the foreign fishery, but they have historically been the smallest size fish for a given age. The geographic size cline consistently noted in the growth data seems to run counter to what might be expected, given the differential fishing pressure. The growth data do not indicate any detectable adverse impacts on the growth to maturity for Atka mackerel due to habitat disturbance.

Habitat Impacts Relative to Feeding

The adults feed mainly on pelagic euphausiids followed by calanoid copepods, which are not one of the affected habitat features (Yang 1999). As euphausiids and copepods are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal or temporary effect on the availability of prey to Atka mackerel.

No direct evidence is available to suggest that feeding distributions have changed. Euphausiids are a major prey of Atka mackerel. Euphausiids are not believed to be directly associated with the bottom, but rather are thought to be advected onshore near bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). This would indicate that any change in feeding distribution is caused by oceanographic influences rather than habitat disturbance.

No direct evidence is available that indicates any change in the diet of Atka mackerel. Because euphausiid and copepod distributions are likely not affected by habitat disturbances and are known to be widespread in the AI, it is doubtful that diet changes would be detectable between heavily fished and lightly fished regions. In summary, there is no evidence that habitat disturbance has affected feeding success of Atka mackerel.

Stock Status and Trends

Stock assessment information for Atka mackerel has been available from fisheries catch and fisheries age composition data since 1977, and trawl survey estimates of abundance and age composition data have been available since 1986 (Lowe et al. 2004). The age-structured stock assessment model indicates that Atka mackerel female spawning biomass increased during the early 1980s and again in the late 1980s to early 1990s. The stock has shown a steep increase in abundance after 2002 due to recruitment of three back-to-back strong year classes (1998, 1999, and 2000). The 2004 female spawning biomass is estimated at 204,400 mt (98 percent of the peak 1993 level). The data do not show a negative trend in spawning biomass or evidence of chronic low abundance. Because information is not available for the years before 1977, the trends prior to 1977 are unknown, as is the influence that long-term impacts to the habitat may have had on Atka mackerel abundance.

Model estimates of recruitment vary greatly but show above average (more than 20 percent of the mean) recruitment from the 1977, 1986, 1988, 1992, 1995, 1998, 1999, and 2000 year classes (Lowe et al. 2004). The 1999 year class is estimated to be the largest year class in the time series, contributing to the increased recent abundance levels. No obvious trend in recruitment is discernable since 1977, other than apparent above-average recruitment throughout the assessment time series. The data do not show a negative trend in recruitment or evidence of chronic low recruitment. Historical estimates of recruitment prior to 1977 are, however, not available for comparison.

There is no evidence that the cumulative effects of fishing activities on habitat have impaired the stock's ability to produce MSY since 1977. Spawning biomass is at a peak level, the stock has produced several years of above average recruitment since 1977, and recent recruitment has been strong (the 1999 year class is estimated to be the largest year class in the time series).

Summary

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Growth to Maturity	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of Atka mackerel are considered to be minimal and temporary or negligible. Affected habitat areas may impact Atka mackerel, but environmental conditions may be the dominant factor affecting the Atka mackerel population, given the moderate exploitation levels since 1977. Environmental conditions since 1977 may favor Atka mackerel and override impacts of fishing on habitat features important to the species. Some information, however, suggests that bottom trawling may have a negative effect on the benthic habitat, especially corals and sponges. The LEI analysis indicates that there is a potential for large reductions in hard coral habitats, which intersect with Atka mackerel habitat, and Atka mackerel have been observed in association with sponges and corals. The extent and nature of the associations between AI Atka mackerel and living and non-living substrate and hard corals are largely unknown. If these are desirable habitat features for Atka mackerel, however, and there is a significant dependance on these features, the potential large reduction (more than 50 percent) in hard corals in many areas of the AI could be of concern. Overall the Atka mackerel stock is in relatively good condition and is currently at a high abundance level. There are no indications that the affected habitat areas that overlap with the distribution of Atka mackerel would impair the ability of the stock to produce MSY over the long term.

There is some presumed overlap of the fishery with the distribution of Atka mackerel nesting sites, but the extent of the overlap with the spatial distribution of fishing impacted areas is likely to be low due a variety of factors. These factors include Steller Sea Lion protection measures, which likely afford protection to several Atka mackerel spawning grounds. Other spawning grounds that are not in closed areas, but that occur in untrawlable habitat, are also afforded protection. Summer resource assessment trawl surveys conducted biennially in the AI at the time of spawning provide a relative measure of abundance of the spawning biomass and have not detected a shift in the spatial distribution of biomass. To date, there is no evidence to suggest a link between habitat disturbance and the spawning/breeding success of AI Atka mackerel. There is also no evidence to suggest that habitat disturbance impairs the stock's ability to produce MSY over the long term through impacts on spawning/breeding success. Therefore, the impact of habitat disturbance on the spawning/breeding success of Atka mackerel is minimal and temporary.

There is no evidence to suggest a link between habitat disturbance and growth to maturity of AI Atka mackerel. There is also no evidence to suggest that habitat disturbance impairs the stock's ability to produce MSY over the long term through impacts on growth to maturity. Analyses of growth data do not indicate any detectable adverse impacts on the growth to maturity for Atka mackerel due to habitat disturbance. Therefore, the impact of habitat disturbance on the growth to maturity of Atka mackerel is minimal and temporary.

The adults feed mainly on pelagic euphausiids followed by calanoid copepods, which are not one of the affected habitat features. As euphausiids and copepods are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal and/or temporary effect on the availability of prey to Atka mackerel. There is no evidence to suggest that the diet or feeding distributions of Atka mackerel have changed. Overall, there is no evidence that habitat disturbance has affected feeding success of Atka mackerel. Therefore, the impact of habitat disturbance on the feeding success of Atka mackerel is minimal and temporary.

Stock assessment data do not show a negative trend in spawning biomass and recruitment or evidence of chronic low abundance and recruitment. There is no evidence that the cumulative effects of fishing activities on habitat have impaired the stock's ability to produce MSY since 1977. Spawning biomass is at a peak level. The stock has produced several years of above average recruitment since 1977, and recent recruitment has been strong.

B.3.3.5 Yellowfin Sole (BSAI)

Habitat Connections

Spawning/Breeding
Yellowfin sole spawn pelagic eggs in nearshore areas. These eggs have been observed in the plankton (Nichol and Acuna 2000), but it is not known what role the seafloor habitat has in spawning success. (See Section 3.2.1.2.3 for further discussion and references.)

Adult Feeding
Adult feeding primarily occurs throughout the continental shelf on benthic infauna and epifauna during the summer. Adults feed upon infauna and epifauna such as clams, polychaete worms, amphipods, other marine worms, and tunicates (Lang et al. 2003).

Growth to Maturity
Within the first year of life, yellowfin sole undergo metamorphosis from a free-swimming larvae stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles exhibit size-dependent sediment preference suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first line of defense for juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structure indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004). Growth from newly settled juveniles to mature adults is dependent on the infaunal and epifaunal supply of clams, polychaete worms, amphipods, other marine worms, and tunicates (Lang et al. 2003).

Evaluation of Effects

LEI Values Relative to Species Distribution
Spatial overlap exists between the areas with high fishing effects and the expansive yellowfin sole summer feeding habitat (Figure B.2-2a, Table B.3-3). This is particularly the case in the northernmost area identified as a high effort area because most of the trawling conducted there was in pursuit of yellowfin sole. The benthic habitat in this area is primarily sand and a sand/mud composite and is utilized by adult and late juvenile yellowfin sole during summer months for feeding on epifauna and infauna (Table B.3-1). The LEI table indicates that the reduction in epifauna and infauna prey is quite

low (2 to 3 percent), but may be as high as 18 percent for living structure in this habitat. The LEI model is, however, intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of flatfish responses to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas (Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

It is unknown what the effects of the physical disturbance of the benthos have on the availability of prey for individual yellowfin sole in the high effects area. It is known, however, that the total feeding area utilized by this species on a population level extends well to the north, east, and south of the identified high fishing effort areas. Because the high fishing effects area does not overlap the spawning or early juvenile habitat areas, and only partially overlaps the summer feeding distribution, it is unlikely that these affected areas would impair the ability of the stock to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding

The shallow inshore areas of Bristol Bay and Kuskokwim Bay where yellowfin sole spawn (and where early juveniles live) do not overlap with the spatial distribution of fishing impacted areas. Resource assessment trawl surveys conducted annually at the time of spawning partially overlap the spawning area and have not detected a shift in the spatial component of spawning since surveys began in 1979. Temporal shifts do occur, however, and are believed to be linked to bottom water temperature. Trends in recruitment success do not correspond with the temporal patterns in fishing effort, further suggesting that there is no link between the existing level of habitat disturbance on the middle portion of the BS shelf and spawning/breeding success in nearshore areas. In the presence of light to moderate exploitation, the stock has sustained an abundance level well above the B_{MSY} level (Wilderbuer and Nichol 2004a).

Habitat Impacts Relative to Growth to Maturity

There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile yellowfin sole. Figure B.2-2a indicates that fishing has not ranged into the nearshore shallow areas of Bristol Bay and Kuskokwim Bay to the extent that it would be classified as a high effects area. Thus, patterns in high or low juvenile survival cannot be linked to patterns in the reduction in habitat quality whereby the removal of living structure utilized as a refuge from predation resulted in increased juvenile mortality.

Yellowfin sole are considered late juveniles at sizes between 20 and 28 cm in length. The distribution of late juveniles ranges more offshore as they begin to be assimilated into the adult population. At this size/age some of their distribution overlaps with high fishing impact areas. To investigate the possible link between habitat disturbance and growth to maturity, diet data on file at the AFSC were examined for the period from 1984 to 1995 for both juvenile and adult yellowfin sole in the high-, low-, and no-fishing impact areas of stratum 3 (southern middle shelf). No trends were discernable in the proportion of empty stomachs encountered in any of the three areas over this period. For all fish examined (including those with empty stomachs) higher values of grams of epifauna/gram predator (averaged over all years) resulted from the low and high effort areas than from the no-fishing-effort area, for both juvenile and adult fish (Figure B.3.3.5-1).

This trend was reversed in the examination of grams infauna/gram predator where higher values were found in the no fishing area compared to the low and high effort areas (Figure B.3.3.5-2). The latter results were due to the high values of gram infauna/grams predator in both 1984 and 1985. After 1985, similar trends were found in all three areas. When total grams prey/grams predator were analyzed, no trends were evident between life-history stage and areas of fishing effort. These data suggest that there has not been an observable change in the diet of late juvenile stage fish or adult fish in high effort versus low effort areas to cause an undesirable effect on the growth to maturity. Furthermore, a comparison of the length and weight at age from fish collected during the 1987, 1994, and 1999 to 2001 trawl surveys indicates that there are only small differences in length and weight at age from 1987 to 2001 for fish 4 to 14 years old (Wilderbuer and Nichol 2004a).

Habitat Impacts Relative to Feeding

Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to discern if differences in growth were discernable between geographical areas. For yellowfin sole, it was determined that 6 years (1994, 1999, and 2001 to 2004) provided adequate sample sizes to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length were only found in 1 year out of the 6 examined (2003), where the higher values were found in the high fishing effort treatment group. This result, combined with the results of the diet study described in the previous section (for adult fish, Figures B.3.3.5-1 and B.3.3.5-2), indicates that current levels of fishing impacts on yellowfin sole habitat do not produce detectable effects on the growth and/or diet of yellowfin sole.

Patterns of the annual distribution and abundance of the summertime feeding distribution of yellowfin sole (available from trawl surveys) relative to the three fishing effort areas also do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). Stations with highest CPUE values are typically broadly dispersed over the middle shelf and upper/northern Bristol Bay and do not exhibit a spatial trend relative to the aggregated commercial fishing effort.

Stock Status and Trends

Stock information for yellowfin sole is available from fisheries catch and catch at age since 1964 and trawl survey estimates of abundance and age composition since 1982 and 1979, respectively. Stock assessment model estimates indicate that the yellowfin sole female spawning biomass was at low levels during most of the 1960s and early 1970s after a period of high exploitation (Figure B.3.3.5-3). Sustained above average recruitment from 1967 to 1976 combined with light exploitation resulted in a biomass increase to a peak in 1985 of 708,000 t. The female spawning biomass has since been in a slow decline, as the strong 1981 and 1983 year classes have passed through the population, and only the 1991 and 1995 years classes have been at levels observed during the 1970s. The 2004 female spawning biomass is estimated at 540,000 t (76 percent of the peak 1985 level).

The female spawning biomass has been sustained well above B_{MSY} for the past 20 years, and the annual fishing mortality rate has been below F_{MSY} during this period (Figure B.3.3.5-3). There is no evidence that the cumulative effects of fishing activity on habitat have impaired the stocks ability to produce MSY over this time period.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas, where spawning occurs and where early juveniles reside, are mostly unaffected by past and current fishery activities. Adult and late juvenile yellowfin sole concentrations primarily overlap with the EBS sand (61 percent and sand/mud 39 percent) habitats on the inner- and mid-shelf areas (Table B.3-3). Projected equilibrium reductions in epifauna and infaunal prey in those overlaps were less than 1 percent for sand and 3 percent for sand/mud. The reduction in living structure is estimated at a range of 5 (sand) to 18 (sand/mud) percent for the summer distribution (relevant because 10 percent of the yellowfin sole diet consists of tunicates). Given this level of disturbance, it is unlikely that late-juvenile and adult feeding would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis also did not provide evidence of spatial shifts on the population level in response to areas of high fishing impacts.

The yellowfin sole stock is currently at a high level of abundance (Wilderbuer and Nichol 2004a) and has been consistently above the B_{MSY} and MSST for the past 20 years. No declines in weight and/or length at age have been documented in this stock for year classes observed over the past 22 years. Such declines might be expected if the quality of the benthic feeding habitat was degraded or essential habitat were reduced. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are either minimal or temporary for BS yellowfin sole.

B.3.3.6 Greenland Turbot (BSAI)

Habitat Connections

Spawning/Breeding
Eggs are bathypelagic, and spawning is widespread throughout the EBS slope. It is not known what role the seafloor habitat has in spawning success. See Section 3.2.1.2.4 for further discussion and references.

Adult Feeding
Adult Greenland turbot feed primarily on pollock, squid, and deep water fish species during the summer throughout the deep slope waters and, to a lesser extent, on the upper slope/shelf margins (see Appendix F for reference). Most of the Greenland turbot feeding behavior is observed to take place off the bottom and is not related to benthic food availability.

Growth to Maturity
Within the first year of life, Greenland turbot undergo metamorphosis from a free-swimming larvae stage to the familiar asymmetrical morphological life form characteristic of flatfish. Upon settlement in nearshore areas, juvenile flatfish preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995). Although the Moles and Norcross (1995) studies did not evaluate Greenland turbot juveniles, they may be relevant for this species. Growth from newly settled juveniles to mature adults is dependent on the infaunal supply of polychaete worms, amphipods, and other marine worms.

Evaluation of Effects

LEI Values Relative to Species Distribution
Greenland turbot are a deep water species that inhabit shallow areas of the BS shelf as juveniles. They are primarily associated with BS sand/mud habitat and do not overlap areas identified as high fishing impact areas (Figure B.2-2a, Table B.3-3). The LEI table indicates that the reduction in epifauna prey (2 percent), as well as living structure (12 to 14 percent) is estimated to be low in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Because the high fishing effects area does not overlap the spawning, feeding, or juvenile distributions, these affected areas would not impair the ability of Greenland turbot to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Impacted habitat from fishing effects does not overlap with Greenland turbot spawning areas in the deep waters of the BS slope and the AI or shallow juvenile nursery habitat. Although trends in recruitment have been declining since the high levels attained in the mid to late 1970s, these reductions cannot be linked to trends in disturbed habitat over this time period due to the non-overlap. Greenland turbot have been above B_{MSY} for the past 20 years.

No information is available on annual winter spawning concentrations of Greenland turbot to discern if there have been spatial or temporal shifts in spawning distributions.

Habitat Impacts Relative to Growth to Maturity
Habitat impacts related to fishing do not occur in areas where early juvenile Greenland turbot reside and, thus, are not a source of early juvenile mortality. Late juveniles may be found on the BS shelf up to about age 4 before joining the adult population in deeper waters, but these fish are primarily distributed on the northern region of the shelf in areas designated as low- or no-fishing-effort areas. It is, therefore, unlikely that any of the documented disturbances on the middle to the southern areas of the shelf would impact their growth to maturity. It is unknown if changes in growth to maturity have occurred.

Habitat Impacts Relative to Feeding
Greenland turbot have not been aged to the extent that it is possible to discern if changes in length or weight at age have occurred over the past 25 years of trawl survey sampling. Given the lack of overlap in distributions discussed above, it is unlikely that the present level of habitat disturbance would be a factor relative to feeding success. Greenland turbot diet is primarily composed of pelagic or semi-pelagic species, which are encountered off-bottom and, thus, would be less likely to be affected by benthic habitat disturbance. The eight trawl surveys conducted on the continental slope over a 25-year period (first in 1979, last in 2004) do not indicate a shift in the summer feeding distribution of Greenland turbot.

Stock Status and Trends
The stock assessment model indicates that the biomass of Greenland turbot increased during the 1970s from the early 1960s level and has since declined to the current level (about 43 percent of the unfished level). The 2004 total biomass estimate is about 98,300 t (Ianelli et al. 2004b). The female spawning biomass is above the B_{MSY} level (Figure B.3.3.6-1). Recruitment of young Greenland turbot has been poor since the late 1970s, based on EBS shelf trawl surveys. Moderate recruitment during the 1980s was followed by poor recruitment during the 1990s. Some signs of improved recruitment beginning in 2000 may be evident.

Summary

Issue	**Evaluation**
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by early juveniles of Greenland turbot are mostly unaffected by current fishery activities. Greenland turbot adult and late juvenile concentrations primarily overlap (65 percent with sand/mud habitats in the BSAI) (Table B.3-3). Infaunal prey reductions would affect growth to maturity for late juvenile Greenland turbot. Infaunal prey reductions in the concentration areas in sand/mud habitats of the EBS are predicted to be 2 percent. This benthic disturbance is not thought to be relevant to adult Greenland turbot feeding success because fish species found in their diet are not directly associated with the seafloor.

The lack of overlap with shelf areas exhibiting effects from the reductions in habitat features from fishing indicate that their effect on Greenland turbot are minimal or temporary for the BSAI area.

B.3.3.7 Arrowtooth Flounder (BSAI and GOA)

Habitat Connections

Spawning/Breeding
Eggs are semi-demersal, and spawning is widespread throughout the outer shelf. In the GOA, spawning occurs in deep water (Blood et al. In prep.). It is not known what role the seafloor habitat has in spawning success. See Section 3.2.1.1.5 for further discussion and references.

Adult Feeding
Adults feed primarily on fish, squid, pandalid and cragonid shrimp, and euphausiids during the summer throughout the outer continental shelf and upper slope areas (see Appendix F for references). Therefore, benthic epifauna is important in their diet.

Growth to Maturity
Within the first year of life, arrowtooth flounder undergo metamorphosis from a free-swimming larvae stage to the familiar asymmetrical morphological life form characteristic of flatfish. Upon settlement in nearshore areas, juvenile flatfish preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments using rock sole and Pacific halibut indicate that sediment choice and cryptic behavior are the first line of defense for rock sole and other juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structure, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first line of defense for juvenile flatfishes (Stoner and Ottmar 2002). Although these studies did not evaluate arrowtooth flounder juveniles, they may be relevant for other juvenile flatfish. Growth from newly settled juveniles to mature adults is dependent on the infaunal supply of polychaete worms, amphipods, and other marine worms.

Evaluation of Effects

LEI Values Relative to Species Distribution
In the BS, spatial overlap exists between the areas with high fishing effects and the arrowtooth flounder summer feeding habitat (Figure B.2-2a, Table B.3-3). Because they are primarily distributed on the outer shelf area during summer, overlap mostly occurs in the southernmost high effort area. The benthic habitat in this area is primarily sand and a sand/mud composite and is utilized by adult and late juvenile arrowtooth flounder during summer months for feeding on epifauna and a diverse diet including crab, fish, and shrimp species (Table B.3-1). Most of the arrowtooth flounder distribution is located outside of these high effort areas in the summer, and there has not been a detectable shift in this seasonal distribution into or away from these areas from 1982 to 2004.

In the GOA, arrowtooth flounder have a widespread distribution with concentrations in the gullies that bisect the continental shelf. Thus, they overlap most high effort fishing areas as well as low- or no-fishing areas. During winter, the distribution moves more offshore, but there is no evidence of shifts in any seasonal distribution relative to high or low fished areas. The LEI table indicates that the reduction in epifauna and infauna prey is quite low (3 to 4 percent), but may be as high as 20 percent for living structure in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of flatfish responses to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas (Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

It is unknown what the effects of the physical disturbance of the benthos have on the availability of prey for individual arrowtooth flounder in the high effects area. It is known, however, that the total feeding area utilized by this species on a population level extends well beyond the identified high fishing effort areas. Because the high fishing effects area only partially overlaps the winter spawning area in both the BS and the GOA, does not overlap the early juvenile habitat areas, and only partially overlaps the summer feeding distribution, it is unlikely that these affected areas would impair the ability of the stock to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Arrowtooth flounder move into deeper waters of the BS shelf and the GOA in the winter for spawning and avoidance of cold water. Their distribution during this season partially overlaps the southernmost high effort area in the BS and the deeper parts of the high effort areas identified for the GOA. The effect of habitat disturbance has on the spawning ability or egg viability of arrowtooth flounder is unknown in this area. The inshore areas of Bristol Bay and Kuskokwim Bay and the bays along the Alaska Peninsula and Kodiak Island, where arrowtooth flounder larvae settle and develop into early juveniles, do not overlap with the spatial distribution of fishing impacted areas. Lacking a target fishery for arrowtooth flounder and a winter survey, it is unknown how their spawning distribution may have changed over time, if at all.

Trends in recruitment success also do not correspond with the temporal patterns in fishing, further suggesting that there is no link between the existing level of habitat disturbance on the middle and southern portions of the BS shelf or in the GOA and spawning/breeding success. In the presence of light exploitation, the stock has sustained an abundance level well above the B_{MSY} level in both sea areas (Wilderbuer and Sample 2004b, Turnock et al. 2003a).

Habitat Impacts Relative to Growth to Maturity

There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile arrowtooth flounder. Figures B.2-2a and B.2-5b indicate that fishing has not ranged into the nearshore shallow areas of Bristol Bay and Kuskokwim Bay to the extent that it would be classified as a high effects area. Similarly, the nearshore areas of Kodiak Island and the Alaska Peninsula have remained areas of low impact. Thus, patterns in high or low juvenile survival cannot be linked to patterns in the reduction in habitat quality whereby the removal of living structure utilized as a refuge from predation resulted in increased juvenile mortality.

Arrowtooth flounder are considered late juveniles when they attain sizes between 20 and 42 cm in length. Fish in this size range move offshore, and they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. However, because their distribution covers such a broad geographical area, the proportion that overlaps these areas is small.

Comparison of length at age over the past two decades in the GOA does not indicate a change in growth for juveniles or adults (Figures B.3.3.7-1 and B.3.3.7-2). Therefore, there is no evidence of a change in growth to maturity.

Habitat Impacts Relative to Feeding

Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing-induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to discern if differences in growth could be detected between geographical areas. For arrowtooth flounder, it was determined that 2 years (1996 and 2004) provided adequate sample sizes in the BS to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length were found in 1 year (1996), where the higher values were found in the low fishing effort treatment group. Because it is unknown to what extent site fidelity persists for arrowtooth flounder (individual fish move between areas), and only 2 years of data were available, this analysis cannot lead to a conclusion.

Patterns of the annual distribution and abundance of the summertime feeding distribution of arrowtooth flounder (available from trawl surveys) relative to the three fishing effort areas in both the BS and the GOA do not indicate a shift away from the heavily fished areas (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm), but rather an expansion of the distribution during the late 1980s from the early part of the decade due to strong year classes and increased abundance. Stations with highest CPUE values typically are broadly dispersed over the outer BS shelf and throughout the central and western GOA, and they do not exhibit a spatial trend relative to the aggregated commercial fishing effort.

Stock Status and Trends

The stock assessment model for the BSAI stock estimates that arrowtooth flounder total biomass increased more than 2.5 times from 1976 to the 1996 value of 759,400 t. The biomass has declined 7 percent since then to the 2004 estimate of 710,000 t (Figure B.3.3.7-3). Female spawning biomass is also estimated to be at a high level, 532,000 t in 2004, a 4 percent decline from the 1996 peak level. Increases in abundance from 1983 to 1995 were the result of five strong year classes spawned in 1980, 1983, 1986, 1987, and 1988. Since 1989, recruitment is estimated to be at or below the average from 1989 to 1993 and then stronger in 1995 and 1998. The 2001 year class also appears strong from small fish observed in the 2003 survey.

For the GOA, the stock assessment model estimates of age 3+ biomass increased from a low of 327,622 t in 1961 to a high of 2,391,550 t in 2003. The 2003 biomass estimate is higher than the estimated 2003 biomass from the 2002 assessment (about 1,800,000 t) due to the large increase in the 2003 survey biomass estimate. The model estimates of age 3 recruits have an increasing trend since the 1970s, providing the present high level of abundance.

The female spawning biomass has been sustained well above B_{MSY} for the past 20 years in both sea areas, and the annual fishing mortality rate has been well below F_{MSY} during this period. There is no evidence that the cumulative effects of fishing activity on habitat have impaired the stocks ability to produce MSY over this period. Both stocks are above B_{MSY} and are harvested well below F_{MSY}.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by arrowtooth flounder early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile concentrations primarily overlap the EBS sand/mud habitat (34 percent) and the GOA deep shelf habitat (35 percent) (Table B.3-3). Overall, epifaunal prey reduction in those overlaps is predicted to be 3 percent for EBS sand/mud and 1 percent for GOA deep shelf habitats. Given this level of disturbance, and the large percentage of the diet of arrowtooth flounder not including epifauna prey, it is unlikely that the adult feeding would be negatively impacted. The arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s and 1990s (Turnock et al. 2002). No change in weight and length at age has been observed in this stock from bottom trawl surveys conducted from 1984 through 2003.

The BS arrowtooth flounder stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Wilderbuer and Sample 2004b). The productivity of the stock is currently believed to correspond to favorable atmospheric forces in which larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). The GOA stock has increased steadily since the 1970s and is at a very high level. Therefore, the combined evidence from individual fish length-weight analysis, length at age analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for BSAI and GOA arrowtooth flounder.

B.3.3.8 Rock Sole (BSAI)

Habitat Connections

Spawning/Breeding
Although eggs are demersal and adhesive (specific gravity of 1.047, Hart 1973), it is not known what role the habitat has in spawning success. See Section 3.2.1.2.6 for further discussion and references.

Adult Feeding
Adults feed primarily on the infaunal supply of polychaete worms, amphipods, other marine worms, and sandlance (Lang et al. 2003) during the summer throughout the continental shelf.

Growth to Maturity
Within the first year of life, rock sole undergo a metamorphosis from free-swimming larvae to the familiar asymmetrical morphological life form characteristic of flatfish. Upon settlement in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first line of defense for rock sole and other juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structures, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004, Stoner and Abookire 2002). Growth from newly settled juveniles to mature adults is dependent on the infaunal supply of polychaete worms, amphipods, other marine worms, and sandlance (Lang et al. 2003).

Evaluation of Effects

LEI Values Relative to Species Distribution
Spatial overlap exists between the areas with high fishing effects and the widespread rock sole summer feeding habitat (Figure B.2-2a, Table B.3-3). They are commonly caught in the northernmost area identified as a high effort area as bycatch in the yellowfin sole fishery. The benthic habitat in this area is primarily sand and a sand/mud composite and is utilized by adult and late juvenile rock sole during summer months for feeding on epifauna and infauna (Table B.3-1). Most of the rock sole are distributed outside of these high effort areas in the summer, and there has not been a detectable shift in this seasonal distribution into or away from these areas from 1982 to 2004. During winter, rock sole distributions partially overlap the southernmost high effort area. The LEI table indicates that the reduction in epifauna and infauna prey are quite low (2 to 3 percent), but may be as high as 18 percent for living structure in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of flatfish responses to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas (Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

The effects of the physical disturbance of the benthos on availability of prey for individual rock sole are unknown in the high effects area. It is known, however, that the total feeding area utilized by this species on a population level extends well to the north, east, and south of the identified high fishing effort areas. Because the high fishing effects area only partially overlaps the winter spawning area, does not overlap the early juvenile habitat areas, and only partially overlaps the summer feeding distribution, it is unlikely that these effected areas would impair the ability of the stock to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Rock sole move into deeper waters of the BS shelf in the winter for spawning and to avoid cold water. Their distribution during this season partially overlaps the southernmost high effort area. The effect of habitat disturbance on the spawning ability or egg viability of rock sole is unknown in this area. The

shallow inshore areas of Bristol Bay and Kuskokwim Bay where rock sole larvae settle and develop into early juveniles do not overlap with the spatial distribution of fishing impacted areas. Observer sampling of the rock sole roe fishery, which occurs in southernmost high effort area, does not indicate a shift in spawning away from this area. Trends in recruitment success also do not correspond with the temporal patterns in fishing effort, further suggesting there is no link between the existing level of habitat disturbance on the middle and southern portions of the BS shelf and spawning/breeding success. In the presence of light exploitation, the stock has sustained an abundance level well above the B_{MSY} level (Wilderbuer and Walters 2004c).

Habitat Impacts Relative to Growth to Maturity
There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile rock sole. Figure B.2-2a indicates that fishing has not ranged into the nearshore shallow areas of Bristol Bay and Kuskokwim Bay to the extent that it would be classified as a high effect area. Thus, it is unlikely that patterns in high or low juvenile survival could be linked to patterns in the reduction in habitat quality whereby the removal of living structure utilized as a refuge from predation resulted in increased juvenile mortality.

Late juvenile rock sole sizes are from 20 to 34 cm long, and their distribution ranges more offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. To investigate the possible link between habitat disturbance and growth to maturity, diet data on file at the AFSC were examined from 1984 to 1995 for both juvenile and adult rock sole in the high-, low-, and no-fishing-impact areas of stratum three (southern middle shelf). No trends were discernable in the proportion of empty stomachs encountered in any of the three areas over this period. For all fish examined (including those with empty stomachs), higher values of grams of epifauna/gram predator (averaged over all years) resulted from the high effort area than from the low and no-fishing-effort areas for juvenile fish and were highest in the low fishing effort area for adults (Figure B.3.3.8-1).

The trend was different for grams infauna/gram predator where higher values were found for juveniles in the high and no-fishing-effort areas, and no discernable differences were present for adults (Figure B.3.3.8-2). When total grams prey/grams predator were analyzed, no trends were evident between life-history stage and areas of fishing effort. These data suggest that there has not been an observable change in the diet of late juvenile stage fish or adult fish in high effort versus low effort areas to cause an undesirable effect on the growth to maturity. A decline in weight and length at age has been documented in this stock for year classes between 1979 and 1987 (Walters and Wilderbuer 2000), but was hypothesized to be a density dependent response to a rapid increase in an expanding population and does not coincide with spatial and temporal patterns of trawl effort in the BS.

Habitat Impacts Relative to Feeding
Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to discern if differences in growth were discernable between geographical areas. For rock sole, it was determined that 3 years (2001, 2002, and 2003) provided adequate sample sizes to ensure the necessary contrast. Statistically significant differences in weight-at-length were found in only 1 year out of the 3 years examined (2001), where the higher values were found in the high fishing effort treatment group. The combination of this result and results of the diet study in the previous section (for adult fish, Figures B.3.3.8-1 and B.3.3.8-2) indicates that fishing-induced changes to habitat do not result in detectable changes in growth and/or diet trends of rock sole.

Patterns of the annual distribution and abundance of the summertime feeding distribution of rock sole (available from trawl surveys) relative to the three fishing effort areas also do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm), but rather an expansion of the distribution during the late 1980s from the early part of the decade due to strong year classes and increased abundance. Stations with the highest CPUE values are typically broadly dispersed over the middle shelf and upper/northern Bristol Bay and the Pribilof Island area, and they do not exhibit a spatial trend relative to the aggregated commercial fishing effort.

Stock Status and Trends

Stock information for rock sole is available from fisheries catch (since 1975), catch at age (since 1980), and trawl survey estimates of abundance and age composition since 1982 and 1980, respectively. The stock assessment model indicates that rock sole total biomass was at low levels from the mid 1970s through 1982 (200,000 to 500,000 t). From 1982 to 1995, a period characterized by sustained above-average recruitment (1980 to 1988 year classes) and light exploitation, the estimated total biomass rapidly increased at a high rate to nearly 2.0 million t by 1995. Since then, the model indicates that the population biomass has declined 38 percent to 1.23 million t in 2004. This decline is attributable to the below-average recruitment to the adult portion of the population during the 1990s. The female spawning biomass is estimated to be at a high, but slowly declining, level of 432,500 t in 2004 (Figure B.3.3.8-3).

The female spawning biomass has been sustained well above B_{MSY} for the past 15 years, and the annual fishing mortality rate has been well below F_{MSY} during this period. There is no evidence that the cumulative effects of fishing activity on habitat have impaired the stock's ability to produce MSY over this time period.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by rock sole early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile rock sole in the BSAI are primarily concentrated in sand/mud (41 percent) and sand (37 percent) habitats and are affected by levels of infaunal prey (Table B.3-3). Predicted reductions of infaunal prey in those concentration overlaps are 3 percent (sand/mud) and less than 1 percent (sand). Given this level of disturbance, it is unlikely that adult feeding would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis did not provide evidence of spatial shifts on the population level in response to areas of high fishing impacts.

The rock sole stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Wilderbuer and Walters 2004). The productivity of the stock is currently believed to correspond to favorable atmospheric forces in which larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). A decline in weight and length at age has been documented in this stock for year classes between 1979 and 1987 (Walters and Wilderbuer 2000), but was hypothesized to be a density dependent response to a rapid increase in an expanding population. Individual rock sole may have been displaced beyond favorable feeding habitat, rather than by a reduction in the quality of habitat. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for BS rock sole.

B.3.3.9 Flathead Sole (BSAI)

Habitat Connections

Spawning/Breeding

Flathead sole spawn large pelagic eggs in deeper waters near the continental shelf margin. These eggs develop into planktonic larvae. The role the habitat has in spawning success is currently unknown. See Section 3.2.1.2.7 for further discussion and references.

Adult Feeding

Adult feeding primarily occurs during summer on the middle and outer continental shelf areas on benthic infauna, epifauna, and certain fish species. Flathead sole are dependent upon an infaunal and epifaunal supply of polychaete worms, mysids, brittle stars, shrimp, and hermit crabs (Lang et al. 2003).

Growth to Maturity

Within the first year of life, flathead sole undergo metamorphosis from a free-swimming larvae state to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first line of defense for rock sole and other juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structures, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004). Although these studies did not evaluate flathead sole juveniles, they may be relevant for other juvenile flatfish. Growth from newly settled juveniles to mature adults is dependent on the infauna supply of polychaete worms, amphipods, and other marine worms (Lang et al. 2003).

Evaluation of Effects

LEI Values Relative to Species Distribution

Spatial overlap exists between the areas with high fishing effects and the widespread flathead sole summer feeding habitat (Figure B.2-2a, Table B.3-3). The benthic habitat in this area is primarily sand and a sand/mud composite and is utilized by adult and late juvenile flathead sole during summer months for feeding on epifauna and infauna (Table B.3-1). Flathead sole are mostly distributed outside of these high effort areas in the summer, and there has not been a detectable shift in this seasonal distribution into, or away from, these areas from 1982 to 2004. During winter, flathead sole distributions contract to the outer margins of the shelf and partially overlap the southernmost high effort area. The LEI table indicates that the reduction in epifauna and infauna prey are quite low (2 to 3 percent), but may be as high as 18 percent for living structure in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of the response of other flatfish species to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas

(Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

The effects of physical disturbance of the benthos on the availability of prey for individual flathead sole are unknown in the high effects area. It is known, however, that the total feeding area utilized by this species on a population level extends well to the north, east, south, and west of the identified high fishing effort areas. Because the high fishing effects area only partially overlaps the winter spawning area, does not overlap the early juvenile habitat areas, and only partially overlaps the summer feeding distribution, it is unlikely that these affected areas would impair the ability of the stock to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding

Flathead sole move into deeper waters of the BS shelf in the winter for spawning and to avoid cold water. Their distribution during this season partially overlaps the southernmost high effort area. The effect of habitat disturbance on the spawning ability or egg viability of flathead sole is unknown in this area. The shallow inshore areas of Bristol Bay and Kuskokwim Bay, where flathead sole larvae settle and develop into early juveniles do not overlap with the spatial distribution of fishing impacted areas. Trends in recruitment success also do not correspond with the temporal patterns in fishing effort, further suggesting that there is no link between the existing level of habitat disturbance on the middle and southern portions of the BS shelf and spawning/breeding success. In the presence of light exploitation, the stock has sustained an abundance level well above the B_{MSY} level (Spencer et al. 2004a).

Habitat Impacts Relative to Growth to Maturity

There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile flathead sole. Figure B.2-2a indicates that fishing has not ranged into the nearshore shallow areas of Bristol Bay and Kuskokwim Bay to the extent that it would be classified as a high effects area. Thus, patterns in high or low juvenile survival cannot be linked to patterns in the reduction in habitat quality whereby the removal of living structure utilized as a refuge from predation resulted in increased juvenile mortality.

Late juvenile flathead sole between 20 and 34 cm long have a distribution that ranges more offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. To investigate the possible link between habitat disturbance and growth to maturity, diet data on file at the AFSC were examined from 1984 to 1995 for both late juvenile and adult flathead sole in the high-, low-, and no-fishing-impact areas of stratum 3 (southern middle shelf). No trends were discernable in the proportion of empty stomachs encountered in any of the three areas over this period. For all fish examined (including those with empty stomachs), there was a trend toward higher values of grams of epifauna/gram predator (averaged over all years) resulting from the higher fished areas than from the no-fishing-effort area for adult fish. The values were highest in the high- and no-fishing-effort areas for juveniles (Figure B.3.3.9-1).

The trend was similar for grams infauna/gram predator where higher values were found for juveniles in the low and high fishing effort areas and trended to higher values in the low and high fished areas for adults (Figure B.3.3.9-2). When total grams of prey/grams predator were analyzed, no trends were evident between life-history stage and areas of fishing effort. These data suggest that there has not been an undesirable change in the diet of late juvenile stage fish or adult fish in high effort versus low effort areas to cause an undesirable effect on the growth to maturity.

Habitat Impacts Relative to Feeding
Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to discern if differences in growth were discernable between geographical areas. For flathead sole it was determined that 7 years (1997 and 1999 to 2004) provided adequate sample sizes to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length were found in 3 years out of the 7 years examined (2001, 2002, and 2004), where the higher values were found in the high fishing effort treatment group in 2001 and in the low fishing area in 2003 and 2004. The combination of this variable result with the diet study described in the previous section (for adult yellowfin sole, Figures B.3.3.5-1 and B.3.3.5-2) indicates that changes in growth and/or diet trends are not detectable among the high-, low-, and no-fishing-effort areas.

Patterns of the annual distribution and abundance of the summertime feeding distribution of flathead sole (available from trawl surveys) relative to the three fishing effort areas also do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm), but rather an expansion of the distribution during the late 1980s from the early part of the decade due to strong year classes and increased abundance. Stations with highest CPUE values are typically broadly dispersed over the middle shelf and outer shelf and around the Pribilof Island area, and they do not exhibit a spatial trend relative to the aggregated commercial fishing effort.

Stock Status and Trends
The stock assessment model uses trawl survey information since 1982 and fisheries catch since 1975 and indicates that the estimated total biomass (ages 3+) increased from a low of 122,374 t in 1977 to a peak of 941,919 t in 1993 (Figure B.3.3.9-3). Since 1993, estimated total biomass has declined to an estimated value of 577,628 t for 2004. Female spawning biomass shows a similar trend, although the peak value (313,028 t) occurred in 1997. The model indicates that the stock has remained above B_{MSY} the past 20 years.

The changes in stock biomass are primarily a function of recruitment, as fishing pressure has been relatively light. This decline is attributable to the below-average recruitment to the adult portion of the population during the 1990s, relative to the high level observed during the 1980s. There is no evidence that the cumulative effects of fishing activity on habitat have impaired the stock's ability to produce MSY over this period.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by flathead sole early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile flathead sole in the BSAI are primarily concentrated in sand/mud habitat (41 percent) and would be affected by reductions in infaunal and epifaunal prey (Table B.3-3). The predicted reductions for infaunal and epifaunal prey in the concentration overlap for EBS sand/mud habitat are 3 and 2 percent, respectively. Given this level of disturbance, it is unlikely that the adult feeding would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis also did not provide evidence of spatial shifts on the population level in response to areas of high fishing effort impacts.

The flathead sole stock is currently at a high level of abundance due to sustained above-average recruitment in the 1980s (Spencer et al. 2002). The productivity of the stock is currently believed to correspond to favorable atmospheric forcing whereby larvae are advected to nearshore nursery areas (Wilderbuer et al. 2002). A decline in weight and length at age has not been documented in this stock during the 22-year time horizon of the trawl surveys (Spencer et al. 2002). Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that effects of the reductions in habitat features from fishing are either minimal or temporary for BS flathead sole.

B.3.3.10 Flathead Sole (GOA)

Habitat Connections

Spawning/Breeding
Flathead sole spawn large pelagic eggs in deeper waters near the continental shelf margin. The eggs then develop into planktonic larvae. The role the habitat has in spawning success is currently unknown. See Section 3.2.1.1.7 for further discussion and references.

Adult Feeding
Adult feeding primarily occurs during summer on the middle and outer continental shelf areas on benthic infauna, epifauna, and certain fish species. Flathead sole are therefore dependent on the infaunal and epifauna supply of polychaete worms, mysids, brittle stars, shrimp, and hermit crabs.

Growth to Maturity
Within the first year of life, flathead sole undergo metamorphosis from a free-swimming larvae stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995). Although flathead sole have not been examined in laboratory experiments for sediment preference, they are likely to exhibit similar behavior to other flatfish species and select sediment suitable for burrowing. Growth from newly settled juveniles to mature adults is dependent on the supply of infauna prey such as polychaete worms, amphipods, and other marine worms (Lang et al. 2003).

Evaluation of Effects

LEI Values Relative to Species Distribution
Some spatial overlap exists between the areas with high fishing effects and the distribution of flathead sole during the summer feeding season. Flathead sole are associated with shallow areas of the GOA in the summer and the deep shelf area during the winter. The LEI table indicates that the reduction in epifauna and infauna prey are low in these areas (1 to 2 percent), but reductions in living structures may range higher (10 percent, Table B.3-3). However, the highest summertime CPUE values have resulted from trawl stations inshore of the high fishing impact areas, indicating that the total feeding area utilized by this species extends well beyond areas of high fishing effort. Thus, it is unlikely that these effected areas (with perceived low LEI scores) would impair the ability of flathead sole to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Flathead sole are known to settle from free-swimming larvae to the bottom in near-shore nursery areas. These areas do not overlap with the spatial distribution of fishing impacted areas, so there is no connection between juvenile mortality and habitat disturbance (removal of living structure utilized for predation protection) from fishing effort. During late fall and winter, flathead sole migrate to the deeper waters of the shelf/slope area for spawning and overwinter protection from extreme cold temperatures. These areas also do not overlap with the high fishing effect areas. There is little fishing for flathead sole during the spawning season in the GOA. Therefore, it is unknown whether any spatial or temporal shift in the spawning distributions has occurred. The stock is estimated to be above the B_{MSY} level (Turnock et al. 2003b). Therefore, there is no evidence that past and current trends in habitat disturbance from fishing impair flathead sole spawning/breeding from producing MSY.

Habitat Impacts Relative to Growth to Maturity
Flathead sole early juvenile habitat is inshore of the high fishing impact areas, generally in bays around Kodiak Island and along the Alaska Peninsula. A reduction in juvenile survival due to degradation in habitat quality from fishing effects is, therefore, unlikely. Late juvenile flathead sole are between 20 and 32 cm long (size at 50 percent maturity is 32 cm), and their distribution ranges more offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. As discussed in a previous section, highest CPUE values from summer surveys (when most growth occurs) did not occur in the high fishing effort areas and were widely distributed throughout the GOA relative to these areas. It is unknown if juvenile growth has changed over the past 20 years, but it is unlikely that the spatial and temporal trends in fishing effort have negatively impacted the growth to maturity.

Habitat Impacts Relative to Feeding
Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing-induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to determine if differences in growth were discernable between geographical areas. For flathead sole it was determined that 5 survey years (1984, 1987, 1999, 2001, and 2003) provided adequate sample sizes to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length existed in all years examined, where the higher values were found in the high fishing effort treatment group for 3 years (1999, 2001, and 2003) and in the lower fishing effort group for 2 years (1984 and 1987). These results, and the attendant assumption requiring site fidelity between years, which is most likely violated, do not allow for the conclusion that changes in growth have occurred due to changes in feeding in the high-, low-, and no-fishing-effort areas.

Patterns of the annual distribution and abundance of the summertime feeding distribution of flathead sole (available from trawl surveys) relative to the three fishing effort areas do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). Stations with the highest CPUE values are typically nearshore and did not exhibit a temporal shift in location over the survey time horizon.

Stock Status and Trend
The stock assessment model estimates that age 3+ biomass increased from about 256,600 t in 1984 to about 298,900 t in 1996, decreased slightly to about 287,000 mt in 2000 before increasing to 291,400 t in 2003 (Figure B.3.3.10-1). The projected 2004 female spawning biomass is estimated at 109,980 mt, well above the B_{MSY} level for this stock estimated at 47,700 t.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by flathead sole early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile flathead sole concentrations in the GOA primarily overlap with the deepwater shelf during winter (15 percent) and shallow water habitats during summer (14 percent, Table B.3-3). This species would be affected by reductions in the availability of infaunal and epifaunal prey. Both infaunal and epifaunal prey are predicted to be reduced 1 percent in concentration overlaps with deepwater shelf areas and less than 1 percent in shallow water habitat. Given this level of disturbance, it is unlikely that the adult feeding would be negatively impacted. Additionally, stock assessment modeling indicates that flathead sole have been at a stable level above B_{MSY} for the past 20 years.

The combined evidence from individual fish length-weight analysis, examination of recruitment, stock biomass, adult and juvenile distribution, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for GOA flathead sole.

B.3.3.11 Rex Sole (GOA)

Habitat Connections

Spawning/Breeding
Rex sole spawn pelagic eggs, and the role the habitat has in spawning success is unknown. See Appendix F for further discussion and references.

Adult Feeding
Adult feeding occurs primarily during summer on the continental slope and to a lesser extent on the outer shelf area. They are thought to be dependent on the infauna supply of polychaete worms, amphipods, and other marine worms (see Appendix F for references).

Growth to Maturity
Within the first year of life, rex sole undergo metamorphosis from a free-swimming larval stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juvenile flatfish preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing for protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments using rock sole and Pacific halibut indicate that sediment choice and cryptic behavior are the first line of defense for juvenile flatfishes (Stoner and Ottmar 2002, Stoner and Titgen 2003). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structures, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004, Stoner and Abookire 2002). Although these experiments were not conducted using rex sole, they may be informative regarding the importance of habitat for juvenile flatfish. Growth from newly settled juveniles to mature adults is dependent on the infauna supply of polychaete worms, amphipods, and other marine worms.

Evaluation of Effects

LEI Values Relative to Species Distribution
Some spatial overlap exists between the areas with high fishing effects and the distribution of rex sole during the summer feeding season. Rex sole are associated with mid- to outer-shelf areas of the GOA in the summer and the deep shelf area during the winter. The LEI table indicates that the reduction in epifaunal and infaunal prey is low in these areas (1 to 2 percent), but reductions in living structures may range higher (8 percent, Table B.3-3). The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Summertime CPUE from survey trawl stations indicates a widespread distribution, mostly outside of the high trawl effort areas, indicating that the total feeding area utilized by this species extends well beyond areas of high fishing effort. Thus, it is unlikely that these affected areas (with perceived low LEI scores) would impair the ability of rex sole to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Rex sole are known to settle from free-swimming larvae to the bottom in nearshore nursery areas. These areas do not overlap with the spatial distribution of fishing impacted areas, so it is unlikely that there is a connection between juvenile mortality and habitat disturbance (removal of living structure utilized for predation protection) from fishing effort. During late fall and winter, rex sole migrate to the deeper waters of the shelf/slope area for spawning and overwinter protection from extreme cold temperatures. These areas also do not overlap with the high fishing effect areas. It is unknown if any shifts in the spawning distributions of rex sole have occurred in the GOA, but the stock is estimated to be above the B_{MSY} level (Turnock et al. 2003b). Therefore, there is no evidence that trends in habitat disturbance from fishing impair rex sole spawning/breeding from producing MSY.

Habitat Impacts Relative to Growth to Maturity
Rex sole early juvenile habitat is inshore of the high fishing impact areas, generally in bays around Kodiak Island and along the Alaska Peninsula. A reduction in juvenile survival due to degradation in habitat quality from fishing effects is, therefore, unlikely. Late juvenile stages of rex sole grow to sizes between 20 and 35 cm long (size at 50 percent maturity is 35 cm, Abookire in review). Late juvenile rex sole are distributed more offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. As discussed in a previous section, most of the widespread summer feeding distribution (when most growth occurs) is located outside of the high fishing effects area. It is unknown if juvenile growth has changed over the past 20 years, but it is unlikely that the spatial and temporal trends in fishing effort have negatively impacted the growth to maturity.

Habitat Impacts Relative to Feeding
Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing-induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to determine if differences in growth were discernable between geographical areas. For rex sole, it was determined that 6 survey years (1984, 1987, 1990, 1993, 1999, and 2003) provided adequate sample sizes to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length existed in 2 of the years examined (1987 and 1993), where the higher values were found in the low fishing effort treatment group. These results, and the attendant assumption requiring site fidelity between years, which is most likely violated,

do not allow for the conclusion that changes in growth have occurred due to changes in feeding in the high-, low-, and no-fishing-effort areas.

Patterns of the annual distribution and abundance of the summertime feeding distribution of rex sole (available from trawl surveys) relative to the three fishing effort areas do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). Stations with the highest CPUE values were typically broadly distributed over the shelf and did not exhibit a temporal shift in location over the survey time horizon.

Stock Status and Trend

The stock assessment model estimates of age 3+ biomass increased from 78,200 t in 1982 to about 102,000 t in 1991, decreased to 73,500 t in 1998, then increased to 82,000 t in 2004. This abundance level is well above the $B_{35\%}$ level of 16,300 t (Figure B.3.3.11-1). Recruitment (estimated at age 3) was high in the mid to late 1980s before declining to below average levels from 1992 to 1996. Since 1998, rex sole recruitment has been above average (Turnock et al. 2004b).

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by rex sole early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile rex sole concentrations in the GOA primarily overlap with deepwater shelf habitat (51 percent) and slope habitat (14 percent) (Table B.3-3). These fish would be affected by reductions in infaunal prey. However, the predicted reductions in these concentration overlaps are 1 percent for deepwater shelf habitat and 1 percent for slope habitat. Given this level of disturbance, it is unlikely that the adult feeding would be negatively impacted. Additionally, stock assessment modeling indicates that rex sole have been at a stable level above B_{MSY} for the past 20 years. The combined evidence from individual fish length-weight analysis, examination of recruitment, stock biomass, adult and juvenile distribution, and CPUE trends indicate that the effects of the reductions in habitat features from fishing are minimal or temporary for GOA rex sole.

B.3.3.12 Alaska Plaice (BSAI)

Habitat Connections

Spawning/Breeding

Alaska plaice spawn eggs that are transparent and pelagic (Zhang et al. 1998), and the role the seafloor habitat has in spawning success is unknown. See Section 3.2.1.2.8 for further discussion and references.

Adult Feeding

Adult feeding primarily occurs on benthic infauna throughout the continental shelf during summer and is, therefore, dependent on the infaunal supply of polychaete worms, marine worms and, to a lesser extent, bivalves (see Appendix F for reference).

Growth to Maturity

Within the first year of life, Alaska plaice undergo a metamorphosis from a free-swimming larval stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first lines of defense for rock sole and other juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structures, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004, Stoner and Abookire 2002). Growth from newly settled juveniles to mature adults is dependent on the infauna supply of polychaete worms, other marine worms, and bivalves.

Evaluation of Effects

LEI Values Relative to Species Distribution

Spatial overlap exists between the northernmost area with high fishing effects and the Alaska plaice summer feeding habitat, which is widely spread over the middle and northern parts of the EBS shelf (Figure B.2-2a, Table B.3-3). They occur as bycatch in the yellowfin sole fishery, which takes place in the northernmost high effort area. The benthic habitat in this area is primarily sand and a sand/mud composite and is utilized by adult and late juvenile stage Alaska plaice during summer months for feeding on epifauna and infauna (Table B.3-1). Most of the Alaska plaice are distributed outside of these high effort areas in the summer, and there has not been a detectable spatial or temporal shift in this seasonal distribution into, or away from, these areas from 1982 to 2004 (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). During winter, Alaska plaice distributions partially overlap these high effort areas although less is known regarding their distribution in this season. The LEI table indicates that the reduction in epifauna and infauna prey are quite low (2 to 3 percent), but may be as high as 18 percent for living structure in this habitat. It is important to recognize that the LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of flatfish responses to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas (Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

The effects of the physical disturbance of the benthos on the availability of prey for individual Alaska plaice in the high effects area are currently unknown. It is known, however, that the total feeding area utilized by this species on a population level extends well to the north, east, and south of the identified high fishing effort areas. Because the high fishing effects area only partially overlaps the spring spawning area, the high impact area does not overlap the early juvenile habitat areas, and the high impact area only partially overlaps the summer feeding distribution, it is unlikely that fishing-induced impacts to habitat areas would impair the ability of the stock to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding

Less is known of Alaska plaice winter distributions relative to other shelf flatfish, as they occur less often in commercial catches during winter, and there are no surveys at this time of year. However, it is known that they spawn in springtime, probably over a broad range of the middle shelf. Therefore, it is likely that their distribution may partially overlap the northernmost high fishing effort area during this season. The effect of habitat disturbance on the spawning ability or egg viability of Alaska plaice in this area is unknown. The shallow inshore areas of Bristol Bay and Kuskokwim Bay, where Alaska plaice larvae settle and develop into early juveniles, do not overlap with the spatial distribution of fishing-impacted areas. There is insufficient information to detect whether a shift in spawning areas has occurred for Alaska plaice because they are seldom captured during the winter months. Trends in recruitment success also do not correspond with the temporal patterns in fishing effort, further suggesting that there is no link between the existing level of habitat disturbance on the middle and southern portions of the BS shelf and spawning/breeding success. In the presence of light exploitation, the stock has sustained an abundance level well above the B_{MSY} level (Spencer et al. 2004b).

Habitat Impacts Relative to Growth to Maturity

There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile Alaska plaice. Figure B.2-2a indicates that fishing has not ranged into the nearshore shallow areas of Bristol Bay and Kuskokwim Bay to the extent that it would be classified as a high effects area. Thus, patterns in high or low juvenile survival cannot be linked to patterns in the reduction in habitat quality whereby the removal of living structure utilized as a refuge from predation resulted in increased juvenile mortality.

Late juvenile stages of Alaska plaice grow to 20 to 34 cm long, and their distribution ranges more offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. To investigate the possible link between habitat disturbance and growth to maturity, diet data on file at the AFSC were examined from 1984 to 1995 for both juvenile and adult Alaska plaice in the high-, low-, and no-fishing-impact areas of stratum 3 (southern middle shelf). No trends were discernable in the proportion of empty stomachs encountered in any of the three areas over this period. For all fish examined (including those with empty stomachs), higher values of grams of epifauna/gram predator (averaged over all years) resulted from the high effort area than from the low- and no-fishing-effort areas for juvenile fish and were equal among all areas for adults (Figure B.3.3.12-1).

The trend was the same for grams infauna/gram predator where higher values were found for juveniles in the high fishing effort areas, and no discernable differences were present for adults (Figure B.3.3.12-2). When total grams prey/grams predator were analyzed, juveniles had higher weight per stomach in fished areas than in the unfished areas. No trends were evident for adults. These figures show that the 95 percent confidence intervals of these estimates overlap, indicating no significant trends exist. These data suggest that there has not been an observable change in the diet of late juvenile stage fish or adult fish in high effort versus low effort areas sufficient to cause an undesirable effect on growth to maturity.

Habitat Impacts Relative to Feeding

Survey size and weight data collected in lightly, moderately, and heavily impacted areas were examined for evidence that fishing-induced impacts to fish habitat triggered changes in the growth of adult fish. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to determine if differences in growth were discernable between geographical areas. For Alaska plaice, it was determined that 6 years (1999 to 2004) provided adequate sample sizes to ensure the necessary contrast. Results indicated that no statistically significant differences in weight-at-length were found at the 95 percent level between the treatment groups. The combination of this result with the diet study described in the previous section (for adult fish, Figures B.3.3.12-1 and B.3.3.12-2) indicate that changes in growth and/or diet trends are not detectable between the high-, low-, and no-fishing-effort areas.

Patterns of the annual distribution and abundance of the summertime feeding distribution of Alaska plaice (available from trawl surveys) relative to the three fishing effort areas do not indicate a shift away from the heavily fished area (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm), but rather show an expansion of the distribution during the late 1980s from the early part of the decade due to strong year classes and increased abundance. Stations with highest CPUE values are typically broadly dispersed over the middle shelf and upper/northern Bristol Bay and do not exhibit a spatial trend relative to the aggregated commercial fishing effort.

Stock Status and Trends

The model results show that estimated total Alaska plaice biomass (ages 3+) increased from 1,114,960 t in 1975 to a peak of 1,731,090 t in 1983 (Figure B.3.3.12-3). Since 1984, estimated total biomass has declined to 908,057 t in 2004, and the estimated 2005 total biomass is 912,872 t. The estimated survey biomass also shows a rapid increase to a peak biomass of 744,281 t in 1985 and a subsequent decline to 405,457 t in 2004.

The changes in stock biomass are primarily a function of recruitment variability, as fishing pressure has been relatively light. The fully selected fishing mortality estimates, although trending upward, show a maximum value of 0.11 in 1988 and have averaged 0.03 from 1975 to 2004. Estimated age-3 recruitment has shown high levels from 1975 to 1984, averaging 1.9 billion. From 1985 to 2003, estimated recruitment has declined, averaging 1.0 by 10^9. The Alaska plaice female spawning biomass has been above the B_{MSY} level for the past 20 years.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal or temporary effect)
Feeding	MT (Minimal or temporary effect)
Growth to maturity	MT (Minimal or temporary effect)

Summary of Effects—The nearshore areas inhabited by Alaska plaice early juveniles are mostly unaffected by current fishery activities. Adult and late juvenile Alaska plaice concentrations in the BSAI primarily overlap with the EBS sand habitat (42 percent) and the EBS sand/mud habitat (52 percent) (Table B.3-3). These fish would be affected by reductions in infaunal prey. However, the levels of reduction in those concentration overlaps are predicted to be less than 1 percent for EBS sand and 2 percent for EBS sand/mud habitat. Given this level of disturbance, it is unlikely that the adult feeding has been or would be negatively impacted. The diet and length-weight analysis presented in the preceding sections supports this assertion. The trawl survey CPUE analysis also did not provide evidence of spatial shifts on the population level in response to areas of high fishing effort impacts.

The Alaska plaice stock is currently at a high level of abundance (Spencer et al. 2004b) and well above the MSST. There have been no observations of a decline in length or weight at age for this stock over the 22 years of trawl survey sampling. Therefore, the combined evidence from diet analysis, individual fish length-weight analysis, examination of recruitment, stock biomass, and CPUE trends indicate that effects of the reductions in habitat features from fishing are either minimal or temporary for BS Alaska plaice.

B.3.3.13 Shallow Water Flatfish (GOA)

Habitat Connections

Eight species of flatfish comprise the shallow water management complex: Alaska plaice, starry flounder, yellowfin sole, southern rock sole, northern rock sole, sand sole, butter sole, and English sole. Southern and northern rock sole are the dominant species in this complex, both in terms of biomass and harvest. For this discussion of habitat relating to life history and biology of shallow water flatfish, the southern rock sole is used to characterize the group of species. The two species of rock sole are, by far, the dominant species in this group, both in terms of biomass and harvest. The habitat requirements of rock sole are not expected to be so different from other species in this group as to require separate analysis. The seafloor habitat is associated with southern rock sole settlement, growth to maturity, and adult feeding.

Spawning/Breeding
Although eggs are demersal and adhesive (specific gravity of 1.047, Hart 1973), it is not known what role the habitat has in spawning success. See Appendix F for further discussion and references.

Adult Feeding
Adult feeding occurs primarily during summer throughout the continental shelf on benthic infauna and is, therefore, dependent on the infauna supply of polychaete worms, amphipods, other marine worms, and sandlance (Lang et al. 2003).

Growth to Maturity
Within the first year of life, rock sole undergo a metamorphosis from a free-swimming larval stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing to achieve protection from predators (Moles and Norcross 1995, Stoner and Abookire 2002). Laboratory experiments indicate that sediment choice and cryptic behavior are the first lines of defense for rock sole and other juvenile flatfishes (Stoner and Ottmar 2002). These experiments further suggest that predators consume more age-zero flatfishes in sand than in sand with sponge or other emergent structures, indicating that bioshelter may influence predator-prey behavior (Ryer et al. 2004, Stoner and Abookire 2002). Growth from newly settled juveniles to mature adults is dependent on the infauna supply of polychaete worms, amphipods, other marine worms, and sandlance (Lang et al. 2003).

Evaluation of Effects

LEI Values Relative to Species Distribution
Spatial overlap exists between the areas with high fishing effects and the wide-spread rock sole summer feeding habitat (Figure B.2-2a, Table B.3-3). Since the first comprehensive surveys began in 1984, there has been a presence of southern rock sole in these high fishing effort areas. However, this species is broadly distributed over the GOA shelf, particularly in the western GOA and around Kodiak Island in areas that are outside the high effort areas. The benthic habitat in this area is primarily sand or sand and mud and is utilized by adult and late juvenile rock sole during summer months for feeding on epifauna and infauna (Table B.3-1). There has not been a detectable shift in this seasonal distribution into, or away from, these areas from 1984 to 2003 (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). During winter, rock sole move into deeper waters, and their distributions may partially overlap some of the high effort area. The LEI table indicates that the reduction in epifauna and infauna prey is quite low (1 percent), but it may be as high as 6 percent for living structures in this habitat. The LEI model is

intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Studies of flatfish responses to habitat disturbance have been conducted in other ecosystems. For North Sea plaice in size classes more than 35 cm, positive growth changes were significantly correlated with seabed disturbance and/or eutrophication in heavily fished offshore areas (Rijnsdorp and van Leeuwen 1996). It is unknown whether similar responses would be expected for a different species adapted to a different ecosystem.

The effects of the physical disturbance of the benthos on the availability of prey for individual rock sole in the high effects area are unknown. It is known, however, that the total feeding area utilized by this species on a population level extends well inshore and to the west end of the identified high fishing effort areas. Because the high fishing effects area only partially overlaps the winter spawning area, does not overlap the early juvenile habitat areas, and only partially overlaps the summer feeding distribution, it is unlikely that these affected areas would impair the long-term productivity of the stock.

Habitat Impacts Relative to Spawning/Breeding

Rock sole move into deeper waters of the GOA shelf in the winter for spawning and to avoid cold water. Their distribution during this season most likely partially overlaps some of the high effort areas, although the extent of their winter distribution is unknown. The effect of habitat disturbance has on the spawning ability or egg viability of rock sole in this area is currently unknown. The shallow inshore areas of the GOA, where rock sole larvae settle and develop into early juveniles do not overlap with the spatial distribution of fishing impacted areas. There is no available information regarding whether there has been a shift in spawning away from these areas. Due to the lack of a stock assessment model for this species, it is unknown if trends in recruitment correspond with the temporal patterns in fishing effort. In the presence of light exploitation, the stock has been in an increasing trend from 1984 to 2003. The biomass point estimates from the trawl surveys have ranged from 137,000 t in 1984 to a high of 207,000 t in 1993 (Turnock et al. 2004).

Habitat Impacts Relative to Growth to Maturity

There is little geographic overlap between areas of high or low fishing effects and areas inhabited by early juvenile rock sole. Figure B.2-5b indicates that fishing has not ranged into the nearshore shallow areas of the GOA, and they have remained areas of low impact. Patterns in high or low juvenile survival cannot be linked to reduction in habitat quality resulting from removal living structure utilized as a refuge from predation.

As rock sole reach 20 to 32 cm in length, they are considered late juveniles, and their distribution ranges offshore as they begin to be assimilated into the adult population. At this size/age, some of their distribution overlaps with high fishing impact areas. However, because their distribution covers such a broad geographical area, the proportion that overlaps these areas is small. It is unknown whether there is a change in length at age for rock sole in the GOA.

Habitat Impacts Relative to Feeding

Changes in growth in adult fish due to habitat destruction could impact the productivity of spawners and the long-term yield from the stock. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to determine if differences in growth were discernable between geographical areas. For rock sole, it was determined that 4 years (1984, 1990, 1999, and 2001) provided adequate sample sizes in the GOA to ensure the necessary contrast. Results indicated that statistically significant differences in weight-at-length were found in 3 years (1990, 1999, and 2001), where the higher values were found in the low fishing effort treatment group for 2 years (1990 and 2001) and in the high fishing effort area in 1999. Because the extent to which site fidelity persists for rock sole (individual fish move between areas) and variable growth results between areas, it cannot be concluded that habitat impacts have had an effect relative to feeding.

Stock Status and Trends
The biomass point estimates from the trawl surveys have ranged from 137,000 t in 1984 to a high of 207,000 t in 1993 (Turnock et al. 2004). Size composition estimates from the trawl surveys indicate a mode of small fish entering the population in 1999 and again in 2003.

Summary

Issue	**Evaluation**
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—The nearshore areas inhabited by early juveniles of GOA shallow water flatfish are mostly unaffected by current fishery activities. Adult and late juvenile rock sole concentrations, as a proxy for GOA shallow water flatfish, primarily overlap with shallow water habitats (13 percent) (Table B.3-3). The predicted reduction of infaunal prey in this overlap is 1 percent. Given this level of disturbance, it is unlikely that adult feeding would be negatively impacted, and effects are believed to be minimal or temporary for rock sole. It is unknown, however, for the other seven species of the shallow water flatfish complex.

The level of information available for rock sole and the other species of the shallow water complex are insufficient to estimate the stock size relative to B_{MSY}, although trawl survey abundance estimates indicate a stable to increasing level of biomass since 1984. Because the population biomass level required to produce long-term sustainability is unknown, the impacts of the effects of fishing on the habitat required for spawning, adult feeding, or juvenile survival and growth to maturity are unknown.

B.3.3.14 Deep Water Flatfish (GOA)

Habitat Connections

Three species comprise this management group: Greenland turbot, Dover sole, and deep sea sole. For this discussion of habitat relating to life history and biology, Dover sole is used to characterize the group of species. Dover sole are, by far, the dominant species in this group, both in terms of biomass and harvest. Their habitat requirements are not expected to be so different from other species in this group that they require separate analysis. The seafloor habitat is associated with Dover sole settlement, growth to maturity, adult feeding, and spawning.

Spawning/Breeding
Dover sole spawn pelagic eggs in the deep waters of the continental shelf and slope. It is not known what role the habitat has in spawning success. See Appendix F for further discussion and references.

Adult Feeding
Adult feeding primarily occurs during summer on the continental slope and, to a lesser extent, on the outer shelf area. The species are thought to be dependent on the infauna supply of polychaete worms, amphipods, and other marine worms.

Growth to Maturity
Within the first 2 years of life, Dover sole undergo metamorphosis from a free-swimming larval stage to the familiar asymmetrical morphological life form characteristic of flatfish. After settling in nearshore areas, juveniles preferentially select sediment suitable for feeding on meiofaunal prey and for burrowing for protection from predators (Moles and Norcross 1995). Although this cited research did not include Dover sole, it is suspected that sediment selection is also important for Dover sole. Growth from newly settled juveniles to mature adults is dependent on the infauna supply of polychaete worms, amphipods, and other marine worms.

Evaluation of Effects

LEI Values Relative to Species Distribution
Dover sole are primarily a deep water species that inhabit shallow areas of the BS shelf as juveniles, but they are also found mid-self as adults during the summer (the 100 to 200 m depth interval has the highest proportion of biomass in each survey. They are primarily associated with GOA deep shelf and slope habitat and overlap some of the high fishing impact areas (Figure B.2-5b, Table B.3-3). The LEI table indicates that the reduction in epifauna prey (1 percent), as well as living structure (6 percent) is estimated to be low in this habitat. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Dover sole are distributed throughout the GOA on the deep shelf during summer, and most of the biomass is not located in the high fishing effect areas. Because the high fishing effects area only partially overlaps the spawning, feeding, or late juvenile distributions, these affected areas are not likely to impair the ability of Dover sole to produce MSY over the long term.

Habitat Impacts Relative to Spawning/Breeding
Impacted habitat from fishing effects is not likely to overlap the Dover sole spawning areas, which are located in the deep waters of the GOA slope and deep shelf during winter and also the shallow juvenile nursery habitat. Trends in recruitment do not correspond with the trend in fishing effort in the GOA such that years of below average recruitment (1988 to 1996) cannot be linked to trends in disturbed habitat. Dover sole have been above B_{MSY} for the past 20 years (Turnock and A'mar 2004a).

Habitat Impacts Relative to Growth to Maturity
Habitat impacts related to fishing do not occur in areas where early juvenile Dover sole reside and, thus, are not a source of early juvenile mortality. Late juveniles may be found on the GOA shelf with the adult population and in deeper waters, but these fish are primarily distributed on the shelf in areas designated as low- or no-fishing-effort areas. It is, therefore, unlikely that any of the documented disturbances in the GOA would impact their growth to maturity. It is unknown if changes in growth to maturity have occurred.

Habitat Impacts Relative to Feeding
Changes in growth in adult fish due to habitat destruction could impact the productivity of spawners and the long-term yield from the stock. Length-weight observations collected from individual fish during the summertime trawl surveys were identified from the high-, low-, and no-fishing areas to discern if differences in growth were discernable between geographical areas. For Dover sole, it was determined that only 1 year (2003) provided adequate sample sizes in the GOA to ensure the necessary contrast. Results indicated that no statistically significant differences in weight-at-length were found between treatment groups. Given the lack of information on weight or length at age by area for Dover sole, it is unknown if growth changes have occurred over the past 20 years. Due to fish movements and the lack of overlap with high fishing areas, it is unlikely that impacts in these areas have had a negative impact relative to feeding.

Stock Status and Trends

The stock assessment model estimates of age 3+ biomass decreased from a high of about 168,000 t in 1986 to about 1,000,000 t in 2001, then increased slightly to 102,000 t in 2004. Female spawning biomass increased from about 55,000 t in 1984 to 62,000 t in 1990 before declining to about 37,000 t in 2004 (Table B.3-4).

The model estimates of age 3 recruits decrease from 1984 to the mid-1990s, then increase and fluctuate about the mean recruitment in recent years.

Summary

Issue	**Evaluation**
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—The nearshore areas inhabited by early juveniles of GOA deepwater flatfish are mostly unaffected by current fishery activities. Adult and late juvenile Dover sole concentrations in the GOA, as a proxy for GOA deepwater flatfish, primarily overlap with deepwater shelf habitat (58 percent), slope habitat (19 percent), and shallow water habitat (21 percent) (Table B.3-3). This species is dependent on infaunal prey. However, reductions of infaunal prey in those concentration overlaps are predicted to be 1 percent for each of those habitats. Given this level of disturbance, it is unlikely that the adult feeding would be negatively impacted.

The level of information available for the species other than Dover sole is insufficient to estimate the stock size relative to B_{MSY}. Because these levels are unknown for most of the species in this complex, the impacts of the effects of fishing on the habitat required for spawning, adult feeding, or juvenile survival and growth to maturity for the deep water complex are unknown.

B.3.3.15 Pacific Ocean Perch (BSAI)

Habitat Connections

Pacific ocean perch (*Sebastes alutus*) are distributed on the outer continental shelf from southern California, north to the GOA and the EBS, and west to the Aleutian and Kuril Islands (Major and Shippen, 1970). In Alaskan waters, concentrations of abundance occur in the GOA and the AI, with smaller concentrations along the EBS slope. Adult Pacific ocean perch occur at depths from 150 m to 460 m (Major and Shippen 1970); mean depths observed in recent summer AI trawl surveys have been approximately 200 m.

Pacific ocean perch exhibit viviparous reproduction, which is marked by three critical points in the reproduction process: mating (the transferring of spermatozoa from males to females), fertilization of ova, and parturition (the release of larvae). Seasonal migrations from deeper water in winter to shallower water in summer affect the habitats in which these events occur. Gunderson (1971) found that Pacific ocean perch off British Columbia were in the shallower water (approximately 200 m) from June to August and deeper water (approximately 325 m) from December to May. Gunderson (1971) concluded that mating occurred in September to October for British Columbia Pacific ocean perch, near the time of migration to deeper water, and estimated that the peak period of parturition occurred in March. Lyubimova (1965) also estimated that for GOA Pacific ocean perch 3 to 4 months passed between mating and fertilization. Observations of larval rockfish in ichthyoplankton surveys are consistent with a spring period of parturition (Matarese et al. 2003).

Larval Pacific ocean perch are pelagic and are thought to become demersal within the first year of life (Carlson and Haight 1976, Carlson and Straty 1981). Little is known about the feeding habits of Pacific ocean perch during the planktonic stage, in part due to the difficulty of identifying larval rockfish to species. Pacific ocean perch are plankton feeders, with juveniles eating calanoid copepods and adults eating largely euphausiids (Yang 1993, 1996). Brodeur (2001) found that adult Pacific ocean perch in Pribilof Canyon feed on swarms of euphausiids that are not associated with benthic habitat, but rather are thought to result from onshore advection to upstream areas of canyons.

Information on the habitat of juvenile Pacific ocean perch (Table B.3-1) is available primarily from a limited number of submersible studies. In an early study using trawl gear in southeast Alaska coastal areas, Carlson and Haight (1976) found that 1- to 2-year-old fish resided in substrates consisting of cobbles, pebbles, and sand, although later studies using submersibles have documented the use of more rugged habitat by juveniles. Carlson and Straty (1981) found juvenile nursery grounds off southeast Alaska to occur at depths of 90 to 100 m over rough bottom (pinnacles and boulder fields interspersed with gravel and invertebrate shells). Straty (1987) found that juvenile Pacific ocean perch occupied rocky coastal areas off southeast Alaska at depths of 134 to 171 m; the ranges in age and size of these juveniles were 1 to 3 years and 78 to 164 mm. These juvenile Pacific ocean perch and other juvenile rockfish took refuge in rocky areas when alarmed by the movement of the submersible. Straty (1987) also noted that juvenile rockfish were associated with stands of large white anemones. Kreiger (1993) conducted transects with a submersible in southeast Alaska waters over a depth range of 188 to 292 m and noted the use of rugged habitat (cobble, boulders, and ledges with coral) by small (less than 25 cm) Pacific ocean perch, with the highest densities occurring over untrawlable areas. Thus, there is evidence relating living and non-living structures to juvenile habitat use and growth to maturity. Based upon the existing studies cited above, these linkages occur in the BS slope (200 to 1,000 m) and in both shallow (less than 200 m) and deep (more than 200 m) in the AI and in soft (sand to gravel) and hard (pebble to rock) habitat types.

Adult Pacific ocean perch occupy deeper waters than juvenile Pacific ocean perch, and adults are generally associated with smoother substrates than juveniles (Table B.3-1). Kreiger (1993) found that adult Pacific ocean perch (more than 25 cm) have been found in pebble substrates with little relief. The 2002 and 2004 trawl surveys in the AI indicate the modal lengths of Pacific ocean perch in the 0 to 100 m depth range is approximately 20 cm, and the modal lengths progressively increase with increasing depths. Adult Pacific ocean perch have been associated with sea whips (Broduer 2001) and sea pens (Kreiger 1993). Thus, there is evidence relating living (sea whips and sea pens) and non-living structure (pebble substrates) to adult habitat use. Based upon the existing studies cited above, these linkages occur in the BS slope (200 to 1,000 m), in both shallow (less than 200 m) and deep (more than 200 m) water in the AI, and in soft (sand to gravel) and hard (pebble to rock) habitat types.

Evaluation of Effects

LEI Values Relative to Species Distribution

The general distribution (95 percent distribution) of the adult Pacific ocean perch population within BSAI waters occurs primarily within the AI deep and the AI shallow habitat types, contributing 21 and 10 percent of the total Alaska Pacific ocean perch distribution, respectively (Table B.3-3). The potential reductions in living structure and non-living structure in the AI deep habitat (200 to 1,000 m) in the general distribution of Pacific ocean perch were projected to be 5 and 3 percent, respectively. In the AI shallow areas, the potential reductions in living and non-living habitat features were projected to be 13 and 8 percent, respectively. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. In addition, such percentages pertain the entire stock over large spatial scales, and examination of the LEI maps indicates that localized areas of higher impacts do occur south of Adak Island, near Seguam Pass, and northeast of Atka Island. Although these areas have not contributed a large portion of the total BSAI biomass in recent surveys, such maps are difficult to interpret (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). The projected impacts on hard corals in the AI deep and AI shallow habitat areas were 12 and 28 percent, respectively. However, Pacific ocean perch generally have not been found to be associated with hard corals. For example, Kreiger and Wing (2002) conducted 11 submersible dives in the GOA at depths from 161 to 365 m and did not find that Pacific ocean perch were associated with *Primnoa*, a gorgonian coral.

Habitat Impacts Relative to Spawning/Breeding

Little information exists on the spawning and breeding behavior of BSAI Pacific ocean perch. Based upon studies conducted in the GOA, mating is expected to occur in the fall and parturition in the spring. The distribution of mating and spawning fish is not available from current data, as both the research surveys and directed fishery for Pacific ocean perch occur in the summer months when Pacific ocean perch are neither mating nor spawning. Summer survey data are not a useful proxy for spawning distributions, as Gunderson (1971) noted seasonally dependent depth changes associated with spawning activity.

Maturity at age studies have not been completed for the BSAI Pacific ocean perch, so it is not possible to state whether changes in maturity at age can be related to habitat impacts. Field specimens collected in 2004 will provide the basis of initial studies on maturity for AI Pacific ocean perch.

For BS Pacific ocean perch, Moiseev and Paraketsov (1961) noted that parturition does not appear to be related to benthic habitat, as spawning females released larvae from 25 to 30 m off the bottom over depths of approximately 400 m. Similarly, the processes of mating and parturition for rockfish have not been observed to critically depend upon benthic habitat features (Love at al. 2002). There is no evidence that suggests that habitat impacts have affected the ability of BSAI Pacific ocean perch to conduct the mating and spawning processes, although it should be noted that very little is known regarding these processes.

Habitat Impacts Relative to Growth to Maturity

The information available on the habitat preferences on juvenile Pacific ocean perch is limited to the few references cited above that relied upon submersible research. As mentioned above, these studies indicate that juvenile Pacific ocean perch use rocky habitats as refuge areas, and Straty (1987) noted that juvenile red rockfish were captured in stands of large white anemones.

Habitat linkages between juvenile Pacific ocean perch and living (anemones) and non-living (rocky habitats) habitat structures were detected; therefore, fishing impacts on living and non-living habitats were evaluated with respect to their potential impact on Pacific ocean perch growth and survival. Based upon the LEI analysis, long-term reductions in either the living or non-living habitat features in the AI deep or shallow habitat types are not expected to exceed 13 percent. However, as mentioned above, localized areas of higher intensity impacts to living and non-living structures occur in the regions south of Adak Island, near Seguam Pass, and northeast of Atka Island. As mentioned above, analysis of summer survey CPUE revealed that only a small fraction of the Pacific ocean perch population utilizes these higher impact areas (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). The uncertainty in the data should also be noted, as the LEI maps in the AI are only a relative indicator of impact (see Sections B.2.5 and B.2.6). They are also difficult to interpret because the pattern of impacts may occur at finer spatial scales than presented in this analysis, and the trawl surveys typically do not sample juvenile rockfish very well.

Distribution maps were examined to evaluate whether habitat impacts resulting from intense fishing may have impacted the growth and survival of juvenile Pacific ocean perch, as revealed by changes in distribution. The distribution of small AI Pacific ocean perch does not appear to have changed substantially in recent surveys, with centers of abundance consistently located in the Buldir Island/Agattu Island areas and south of Amchitka Island. Given the rather large sampling variability in rockfish biomass estimates from trawl surveys, changes in distribution, particularly over small spatial scales, will be difficult to detect.

Length-weight data were examined to evaluate whether habitat impacts resulting from intense fishing may have reduced weight at length. A statistical analysis was conducted to examine this potential effect; data are available in 1986, 1997, and 2000, with the sample size in the high fished areas not exceeding 90 fish for any year. In 1986 and 2000, the weight at lengths were greater in highly fished areas, whereas in 1997 the weight at lengths were greater in low fish areas. The results are inconclusive, as no consistent pattern emerged between the years, and the statistical power is expected to be low due to the small sample size.

No direct evidence suggests that the growth to maturity of BSAI Pacific ocean perch has been affected by habitat disturbance, although the reliance of juvenile Pacific ocean perch upon both living and non-living habitat features and the potential for fishing to affect these habitats raises concerns. For example, if Pacific ocean perch show spatial heterogeneity related to timing of parturition, as proposed by Berkeley et al. (2004), then impacts on growth to maturity on smaller spatial scales could affect the BSAI stock. The extent to which habitat impacts occur at smaller spatial scales and the importance of these impacts to the overall BSAI population are unknown.

Habitat Impacts Relative to Feeding

The major prey items for Pacific ocean perch are calanoid copepods (as juveniles) and euphausiids (as adults). Because both of these prey items reside in pelagic habitats and are not associated with benthic environments, there is no reason to suspect a link between benthic habitat disturbance and prey availability or feeding success.

Information from a recent AI survey does not suggest major changes in the distribution of Pacific ocean perch. Because the prey of Pacific ocean perch occur within pelagic habitats and are not associated with benthic habitats, any changes in the distribution of prey are more likely to occur from changes in oceanographic conditions than from benthic habitat impacts. For example, Brodeur (2001) proposed that euphausiid populations within Pribilof Canyon resulted from advection from areas off the continental slope.

Although limited information exists on diet, no direct evidence suggests that diet of Pacific ocean perch has changed substantially over time. The diet studies of Yang (1993, 1996) for AI Pacific ocean perch are consistent with the results on Carlson and Haight (1976) for Pacific ocean perch off southeast Alaska.

Stock Status and Trends

Estimates of spawning biomass from population assessment models indicate that BSAI Pacific ocean perch spawning biomass has fluctuated dramatically in response to fishing pressure. The spawning stock biomass, as estimated in the 2004 Pacific ocean perch stock assessment (Spencer and Ianelli 2004), was approximately 109,000 t in 1960, decreased to 24,000 in 1979, and increased to 134,000 t in 1998 and has remained at approximately that level (Figure B.3.3.15-1). These changes in spawning biomass are consistent with high exploitation rates of Pacific ocean perch in the 1960s and early 1970s and the rebuilding of Pacific ocean perch beginning in the early 1980s.

Estimated recruitment of BSAI Pacific ocean perch has varied considerably, and the strong recruitment of the 1981, 1984, and 1986 year classes has allowed stock increases from the low levels in the late 1970s. With the exception of the 1962 year class, the strong recruitment in the early 1980s is comparable to that estimated for the early 1960s.

Trends in recruitment success also do not correspond with the temporal patterns in fishing effort (Figure B.3.315-2) and recruitment for Pacific ocean perch, further suggesting that if a relationship exists between local regions of heavy fishing and future recruitment, this impact does not manifest itself at the population scale.

Information on stock status does not suggest that the cumulative effects of fishing have impaired the ability of BSAI Pacific ocean perch to produce MSY. Recruitment was strong for several year classes in the early 1980s, resulting in the increase in biomass.

Summary

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Growth to Maturity	U (Unknown)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of BSAI Pacific ocean perch are rated as either unknown or minimal and temporary. The percent reduction in living and non-living substrates in the areas most commonly inhabited by BSAI Pacific ocean perch (the AI deep and AI shallow habitats) do not exceed 13 percent. Although larger percent reductions for hard corals are estimated, studies on habitat associations have not associated Pacific ocean perch with hard coral (Kreiger and Wing 2002). There is little information to suggest that these habitat reductions would affect spawning/breeding or feeding in a manner that is more than minimal or temporary, although much is unknown for these processes for BSAI Pacific ocean perch.

Regarding growth to maturity, the available literature does indicate that juvenile red rockfish do use living (anemones) and non-living (rocky areas) habitat features, with one specific use being the ability to find refuge from predators. Trawling would be expected to have negative impacts for these life stages, although the extent to which the BSAI Pacific ocean perch stock is dependent upon these habitat features is not well known. Although the LEI percentages do not exceed 13 percent for the living and non-living substrates, these figures should be interpreted as rough guidelines that are estimated with some error and relate to entire BSAI stock. Examination of LEI maps indicates that finer scale impacts do occur and could be important for stocks such as Pacific ocean perch, which are thought to show population structure on small spatial scales (Withler et al 2001). Similarly, although the current population level data do not indicate declining trends in spawning biomass or recruitment, it is not clear what effects may have occurred at finer spatial scales.

B.3.3.16 Pacific Ocean Perch (GOA)

The Pacific ocean perch is the most abundant GOA rockfish and the most important commercially. The species was fished intensely in the 1960s by foreign factory trawlers (350,000 mt at its peak in 1965), and the population declined drastically due to this pressure. The domestic fishery began developing in

1985. Quotas climbed rapidly, and the species was declared overfished in 1989. A rebuilding plan was put into place, and quotas were small in the early 1990s. After some good recruitments and high survey biomass estimates, the stock was declared to be recovered in 1995. Data showing effects of fishing on habitat for Pacific ocean perch are sparse. Most associations with particular habitats, living and non-living structures, are tenuous. Catch-per-unit-effort data are limited for the small amounts of area that are considered high-intensity trawling areas in the GOA. Very little is known regarding the reproductive behavior of Pacific ocean perch. Additionally, only several hundred individual specimens were collected over the entire GOA in the high-intensity trawl area, which results in low-power analyses on growth changes. The potential linkages between habitat disturbance by fishing and the health of the Pacific ocean perch population in the GOA are described below.

Habitat Connections

Though more is known about the life history of Pacific ocean perch than about other rockfish species (Kendall and Lenarz 1986), much uncertainty still exists about specific habitat preferences (Table B.3-1). Pacific ocean perch is primarily a demersal species that inhabits the outer continental shelf and upper continental slope regions of the North Pacific Ocean and the EBS from southern California to northern Honshu Island, Japan (Allen and Smith 1988). The species appears to be most abundant in northern British Columbia (Schnute et al. 2001), the GOA (Hanselman et al. 2003), and the AI (Spencer and Ianelli 2003). As adults, they most commonly live on or near the sea floor at depths ranging from about 150 to 420 m, with summer surveys revealing high density patches between 180 and 225 m (Hanselman et al. 2001). Following insemination, females appear to migrate into deeper waters to overwinter (500 to 700 m), often near the mouths of submarine gullies, and stay there until the time of larval release (Love et al. 2002).

Spawning/Breeding

Similar to other rockfish, Pacific ocean perch have internal fertilization and release live young. There is little information on reproductive behavior for Pacific ocean perch, except that insemination occurs in the fall, and larvae release occurs in April or May. A number of studies have examined length-at-maturity and age-at-maturity of Pacific ocean perch for different regions. Although studies prior to 1983 used surface reading of otoliths, the bias of ages from surface reading was not large until well after the average age at 50 percent maturity. Westrheim (1975) estimated an age at 50 percent maturity of 10 for the western GOA and 15 for the eastern GOA. Chikuni (1975) estimated an age at 50 percent maturity of 7 for the overall GOA. Lunsford (1999) conducted the largest study that resulted in an age at 50 percent maturity of 10.5 for the GOA. Other areas south of the GOA had estimated ranges for age at 50 percent maturity between 7 and 12 (Gunderson 1976, Westrheim 1975, Gunderson 1977, Gunderson 1997, Richards and Olsen 1996). Little is known about the location or behavior of spawning in Pacific ocean perch. Consequently, there is no evidence that links habitat features with the ability of Pacific ocean perch to accomplish the spawning/breeding process.

Feeding

Pacific ocean perch are mostly planktivorous (Carlson and Haight 1976, Yang 1993, 1996, Yang and Nelson 2000, Yang 2003). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. Larger juveniles and adults fed primarily on euphausiids and, to a lesser degree, on copepods, amphipods, and mysids (Yang and Nelson 2000). In the AI, myctophids have increasingly comprised a substantial portion of the Pacific ocean perch diet and also compete for euphausiid prey (Yang 2003). Habitat for euphausiids has been more commonly related to oceanographic conditions like sea surface temperature, currents, and chlorophyll *a* than bottom structure (Mackas and Tsuda 1999, Siegel 2000, Yoon et al. 2000). Based on remote operating vehicle (ROV) observations of Pacific ocean perch feeding in the BS, Brodeur (2001) suggested that copepods and euphausiids are not directly associated with bottom habitat. Instead, they are advected onshore near the bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes. Predators of Pacific ocean perch are likely sablefish, Pacific halibut, sperm whales (Major and Shippen 1970), seabirds (Ainley et al. 1993), and other rockfish (Hobson et al. 2001). There is no evidence that links the habitat features with the ability of Pacific ocean perch to accomplish the feeding process.

Growth to Maturity

Pacific ocean perch larvae are thought to be pelagic and drift with the current. Oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993) resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification because many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species, but are expensive and time-consuming. Post-larval and early young-of-the-year Pacific ocean perch have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002). Because larval and early young-of-the-year Pacific ocean perch are thought to be pelagic, there is no evidence that links sea floor habitat features with the ability of Pacific ocean perch to accomplish the growth to maturity process during the post larval or early juvenile stages.

Later stage juveniles of reddish rockfish have been observed in an inshore, demersal habitat (Carlson and Haight 1976, Carlson and Straty 1981, Straty 1987, Pearcy et al. 1989, Krieger 1993). Carlson and Haight (1976) collected juvenile Pacific ocean perch during 3 years in Southeast Alaska fjords. They found that age 1- and 2-year-old fish were found demersally over high relief habitat including walls and boulders, while older juveniles from 3 to 6 years old were found on smoother, unbroken substrate, both at a median depth of 70 m. These juveniles were most commonly found with brittle stars, basket stars, and sponges. Carlson and Straty (1981) observed small reddish rockfish believed to be juvenile Pacific ocean perch with a submersible at 90 to 100 m in offshore Southeast Alaska. The reddish rockfish were observed along rocky areas exposed to open sea conditions that ranged from rugged, steep, rocky pinnacles to boulder fields interspersed with gravel beds (Carlson and Straty 1981). Krieger (1993) observed small reddish rockfish believed to be juvenile Pacific ocean perch with a submersible at 188 to 290 m in offshore Southeast Alaska. The highest densities of these small reddish rockfish were observed at untrawlable sites over rugged habitat, including cobble, cobble and boulders, and among ledges and coral (the type of coral was not specified) (Krieger 1993). Other species of rockfish in submarine canyons have been associated with high-relief structures such as vertical rock walls, ridges, and boulder fields, which may act as natural refugia from trawling (Yoklavich et al. 2000). Large schools of juvenile Pacific ocean perch have also been found on the shelf in other areas of the GOA, including Albatross Bank and Shumagin Bank (Westrheim 1970). Submersible work in California detected a strong association for juvenile rockfish with untrawlable bottom (Nasby-Lucas et al. 2002). Another study using a submersible in the eastern GOA observed other species of rockfish associated with *Primnoa* spp. corals (Krieger and Wing 2002). Freese and Wing (2004) also used a submersible in the GOA, and in a single dive they observed 82 juvenile red rockfish, suspected to be Pacific ocean perch, closely associated with boulders that had attached sponges. No rockfish were observed near boulders without sponges. Rooper and Boldt (2004) noted a relatively strong positive relationship with the catch of sponges and the catch of juvenile Pacific ocean perch.

As they mature into adults, juvenile Pacific ocean perch move to progressively deeper waters of the continental shelf/slope (approximate 3 m deeper per cm of length), ranging from an average depth of 125 m at 7 cm in length, to an average depth of 270 m at 50 cm in length (unpublished NMFS survey data). They also shift into smoother, more trawlable bottom (Carlson and Haight 1976, Krieger 1993). Length frequencies of Pacific ocean perch captured in NMFS bottom trawl surveys and observed in commercial fishery bottom trawl catches, indicate that older juveniles are often found, together with adults at shallower locations of the continental slope in the summer months (unpublished NMFS survey data). Commercial fishing data indicate that adult Pacific ocean perch are most prevalent on the shelf break (100 to 200 m), slope (more than 200 m), and inside major gullies and trenches (200 to 500 m) running perpendicular to the shelf break (Lunsford 1999, Lunsford et al. 2001). Krieger (1993) noted that most large (longer than 25 cm) rockfish identified as adult Pacific ocean perch were associated with pebble substrates on flat or low-relief bottom. Other studies with trawl and sunken gill nets have found Pacific ocean perch predominantly over relatively smooth, trawlable bottoms (bottom type was not identified) (Westrheim 1970, Matthews et al. 1989). In the EBS and GOA, Pacific ocean perch have also been observed associated with forests of epibenthic sea whips (*Halipteris willemoesi*, Brodeur 2001) and sea pens (possibly misidentified sea whips) (Krieger 1993). Scott (1995) reports that adult Pacific ocean perch habitat can be defined using physical variables such as sea surface temperatures, coastal wind patterns, and steep bathymetry.

Consequently, there is evidence that links the habitat features, living structure, and non-living structure with the ability of Pacific ocean perch to accomplish the growth to maturity process during the demersal juvenile and adult stages. Based upon the depth distributions and substrate types described above, these links most likely occur in deeper shelf areas (100 to 300 m) and slope (200 to 1,000 m) habitat types over soft (sand and gravel) and hard (pebble to rock) substrates and are included as such in the GOA Pacific ocean perch connections table (Table B.3-1).

Evaluation of Effects

LEI Values Relative to Species Distribution
The habitat information that is available for Pacific ocean perch indicates they are associated with living structure and non-living structure (Table B.3-1). Pacific ocean perch are present in the slope and shallows, but are predominant in deep shelf habitats (Table B.3-3). The LEI shows a potential 7 to 10 percent equilibrium reduction in living structure features of habitat in areas where Pacific ocean perch are found (Figure B.2-3B, Table B.3-3). LEI maps in the GOA are difficult to interpret, however, because of the irregularity and patchiness in the distribution of habitat features. This is especially true for living structure features such as sponges and corals, which may be patchily distributed and occur on a finer scale than presented in this analysis. The reduction in non-living structure is likely quite low (less than 2 percent) because Pacific ocean perch appear to be associated with hard substrates such as rocks and boulders, which are not greatly affected by fishing (Figure B.2-4B, Table B.3-3). The extent of association between Pacific ocean perch and living and non-living structures as habitat is uncertain. There is evidence that juvenile red rockfish use coral habitat, but it is not known whether these rockfish are juvenile Pacific ocean perch. Thus, there is no direct evidence of an association of Pacific ocean perch with hard corals. If information becomes available that suggests that coral is important habitat, it will be a concern because of the potential large reduction (46 percent) in hard corals in the GOA, as indicated by the LEI index. This may be even more important because it is unknown how much coral there presently is in the GOA, or how much there was prior to fishing effects. The loss of hard corals may be even more critical if juvenile life stages are more dependent on coral than adults. Further research investigating the importance of hard corals as Pacific ocean perch habitat is necessary to determine the effect of coral loss on these fish.

Habitat Impacts Relative to Spawning/Breeding
There is no information on reproductive behavior for Pacific ocean perch, except that spawning likely occurs in deep depths in the winter and parturition occurs in the spring. The rockfish fishery in the GOA

and the NMFS trawl surveys occur in the summer months. Information regarding distribution patterns in the winter and spring months when spawning is thought to occur comes from non-target fisheries, which do not offer accurate comparisons of distribution. Studies have shown no temporal changes in maturity at age, but different methods of assessing maturity-at-age may be too variable to detect changes.

There is no direct evidence that links habitat features with the ability of Pacific ocean perch to accomplish spawning/breeding. Because very little is known regarding the requirements for reproduction, however, caution is warranted.

Habitat Impacts Relative to Feeding

After 1 year of age, the major prey of Pacific ocean perch appears to be euphausiids, based on the limited food information available for this species (Carlson and Haight 1976, Yang 1993, Yang and Nelson 2000, Yang 2003). Because euphausiids are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal or temporary effect on the availability of prey to Pacific ocean perch.

No direct evidence is available that indicates the feeding distributions have changed. Euphausiids are not believed to be directly associated with the bottom, but are more commonly related to oceanographic conditions like sea surface temperature, currents and chlorophyll *a* (Mackas and Tsuda 1999, Siegel 2000, Yoon et al. 2000). This would indicate that any change in feeding distribution is most influenced by oceanographic factors, rather than benthic habitat disturbance.

No direct evidence is available that indicates any change in the diet of Pacific ocean perch. Because euphausiid distributions are widespread (Mackas and Tsuda 1999) and are likely not affected by benthic habitat disturbances, it is doubtful that diet changes would be detectable between heavily fished and lightly fished regions. In summary, there is no evidence that habitat disturbance has affected feeding success.

Habitat Impacts Relative to Growth to Maturity

In the past, juveniles (less than 30-cm fork length) made up a considerably proportion of the catch, but recently contribute less than 8 percent in numbers. It is possible that fishing does not occur and, thus, has no direct effect on the primary habitat of juveniles. However, older juveniles and adults have been observed in association with sponges (Krieger and Wing 2002, Freese and Wing 2004) and possibly coral (Heifetz 2002), and both juvenile and adult life stages may prefer the rocky substrate inhabited by such epifauna. Adult rockfish seem to be more influenced by oceanographic conditions and prey availability and are usually found on smoother, more trawlable habitat than juveniles (Krieger 1993, Scott 1995, Nasby-Lucas et al. 2002).

Growth analyses of length-at-age, weight-at-age, and weight-at-length of Pacific ocean perch caught in low trawl intensity (less than 50 percent of the area swept) areas versus high trawl intensity (more than 50 percent of the area swept) areas have been computed and show significant differences. The data were pooled over time and area due to lack of adequate samples to parse into smaller comparisons. For von Bertalanffy (LVB) length-at-age models, the Brody growth parameter (κ) and the intercept (t_0) were significantly higher for the high-intensity fishing areas than for the low-intensity areas. Weight-at-age parameters were not significantly different among the different effort-intensities. For the allometric weight-length relationship, which had the most data, both the α and β parameters were significantly different for high-intensity effort compared with low-intensity effort areas.

In another approach, the mean difference between individual weights and mean weights for each length were compared over survey years that had data in high and low fishing-effort areas. This approach yielded significant effects for both year and fishing intensity under an analysis of variance (ANOVA) unequal sample size design. The differences were in both directions depending on the year, with the grand mean of residuals showing a small positive effect on weight-at-age in the high-intensity fishing samples.

The general results of the first analysis were that the fish in the high-intensity areas grew slightly heavier and faster, but had a smaller maximum length. The second analysis had contradictory results between years with both positive and negative effects on growth. These results are based on fairly small sample sizes in the high-intensity area and could be caused by a number of confounding factors. Possible explanations are as follows: (1) the high-intensity effort areas are likely areas with the highest density of fish, so fishery removals are easing intraspecific competition for food resources, allowing faster growth, and/or (2) areas are subject to low-intensity trawling are poor habitat for Pacific ocean perch due to prey availability or oceanographic conditions.

No direct evidence exists that indicates habitat disturbance affects the growth to maturity of Pacific ocean perch. However, the potential reduction of living substrates such as sponge evidenced by the LEIs in Pacific ocean perch habitat raises concern regarding the growth requirements of younger Pacific ocean perch. Associations between juvenile red rockfish and living structure have been established, and impacts to sponge habitat may affect survival of juveniles because they may become more vulnerable to predation without adequate refugia. Juvenile survival is essential, but virtually nothing is known about it. The growth analysis showed some significant differences in growth between high and low intensity trawl groups, but the cause is uncertain.

Stock Status and Trends

Stock status for the Pacific ocean perch has been assessed with an age-structured model since the early 1990s. The model incorporates survey biomass estimates, age data from the fishery and trawl survey, and length data from the fishery (Hanselman et al. 2003).

Model estimates of spawning biomass in the 1960s were high and were subsequently depleted by large catches by foreign trawlers. Biomass increased rapidly in the 1990s due to some large recruitment events in the late 1980s, as indicated by several large survey biomass estimates. Biomass has remained relatively steady since then (Hanselman et al. 2003). During this time, there have been no major declines in estimated abundance. Little data beyond catch and fishery lengths are available prior to the 1980s, but presumably the bulk of habitat impacts would have occurred in the 1960s when trawl effort was much higher.

Since 1989, there has been a considerable decrease in effort, and catch-per-unit-effort has been increasing in the fishery since the mid-1990s. Effort analysis has shown that the fishery has moved since the early 1980s from shallower areas that are no longer targeted in rockfish fisheries to deeper areas along the outer shelf and upper slope. The overall number of hauls targeting rockfish has decreased by more than 80 percent since 1989, even though the current quota is similar to that of 1989, indicating both an increase in abundance and an increase in fleet efficiency. The fishery was taking a larger proportion of juvenile rockfish between 1989 and 1992, probably due to lower abundance of adults. Survey catch-per-unit effort increased from 1993 to 2001 and leveled off in 2003. The NMFS survey in 2003 did not have any extraordinary hauls of Pacific ocean perch like those in previous surveys, but showed a more uniform distribution of moderate catches along the continental slope. This may indicate a decrease in aggregating behavior or an increase in abundance.

Model estimates of recruitment vary greatly, which is typical of rockfish in the GOA. Most researchers agree that a climatic regime shift occurred around 1977 that reorganized the biotic community in Alaskan waters (Francis et al. 1998), so recruitment estimates are generally compared after 1977. No obvious trend in recruitment is discernable since 1977. Recruitments in the late 1980s appear stronger than average, and recent recruitments appear to be average.

Between 1977 and the mid-1990s, the spawning biomass was below B_{MSY}. Spawning biomass has since surpassed B_{MSY} and the target biomass of $B_{40\%}$ and has appeared to stabilize. In recent years, however, the estimate of B_{MSY} has shifted downward with a slight decrease in spawning biomass. This is because no new above-average recruitments have appeared. Therefore, the estimated stock size is above the current MMST, B_{MSY}, and $B_{40\%}$, but these reference points are not static and have been both higher and lower in the past.

Overall, the stock status seems to be good compared to the recent past, and it is unlikely that habitat impacts are affecting the stock's ability to maintain MSY in the near future.

Summary

Issue	**Evaluation**
Spawning/Breeding	U (Unknown effect)
Growth to Maturity	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of Pacific ocean perch are either unknown or negligible; however, caution is warranted. There is some information to suggest that bottom trawling has a negative impact on benthic habitat, especially sponges. The LEI analysis indicates that there is a potential for minor reductions in living substrates inhabited by Pacific ocean perch. Whether the potential loss of these substrates would have an effect on spawning/breeding of Pacific ocean perch is unknown. Any effect on their ability to feed would likely be negligible. Very little information is available on these aspects of their life history, however, and further investigation may prove otherwise. A reduction in living structure may jeopardize these fishes' ability to grow to maturity. Several observations have shown juvenile red rockfish to be associated with sponges. The extent of this association is largely unknown, but it may be important if these substrates increase survival rates by acting as refugia to juveniles or adults. Significant differences in growth were found between heavily trawled and lightly trawled areas, but the cause is unknown. Current stock status trends show no indications of fishing impacting the ability of the stock to maintain MSY.

B.3.3.17 Shortraker and Rougheye Rockfish (BSAI)

Rougheye (*Sebastes aleutianus*) and shortraker (*Sebastes borealis*) rockfish are distributed from southern California, north to GOA and the EBS, and west to the Aleutian and Kuril Islands and the Okhotsk Sea (Love et al. 2002). In Alaskan waters, concentrations of abundance occur in the GOA and the AI, with smaller concentrations along the EBS slope. The mean depth at which shortraker and rougheye rockfish appear in recent AI summer trawl surveys is approximately 400 and 375 m, respectively.

Habitat Connections

Very little is known about the spawning and breeding behavior of rougheye and shortraker rockfish. Reproduction is viviparous, which is marked by three critical points in the reproduction process: mating (the transferring of spermatozoa from males to females), fertilization of ova, and parturition (the release of larvae). McDermott (1994) examined specimens from the United States continental west coast, the GOA, and the AI and found that for rougheye rockfish, fertilization predominated in November and December and peak parturition occurred anywhere between December and April. For shortraker rockfish, fertilization appeared to occur in January and parturition between February and August. Shortraker rockfish appeared to show a longer developmental period than rougheye rockfish.

The larval and early juvenile stages of rougheye and shortraker rockfish are pelagic, but little is known of the duration of this stage or the extent to which pelagic juveniles are distributed by ocean currents. One source of difficulty is identifying larval rockfish to species.

Pandalid and hippolytid shrimp are the largest components of the rougheye rockfish diet (Yang 1993, 1996, Yang and Nelson 2000). In a study of diet data collected from specimens from the AI trawl survey, Yang (2003) found that the diet of large rougheyes had proportionally more fish (e.g., myctophids) than small rougheye, whereas smaller rougheye consumed proportionally more shrimp. The diet of shortraker rockfish consists largely of squid and shrimp. From specimens collected in the 1990 and 1993 GOA trawl surveys, Yang and Nelson (2000) observed that squid was the most important prey item in 1990, whereas shrimp was the most important prey item in 1993. From data collected in the 1994 and 1997 AI trawl surveys, Yang (2003) also found that the diet of large shortrakers had proportionally more fish (e.g., myctophids) than small shortrakers, whereas smaller shortrakers consumed proportionally more shrimp.

Information on the habitat use of juvenile rockfish is available primarily from a limited number of submersible studies. Carlson and Straty (1981) found juvenile nursery grounds off southeast Alaska to occur at depths of 90 to 100 m over rough bottom (pinnacles, boulder fields interspersed with gravel, and invertebrate shells). Although this study was focused upon Pacific ocean perch, juvenile rockfish of other species (including rougheye rockfish) were observed to follow similar patterns. Other studies using submersibles have indicated that several species of rockfish appear to use rocky, shallower habitats during their juvenile stage (Straty 1987, Kreiger 1993). Straty (1987) noted that juvenile red rockfish were associated with stands of large white anemones, and juvenile rockfish took refuge in rocky areas when alarmed by the movement of the submersible. Although these studies did not specifically observe rougheye/shortraker rockfish, it is reasonable to suspect that juvenile rougheye and shortraker rockfish also use these shallower habitats as refuge areas. Length frequency distributions from AI summer trawl survey indicate that small rougheye rockfish (less than 35 cm) are found throughout a range of depths but primarily in shallower water (200 to 300 m) than larger fish. Based upon the existing studies cited above, juvenile shortraker and rougheye rockfish are expected to occur in the BS slope (200 to 1,000 m), in both shallow (less than 200 m) and deep (more than 200 m) water in the AI, and in soft (sand to gravel) to hard (pebble to rock) habitat types.

Adult rougheye/shortraker rockfish have been found at depths of 300 to 500 m in AI trawl surveys. In a submersible study designed to examine the spatial distribution and habitats of shortraker and rougheye rockfish off southeast Alaska, Kreiger and Ito (1999) found that rougheye/shortraker rockfish were associated with habitats containing frequent boulders, steep slopes (more than 20°), and sand-mud substrates. Based upon this information, linkages between habitat features and adult shortraker and rougheye rockfish are expected to occur on the BS slope (200 to 1,000 m) and in deep (more than 200 m) water in the AI in soft (sand to gravel) to hard (pebble to rock) habitat types.

Evaluation of Effects

LEI Values Relative to Species Distribution

The general distribution (95 percent distribution) of the adult shortraker and rougheye population within BSAI waters occurs primarily within the AI deep and the AI shallow habitat types, contributing 22 and 16 percent of the total Alaska rougheye and shortraker distribution, respectively. The potential reduction in living structure and non-living structure in the AI deep habitat (200 to 1,000 m) was projected to be 3 and 2 percent, respectively. In the AI shallow areas, the potential reduction in living structure and non-living structure was projected to be 7 and 4 percent, respectively. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Furthermore, these percentages pertain to the entire stock over large spatial scales, and examination of the LEI maps indicates that localized areas of higher impacts do occur in areas such as south of Adak Island, Seguam Pass, and northeast of Atka Island. Analysis of survey CPUE shows that during summer months these areas have not contributed a high portion of the AI biomass in recent surveys. However, the LEI maps are difficult to interpret because the pattern of impacts may occur at finer spatial scales than presented in this analysis, and the extent to which these localized impacts may affect the entire population is unclear. The projected impacts on hard corals in the AI deep and AI shallow habitat areas were 8 and 17 percent, respectively. Kreiger and Wing (2002) used a submersible to examine *Primnoa*, a deepwater gorgonian coral, in the GOA at depths from 161 to 365 m and found that 85 percent of large rockfish (including rougheye and shortraker rockfish) occurred next to boulders with coral, although less than 1 percent of the observed boulders contained coral. Kreiger and Wing (2002) also found that several species of rockfish, including rougheye, showed a depth-size relationship in their association with *Primnoa*, with smaller rockfish (less than 40 cm) generally occurring at stations less than 263 m, whereas large rockfish (40 to 70 cm) occur at depths more than 340 m.

Habitat Impacts Relative to Spawning/Breeding

Little information is available from fisheries or survey data regarding the distribution and habitat use during the breeding and spawning processes. The trawl research surveys are conducted in the summer months when the bulk of the spawning activity is expected to be completed. Summer survey data may not be a useful proxy for spawning distributions if rougheye and shortraker rockfish undergo seasonally dependant depth changes associated with spawning activity, as observed for Pacific ocean perch (Gunderson 1971). Rougheye and shortraker rockfish are captured as bycatch in the Pacific ocean perch fishery, which began in July in recent years. Fishery catches of rougheye and shortraker captured during other months are also obtained from bycatch fisheries and, thus, may not be representative of total species distribution and habitat use.

Maturity at age studies have not been completed for the BSAI rougheye and shortraker rockfish, and future collections and analysis would be necessary to determine if changes in maturity at age occur.

There is no evidence that suggests that habitat impacts have affected the ability of BSAI shortraker and rougheye rockfish to conduct the mating and spawning processes, although very little is known regarding these processes. For rockfish in general, the processes of mating and parturition have not been observed to depend critically upon benthic habitat features (Love et al. 2002).

Habitat Impacts Relative to Growth to Maturity

The information available on the habitat preferences on juvenile rockfish is limited to the few references cited above that relied upon submersible research. As mentioned above, these studies indicate that juvenile rockfish use rocky habitats as refuge areas, and Carlson and Straty (1981) noted that juvenile red rockfish, including rougheye rockfish, were captured in rough habitats in relatively shallow water.

Habitat linkages between juvenile rougheye and shortraker rockfish and living and non-living (rocky habitats) habitat types could potentially affect growth and survival. Based upon the LEI analysis, the long-term reduction in either the living or non-living habitat features in the AI deep or shallow habitat types is not expected to exceed 7 percent. As mentioned above, the localized areas of higher impacts for living and non-living substrates have not occurred in locations where the highest survey CPUE levels have been found (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). The expected long-term reduction in hard corals is higher, reaching 8 and 17 percent for the AI deep and shallow areas, respectively, and rougheye and shortraker rockfish have been associated with hard corals at various life stages. The interpretations of the data from the LEI maps in the AI are uncertain because the pattern of impacts may occur at finer spatial scales than presented in this analysis, and the trawl surveys typically do not sample juvenile rockfish very well.

Habitat impacts upon the growth and survival of juvenile rougheye and shortraker rockfish may be revealed by changes in juvenile distribution as a function of fishing intensity. To the extent that the summer trawl surveys sample juvenile rougheye and shortraker rockfish, their distribution does not appear to have changed substantially in recent years, with centers of abundance often located near Amlia Island and the Delarof Islands. Given the rather large sampling variability in rockfish biomass estimates from trawl surveys, any changes in distribution, particularly over small spatial scales, will be difficult to observe.

No direct evidence suggests that the growth to maturity of BSAI rougheye and shortraker rockfish has been affected by habitat disturbance, although the reliance of smaller rougheye and shortraker rockfish upon hard coral (such as *Primnoa*) and the potential for fishing to affect these habitats raise concerns. If, for example, rougheye and shortraker rockfish show spatial heterogeneity related to the timing of parturition, as proposed by Berkeley et al. (2004), then impacts on growth to maturity on smaller spatial scales could affect the BSAI stock. The extent to which habitat impacts occur at smaller scales and the importance of these impacts to the overall BSAI population are unknown.

Habitat Impacts Relative to Feeding

The extent to which bottom trawling may affect the main prey items for shortraker and rougheye rockfish (shrimp, squid, and small fish such as myctophids) is likely to be minimal because these organisms are generally too small to show high selectivities in trawl gear, as indicated by the low LEI values for epifaunal prey in shortraker and rougheye habitat.

Based upon summer survey data, no direct evidence suggests that BSAI shortraker and rougheye populations have changed their feeding distributions, although these species are somewhat patchily distributed, and the sampling variability of NMFS' survey data hinders the ability to infer spatial changes in population distributions.

Kreiger and Ito (1999) hypothesized that shortraker/rougheye rockfish may use boulders to avoid currents and/or capture prey. Kreiger and Wing (2002) also hypothesized that large rockfish associate with *Primnoa* because of the presence of several prey species, including shrimp. However, it is unclear the extent to which diet to rougheye and shortraker rockfish depends upon *Primnoa* or other habitat features.

Although limited information exists on diet, no direct evidence exists to suggest that diet of Pacific ocean perch has changed substantially over time. Yang's diet studies (1993 and 1996) are largely consistent with the results obtained in 2003 (Yang 2003), with differences largely due to sampling variability associated with small sample sizes.

No direct evidence suggests that the feeding of BSAI rougheye and shortraker rockfish has been affected by habitat disturbance, although data is limited in this area.

Stock Status and Trends

Information on rougheye and shortraker population status can be obtained from a non-age-structured population model. Estimates of spawning biomass and recruitment are not available, but total biomass has appeared to be relatively stable since 1991. The total rougheye biomass estimate was 11,000 t in the 1991 AI survey and 15,000 t in the 2004 survey; the corresponding numbers for shortraker rockfish were 23,700 t and 33,300 t. The range of variation in these point estimates are small relative to the sampling variability associated with the AI trawl surveys, indicating that, although the observed trend has been relatively flat, the biomass estimates are observed with considerable uncertainty. Lower levels of biomass were observed in cooperative United States/Japan AI surveys conducted in the 1980s, but these surveys are not directly comparable to the post-1991 United States surveys due to differences in sampling gear, vessels, and sampling design.

Information on stock status does not suggest that the cumulative effects of fishing has impaired the ability of BSAI rougheye and shortraker rockfish to maintain stable population sizes since the early 1990s.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal, temporary, or no effect)
Growth to maturity	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of BSAI rougheye and shortraker rockfish are rated as either unknown or minimal and temporary. There is little information to suggest that these habitat reductions would affect spawning/breeding or feeding in a manner that is more than minimal or temporary, although much is unknown about these processes for BSAI shortraker and rougheye rockfish.

Regarding growth to maturity, the available literature indicates that juvenile red rockfish use living (corals) and non-living (rocky areas) habitat features, with one specific use being the ability to find refuge from predators. Although several of these studies did not specifically observe shortraker or rougheye rockfish, it is reasonable to assume that their juvenile habitat use would follow a similar pattern. Trawling would be expected to have negative impacts for these life stages, although the extent to which the BSAI rougheye and shortraker stocks are related to these habitat features is not well known. The expected percent reduction in living and non-living habitat features does not exceed 7 percent in the AI deep and AI shallow habitats, suggesting that fishing impacts on these features are not likely to substantially affect BSAI rougheye and shortraker rockfish. However, larger percent reductions for hard corals are estimated, and studies on habitat associations have indicated that rougheye rockfish are associated with hard corals such as *Primnoa,* possibly due to the concentration of prey items in these habitats or for providing refuge for juveniles (Kreiger and Wing 2002). The extent to which habitat impacts occur at smaller scales and the importance of these impacts to the overall BSAI population are unknown.

B.3.3.18 Shortraker and Rougheye Rockfish (GOA)

Since 1991, shortraker rockfish (*Sebastes borealis*) and rougheye rockfish (*S. aleutianus*) have been managed as a separate group in the GOA within the slope rockfish assemblage. As adults, these two species often co-occur in trawl and longline hauls on the upper continental slope, and they are sometimes difficult to differentiate visually. For these reasons, they have been grouped together into a single management category in the GOA.

Habitat Connections

Except for adults, habitat preferences for shortraker and rougheye rockfish are either unknown or very poorly known (Table B.3-1). Similar to all other species of *Sebastes*, the egg stage is completed inside the female. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is both expensive and labor-intensive. The post-larval and early young-of-the-year stages also appear to be pelagic for both species (Matarese et al.1989; Gharrett et al. 2002). Very few small juvenile shortraker rockfish (less than 35-cm fork length) have ever been caught in the GOA, so the habitat for this life stage is completely unknown. However, it is presumed to be demersal, as there is no documentation of juvenile shortraker in midwater trawls. In contrast, juvenile rougheye rockfish (15- to 40-cm fork length) are frequently caught in GOA bottom trawl surveys. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. In the categories in Table B.3-1, they occur in the shallow and deep shelf, but their habitat preference within this environment has not been documented. They certainly are found in reasonably flat, trawlable bottom areas, which suggests they inhabit relatively soft substrates. They may also occur in harder bottom areas that are trawlable. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify shortraker or rougheye rockfish, it is reasonable to suspect that juvenile shortraker and rougheye rockfish may be among the species that utilize this habitat as refuge during their juvenile stage. Consequently, Table B.3-1 shows juvenile shortraker/rougheye in the GOA inhabiting soft and hard substrates on the shallow and deep shelf and possibly connected with three habitat features: epifaunal prey, living structure, and non-living structure.

The habitat preference for adults of both species has been fairly well documented. Adults are concentrated in a narrow band along the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). In the GOA, these areas on the slope are known to be generally steep, rocky, and difficult to trawl. Observations from a manned submersible in this habitat indicate the fish prefer steep slopes where they are often associated with boulders (Krieger 1992, Krieger and Ito 1999). Submersible studies have also shown that adults of the two species are sometimes associated with *Primnoa* spp. coral (Krieger and Wing 2002). Therefore, Table B.3-1 shows adult shortraker and rougheye rockfish as occurring on hard substrate on the slope and associated with non-living structure and with corals. In addition, because of this preference for rocky habitat, it is likely that adult shortraker and rougheye rockfish are also associated with other living structure such as sponges that frequently grow on rocks. Hence, Table B.3-1 also shows a connection between adult shortraker/rougheye and living structure on hard substrate of the GOA slope.

Spawning/Breeding

There is no information on reproductive behavior for either species, except that parturition is believed to occur in February through August for shortraker rockfish and in December through April for rougheye rockfish (McDermott 1994). Because of this lack of knowledge, the effects of fishing on spawning/breeding of these fish are unknown.

Feeding

Food habit studies in Alaska indicate that the diet of rougheye rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). However, juvenile rougheye rockfish (less than 30-cm fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). The diet of shortraker rockfish in the GOA is not well known; however, based on a very small sample size in the Yang and Nelson (2000) study, the diet appears to be mostly squid, shrimp, and deepwater fish such as myctophids. A food study in the AI with a larger sample size of shortraker rockfish also found myctophids, squid, and shrimp to be major prey items (Yang 2003). In addition, gammarid amphipods, mysids, and miscellaneous fish were important food items in some years. Because the prey items for rougheye and shortraker rockfish are generally pelagic or semipelagic in their distribution, and most are also small in size, they are not generally not vulnerable to substantial impacts from bottom fishing gear. Consequently, fishing probably has little or no direct effect on prey availability to shortraker and rougheye rockfish.

Growth to Maturity

As previously discussed, habitat requirements for the various life stages of both species are mostly unknown. Small juvenile shortraker rockfish (less than 35-cm fork length) have almost never been caught on any fishing gear, so it is likely that fishing does not occur and, thus, has no direct effect on whatever habitat they do occupy. Juvenile rougheye rockfish are frequently taken in bottom trawls on the shelf, which indicates that trawling may have an impact on the habitat of these fish. Unidentified juvenile rockfish have been observed on the GOA shelf in association with rocky bottom and sponges (Carlson and Straty 1981, Straty 1987, Krieger 1993, Freese and Wing 2004), and some of these unidentified fish may have been rougheye rockfish. However, the preferred habitat of juvenile rougheye rockfish and whether they associate with certain habitat features are uncertain. In contrast, adults of both species are known to particularly inhabit steep, rocky areas of the continental slope, and they have been observed in association with boulders and corals (Krieger 1992, Krieger and Ito 1999, Krieger and Wing 2002). Bottom trawling is known to displace boulders and damage corals, and it could have a negative impact on growth and survival of these fish. However, to really evaluate this possible problem, additional research is needed to determine how essential these associations are to the health of the stocks and how much damage is actually occurring due to fishing gear. Taking into consideration all these factors, effects of fishing on growth to maturity for shortraker and rougheye rockfish are unknown.

Evaluation of Effects

LEI Values Relative to Species Distribution

The habitat information that is available for shortraker and rougheye rockfish in the GOA indicates that juveniles may be associated with epifauna prey, living structure, and non-living structure, whereas adults are associated with living structure, non-living structure, and hard corals (Table B.3-1). The LEI data in Table B.3-3 for GOA shortraker and rougheye rockfish show that for the habitat areas where the most of the fish live (GOA deep shelf and GOA slope), there is an especially large potential reduction in hard corals of 17 to 37 percent. This is of particular concern because, as previously noted, submersible observations have found shortraker and rougheye rockfish in association with coral. These observations, however, were limited to just a few sites, so the extent of this association is uncertain. The only other habitat feature in Table B.3-3 to show a potential concern for GOA shortraker and rougheye rockfish is living substrate. However, the possible reduction in living structure for shortraker and rougheye rockfish in the GOA is only 5 to 7 percent, so this habitat feature appears to be much less of a problem than hard corals. Epifauna prey and non-living structure, which were identified in Table B.3-1 as possibly having a connection with GOA shortraker and rougheye rockfish, had extremely low LEI values (1 to 2 percent).

Spatial overlap exists between areas in the GOA with high LEIs for hard corals (Figure B.2-6b) and localities with high catches of shortraker and rougheye rockfish in the commercial fishery (Fritz et al. 1998). For example, many blocks on the slope to the east and northeast of Kodiak Island show high coral LEIs of more than 75 percent in Figure B.2-6b, and most of these blocks correspond to areas with relatively high catch-per-unit-effort for shortraker and rougheye rockfish based on the trawl observer data in the Fritz et al. report. This geographic relationship between areas of high coral LEIs and areas of shortraker and rougheye rockfish abundance suggests that some negative impact upon these two species could occur if coral is present in these locations.

Habitat Impacts Relative to Spawning/Breeding

As discussed previously, there is virtually no information on spawning activities or spawning distributions for shortraker or rougheye rockfish. Shortraker rockfish have not been successfully aged, so information on age at maturity for this species is unknown. Estimates of age at maturity for rougheye rockfish are tenuous at best, as they have been indirectly computed from length at maturity data. Therefore, possible habitat impacts upon spawning and age at maturity of shortraker and rougheye rockfish are unknown.

Habitat Impacts Relative to Growth to Maturity

Information on habitat for juvenile shortraker and rougheye rockfish is very limited, except for the fact that juvenile rougheye are commonly caught in bottom trawls on the shelf. This indicates that at least a portion of the juvenile rougheye population is associated with relatively smooth, trawlable bottom. Studies are needed about the possible effects of trawling on habitat of these fish and on whether trawling degrades this habitat. In contrast to juvenile shortraker and rougheye rockfish, there is strong evidence that adults of these two species are primarily associated with rocky habitats on the slope (see "Habitat Connections" in this section), where the fish have also been observed in association with coral. There is no direct evidence to indicate that habitat disturbances due to fishing activities have affected growth to maturity of shortraker and rougheye rockfish. However, because adult shortraker and rougheye rockfish apparently utilize coral as shelter on some occasions, it is likely that bottom trawling damages this shelter and, therefore, could have an adverse effect on survival of these fish.

Growth analyses that compare fish length, weight, and age in low versus high intensity fishing areas of the GOA are one tool that could be used to evaluate possible effects of habitat perturbations caused by fishing. Unfortunately, such analyses are not possible at present for GOA shortraker and rougheye rockfish because of small sample sizes for each species in the fishing areas and the lack of age data for the fish.

Habitat Impacts Relative to Feeding

Pandalid shrimp, myctophids, and squid generally appear to be the major food items for adult shortraker and rougheye rockfish in Alaska (see summary of food habits in "Habitat Connections" in this section). As all these foods tend to be semipelagic in their distribution, bottom trawling probably has little effect on their abundance. The items are also small enough that relatively few are retained in pelagic trawls, which suggests that this latter gear type also has little effect on the availability of food to shortraker and rougheye rockfish. In common with most fish species, smaller shortraker and rougheye rockfish tend to eat smaller prey items, such as smaller-sized shrimp or mysids and amphipods, which are retained in trawls even less frequently than the larger food items. Sample sizes were quite small in the two diet studies that have been conducted for shortraker and rougheye rockfish in Alaska, which means comparisons of food habits in low versus high intensity fishing areas are not possible. Moreover, there is no available information on whether distribution and abundance of the major prey items have changed over time in response to fishing effort. In summary, there is no evidence that fishing activities have affected feeding success for shortraker and rougheye rockfish.

Stock Status and Trends
There is relatively little information available to determine the stock status and trends in abundance of shortraker and rougheye rockfish in the GOA. Because of this lack of information, past assessments of stock condition for both species have been based on biomass estimates from bottom trawl surveys of the GOA rather than modeling (Clausen et al. 2003). The assessments have been particularly hindered by an absence of age data. Shortraker rockfish have not yet been successfully aged, and age data have only recently become available for a limited sample of rougheye rockfish. A preliminary age-structured model has been developed for rougheye rockfish, but additional age data are needed before this model is actually used for assessments.

The biomass estimates are based on results of eight bottom trawl surveys conducted in the GOA between 1984 and 2003. The estimates for rougheye rockfish have been relatively constant over the years, and none of changes has been statistically significant. Biomass of shortraker rockfish has shown an increasing trend since 1990, and the estimate for 2003 was statistically more than that for 1990. Size composition data indicate there has been at least moderate recruitment of rougheye rockfish in the last five surveys, and that increased recruitment appears to be the cause of most of the biomass increase seen for shortraker rockfish in the recent surveys.

Although information on stock status is limited, the information that is available suggests that habitat effects due to fishing have not caused a decline in stock condition for either shortraker or rougheye rockfish. The biomass estimates for both species have been stable or increasing for the last 13 years, and recruitment has also been steady or increasing during this period. Therefore, it is unlikely that habitat impacts are affecting either species' ability to maintain MSY.

Summary

Issue	**Evaluation**
Spawning/Breeding	U (unknown effect)
Growth to Maturity	U (unknown effect)
Feeding	MT (minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of shortraker and rougheye rockfish in the GOA are either unknown or minimal. There is not enough information available to determine whether the habitat impacts of fishing affect spawning or growth to maturity of these fish. Virtually nothing is known about the spawning behavior of these fish, and information on the juvenile life history of shortraker rockfish is nil. However, adults of both species inhabit areas subject to bottom trawling, as do juveniles of rougheye rockfish, so fishing may be affecting the habitat of these fish. Of particular concern is the observed association of adult shortraker and rougheye rockfish with corals such as *Primnoa* spp. on rocky substrate of the slope. This coral is known to be easily damaged by bottom trawls, and it also may take years to recover from such damage. The fragile nature of corals and their long recovery time are reflected in the high values of LEI estimated for corals in this document. If corals are important to the long-term survival of adult shortraker and rougheye rockfish, damage to corals by fishing gear may have a negative impact on these fish. The habitat requirements of juvenile rougheye rockfish on the shelf are unknown. However, several studies have observed unidentified small juvenile rockfish on the shelf associated with rocks or sponges. If juvenile rougheye rockfish utilize this habitat, they could be adversely affected by trawling. Effects of fishing on the feeding of shortraker and rougheye rockfish appears to be negligible, as the major food items of these fish are relatively small and semipelagic; therefore, these items are generally not retained in large amounts by fishing gear.

B.3.3.19 Northern Rockfish (BSAI)

Northern rockfish (*Sebastes polyspinus*) are distributed from northern British Columbia north to the GOA and the EBS and west to the AI and the Kamchatka Peninsula (Love et al. 2002). Northern rockfish are poorly studied species, and little is known about their life history.

Habitat Connections

Very little is known about the spawning and breeding behavior of northern rockfish. Reproduction is viviparous, which is marked by three critical points in the reproduction process: mating (the transferring of spermatozoa from males to females), fertilization of ova, and parturition (the release of larvae). Specimen samples from the GOA indicate that parturition in this area occurs in the spring.

The larval and early juvenile stages of northern rockfish are pelagic, but little is known of the duration of this stage or the extent to which pelagic juveniles are distributed by ocean currents. One source of difficulty is identifying larval rockfish to species. Northern rockfish are plankton feeders, with juveniles eating calanoid copepods and adults eating largely euphausiids (Yang 2003). Brodeur (2001) proposed that euphausiids are advected to upstream areas of canyons, thus providing concentrations of prey.

Information on the habitat use of juvenile rockfish is available primarily from a limited number of submersible studies. Carlson and Straty (1981) found juvenile nursery grounds off Southeast Alaska to occur at depths from 90 to 100 m over rough bottom (pinnacles, boulder fields interspersed with gravel, and invertebrate shells); although this study was focused upon Pacific ocean perch, juvenile rockfish of other species were observed to follow similar patterns. Other studies using submersibles have indicated that several species of rockfish appear to use rocky, shallower habitats during their juvenile stage (Straty 1987, Kreiger 1993). Straty (1987) noted that juvenile red rockfish were associated with stands of large white anemones, and that juvenile rockfish took refuge in rocky areas when alarmed by the movement of the submersible. The extent to which juvenile rockfish showed a habitat preference for anemones over other types of habitat is unclear. Although these studies did not specifically observe northern rockfish, it is reasonable to suspect that juvenile northern rockfish also use these shallower habitats as refuge areas. Additionally, length frequency distributions from AI summer trawl survey indicate that small northern rockfish (less than 20 cm) are found primarily in shallow water (less than 100 m) whereas larger northern rockfish are primarily found between 100 and 200 m. Survey tows with the highest levels of northern rockfish catch appear to be located in relatively rough habitat (Clausen and Heifetz 2002), and information from submersible studies indicates that northern rockfish also occur in relatively smooth habitats of mixed sand/gravel as well. Based upon the existing studies cited above, juvenile northern rockfish are expected to occur in small amounts along the BS slope (200 to 1,000 m), in shallow water (less than 200 m) in the AI, and in soft (sand to gravel) to hard (pebble to rock) habitat types. Adult northern rockfish are expected to occur in small amounts along the BS slope (200 to 1,000 m), in primarily shallow water (less than 200 m) in the AI, and in both soft (sand to gravel) to hard (pebble to rock) habitat types.

Evaluation of Effects

LEI Values Relative to Species Distribution
The general distribution (95 percent distribution) of the adult northern rockfish population within BSAI waters occurs primarily within the AI deep and the AI shallow habitat types, contributing 19 and 27 percent of the total Alaska northern rockfish distribution, respectively (Table 3-3). The potential reduction in living structure and non-living structure in the AI deep habitat (200 to 1,000 m) were projected to be 6 and 4 percent, respectively (Table B.3-3). In the AI shallow areas, the potential

reduction in living structure and non-living structure is projected to be 8 and 5 percent, respectively. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other. Close examination of these percentages shows that localized areas of higher impacts do occur in areas such as south of Adak Island, Seguam Pass, and northeast of Atka Island. These areas have not contributed a high portion of the AI biomass in recent surveys, with the highest survey CPUEs being observed in the Tahoma Bank and Stalemate Bank areas (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). However, the LEI maps are difficult to interpret because the pattern of impacts may occur at finer spatial scales than presented in this analysis, and the extent to which these localized impacts may affect the entire population is unclear. The projected impacts on hard corals in the AI deep and AI shallow habitat areas were 16 and 19 percent, respectively. However, northern rockfish have not been found to be associated with hard corals. For example, Kreiger and Wing (2002) conducted submersible dives in the GOA at depths from 161 to 365 m and did not find that northern rockfish were associated with *Primnoa*, a deepwater gorgonian coral.

Habitat Impacts Relative to Spawning/Breeding
Little information is available from fisheries or survey data regarding the distribution and habitat use during the breeding and spawning processes. The trawl research surveys are conducted in the summer months when the bulk of the spawning activity is expected to be completed. Summer survey data may not be a useful proxy for spawning distributions if northern rockfish undergo seasonally dependant depth changes associated with spawning activity, as observed for Pacific ocean perch (Gunderson 1971). Northern rockfish are captured as bycatch in the AI Atka mackerel fishery and fishery catches of northern rockfish, thus, may not be representative of total species distribution and habitat use.

Maturity at age studies have not been completed for the BSAI northern rockfish, so it is not possible to state whether changes in maturity at age can be related to habitat impacts. Field specimens collected in 2004 will provide the basis for initial studies on the maturity of BSAI northern rockfish.

There is no evidence that suggests that habitat impacts have affected the ability of BSAI northern rockfish to conduct the mating and spawning processes, although very little is known regarding these processes. While there is little information on the process that northern rockfish use to select sites for spawning and parturition, the estimated recruitment (Figure B.3.3.19-1) from age-structured stock assessment models indicates that breeding and spawning have successfully occurred in recent years. For rockfish in general, the processes of mating and parturition have not been observed to depend critically upon benthic habitat features (Love et al. 2002).

Habitat Impacts Relative to Growth to Maturity
The information available on the habitat preferences on juvenile rockfish are limited to the few references cited above that relied upon submersible research. As mentioned above, these studies indicate that juvenile rockfish use rocky habitats as refuge areas, and Carlson and Straty (1981) noted that juvenile red rockfish were captured in rough habitats in relatively shallow water. Although these studies did not specifically observe northern rockfish, it is reasonable to assume that juvenile northern rockfish use similar habitats as other juvenile red rockfish.

Habitat linkages between juvenile northern rockfish and non-living habitat features (rocky habitats) were detected; therefore, fishing impacts on non-living habitats were evaluated with respect to their potential impact on northern rockfish growth and survival. Based upon the LEI analysis, the long-term reduction in either the living or non-living habitat features in the AI deep or shallow habitat types is not expected to exceed 8 percent. As mentioned above, the localized areas of higher impacts for living and non-living substrates have not occurred in locations where the highest survey CPUE levels have been found (http://www.afsc.noaa.gov/refm/stocks/EISEFH/maps.htm). The expected long-term reduction in hard corals is higher, reaching 16 and 19 percent for the AI deep and shallow areas, respectively. However, Kreiger and Wing (2002) did not find juvenile northern rockfish to be associated with *Primnoa* in submersible work off of southeast Alaska. The uncertainty in the data should also be noted, as the trawl surveys typically do not sample juvenile rockfish very well. The high variability in survey data prevents measurement of the contribution of impacts of small scale habitat disturbance on the growth and survival of northern rockfish at the population scale.

Habitat impacts upon the growth and survival of juvenile northern rockfish may be revealed by changes in juvenile distribution as a function of fishing intensity. However, the distribution of small AI northern rockfish does not appear to have changed substantially in recent surveys, with centers of abundance consistently located in the Tahoma Bank and Stalemate Bank areas. Given the rather large sampling variability in NMFS' rockfish biomass estimates from trawl surveys, any changes in distribution, particularly over small spatial scales, will be difficult to observe.

Habitat impacts may also be revealed by reduced weight at length in highly fished areas relative to low fished areas. A statistical analysis could potentially compare the relative weight at length between high and low fished areas. For AI northern rockfish, however, only 11 survey specimens occurred in the high fished area (all in 1997), so this analysis was not pursued further.

No direct evidence suggests that the growth to maturity of BSAI northern rockfish has been affected by habitat disturbance, although the reliance upon smaller northern rockfish upon rough habitat (such as *Primnoa*) and the potential for fishing to affect these habitats raise concerns. If, for example, northern rockfish show spatial heterogeneity related to the timing of parturition as a bet-hedging mechanism, as proposed by Berkeley et al. (2004), then impacts on growth to maturity on smaller spatial scales could affect the BSAI stock. The spatial boundaries of stock structure of BSAI northern rockfish, the extent to which habitat impacts occur at smaller scales, and the importance of these impacts to the overall BSAI population are unknown.

Habitat Impacts Relative to Feeding

The major prey items for northern rockfish are calanoid copepods (as juveniles) and euphausiids (as adults) (Yang 2003). Because both of these prey items reside in pelagic habitats and are not associated with benthic environments, there is no reason to suspect a link between benthic habitat disturbance and prey availability or feeding success.

Information from recent AI surveys does not suggest major changes in the distribution of northern rockfish. Because the prey of northern rockfish occur within pelagic habitats, any changes occurring in the distribution of prey are more likely due to changes in oceanographic conditions than benthic habitat impacts. For example, Brodeur (2001) proposed that euphausiid populations within Pribilof Canyon resulted from advection areas off the continental slope.

Although limited information exists on diet, no direct evidence exists to suggest that diet of northern rockfish has changed substantially over time. The diet study of Yang (2003) for AI northern rockfish from the 1994 and 1997 AI surveys is consistent with the results of Yang (1996) for the 1991 AI survey.

Stock Status and Trends

Estimates of spawning biomass from population assessment models indicate that BSAI northern rockfish spawning biomass has increased from low levels in the 1980s and has been relatively stable since the early 1990s, although observed with substantial observation error. The spawning stock biomass, as estimated in the 2004 stock assessment (Spencer et al. 2004) was approximately 45,000 in

1980, increased to 59,600 t in 1991, and increased gradually to the 2004 estimate of 66,900 t (Figure B.3.3.19-1). These changes in spawning biomass are consistent with several year classes of high recruitments in the 1980s, as the 1984, 1988, and 1989 year classes were all above average. Information on stock status does not suggest that the cumulative effects of fishing have impaired the ability of BSAI northern rockfish to produce MSY.

Trends in recruitment success also do not correspond with the temporal patterns in fishing effort (Figure B.3.3.19-2), which has been generally stable in the AI shallow habitat over the last 20 years. The lack of relationship between recruitment (Figure B.3.3.19-1) and fishing effort (Figure B.3.3.19-2) suggest that potential impacts from local regions of heavy fishing on future recruitment do not manifest themselves at the population scale.

Summary

Issue	**Evaluation**
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Growth to Maturity	U (Unknown)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of BSAI northern rockfish are rated as either unknown or minimal and temporary. The percent reduction in living and non-living substrates in the areas most commonly inhabited by BSAI northern rockfish (the AI deep and AI shallow habitats) do not exceed 8 percent. Although larger percent reductions for hard corals are estimated, studies on habitat associations have not associated northern rockfish with hard coral (Kreiger and Wing 2002). The diet of northern rockfish, copepods, and euphausiids is not associated with benthic habitats and would not be expected to be impacted by fishing gear. There is little information to suggest that these habitat reductions would affect spawning/breeding or feeding in a manner that is more than minimal or temporary, although much is unknown for these processes for BSAI northern rockfish.

Regarding growth to maturity, the available literature does indicate that juvenile red rockfish do use living (anemones) and non-living (rocky areas) habitat features, with one specific use being the ability to find refuge from predators. In particular, northern rockfish are associated with rough and rocky habitats (Clausen and Heifetz 2002). Trawling would be expected to have negative impacts for these life stages, although the extent to which the BSAI northern rockfish stock is related to these habitat features is not well known. The LEI percentages of habitat reduction should be interpreted as rough guidelines that are estimated with some error and relate to the entire BSAI stock. Examination of LEI maps indicates that finer scale impacts do occur, and the extent to which these finer scale impacts may be important for northern rockfish is dependent upon the spatial scale of their population structure, which is currently unknown. Similarly, although the current population level data do not indicate declining trends in spawning biomass or recruitment, it is not clear what effects may have occurred at finer spatial scales.

B.3.3.20 Northern Rockfish (GOA)

Habitat Connections

Northern rockfish (*Sebastes polyspinis*) in the northeast Pacific Ocean range from the EBS, throughout the AI and the GOA, to northernmost British Columbia (Allen and Smith 1988, Love et al. 2002, Mecklenburg et al. 2002). Little is known about the biology and life history of northern rockfish (Clausen and Heifetz 2003, Courtney et al. 2003).

There is anecdotal evidence that may link living and non-living structure with early juvenile (less than 20 cm) northern rockfish. Studies in the eastern GOA and Southeast Alaska using trawls and submersibles have indicated that several species of juvenile (less than 20 cm) red rockfish (*Sebastes* spp.) associate with benthic nearshore living and non-living structure and appear to use the structure as a refuge (Carlson and Haight 1976, Carlson and Straty 1981, Straty 1987, and Kreiger 1993). Freese and Wing (2004) also identified juvenile (5 to 10 cm) red rockfish (*Sebastes* sp.) associated with sponges (primarily *Aphrocallistes* sp.) attached to boulders 50 km offshore in the GOA at 148 m depth over a substrate that was primarily a sand and silt mixture. Only boulders with sponges harbored juvenile rockfish, and the juvenile red rockfish appeared to be using the sponges as shelter (Freese and Wing 2004). However, none of these studies specifically identified northern rockfish.

There is also anecdotal evidence that may link non-living structure with northern rockfish during the adult stage. Length frequencies of northern rockfish captured in NMFS bottom trawl surveys and observed in commercial fishery bottom trawl catches indicate that older juveniles (more than 20 cm) are found on the continental shelf, generally at locations inshore of the adult habitat. Trawl surveys and commercial fishing data indicate that the preferred habitat of adult northern rockfish in the GOA is relatively shallow rises or banks on the outer continental shelf at depths of approximately 75 to 150 m (Clausen and Heifetz 2003). The highest concentrations of northern rockfish from NMFS trawl survey catches appear to be associated with relatively rough (variously defined as hard, steep, rocky, or uneven) bottom on these banks (Clausen and Heifetz 2003). Heifetz (2002) identified rockfish (including *Sebastes* spp.) as among the most common commercial fish captured with gorgonian corals (primarily *Callogorgia, Primnoa, Paragorgia, Fanellia, Thouarella*, and *Arththrogorgia*) in NMFS trawl surveys of GOA and Aleutian waters. Krieger and Wing (2002) identified six rockfish species (*Sebastes* spp.) associated with gorgonian coral (*Primnoa* spp) from a manned submersible in the eastern GOA. However, neither Heifetz (2002) nor Krieger and Wing (2002) specifically identified northern rockfish in their studies, and more research is required to determine if northern rockfish are associated with living structure, including corals, in the GOA and the nature of those associations if they exist.

Based upon the existing studies cited above, juvenile northern rockfish are expected to occur with living and non-living structure along the shallow (0 to 100 m) and deeper shelf (100 to 300 m) habitat types over soft (sand and gravel) and hard (pebble to rock) substrates (Table B.3-1). Adult northern rockfish are expected to occur with non-living structure along the shallow (0 to 100 m), and deeper shelf (100 to 300 m) habitat types over soft (sand and gravel) and hard (pebble to rock) substrates (Table B.3-1).

Spawning/Breeding

There is no evidence (e.g., publications, field studies, etc.) that links habitat features with the accomplishment of the spawning/breeding process of northern rockfish. Like other members of the genus *Sebastes*, northern rockfish bear live young, and birth is believed to occur in the early spring (Clausen and Heifetz 2003). There is little information available on spawning/breeding biology and no information available on spawning/breeding habitat requirements.

Feeding

There is no evidence that links habitat features with northern rockfish accomplishing the feeding process. Northern rockfish are generally planktivorous. They eat mainly euphausiids, and calanoid copepods by weight in both the GOA and the AI (Yang 1993, 1996, 2003). There is no indication of a shift in diet over time or a difference in diet between the GOA and AI (Yang 1996, 2003). In the AI, calanoid copepods were the most important food of smaller-size northern rockfish, while euphausiids were the main food of larger sized fish (more than 25 cm) (Yang 1996). The largest size group also consumed myctophids and squids (Yang 2003). Arrow worms, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities (Yang 1993, 1996). Large offshore euphausiids are not directly associated with the bottom, but rather are thought to be advected onshore near the bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). Predators of northern rockfish are not well documented, but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

Growth to Maturity
There is anecdotal evidence that links living and non-living structure with northern rockfish accomplishing the growth to maturity process, but no scientific studies have been conducted that specifically identify northern rockfish associations with living or non-living structures or the nature of those associations if they exist.

Evaluation of Effects

LEI Values Relative to Species Distribution
The habitat information that is available for northern rockfish indicates they may be associated with living and non-living structure in the shallow shelf (0 to 100 m) and deep shelf (100 to 300 m) habitats. The LEI predicts the potential percent reduction in living and non-living structure associated with northern rockfish EFH along the GOA shallow and deep shelves to range between 1 and 10 percent. The LEI predicts the potential percent reduction of hard corals in northern rockfish EFH in the GOA shallow and deep shelf regions to range between 22 and 42 percent. If northern rockfish are associated with hard corals, and if hard corals exist in northern rockfish EFH, then a 42 percent reduction in hard corals could be a cause for concern. However, further research is needed to determine if northern rockfish are associated with hard corals and the nature of the association if one exists.

Habitat Impacts Relative to Spawning/Breeding
There is no evidence (e.g., publications, field studies, etc.) that links habitat features with northern rockfish accomplishing the spawning/breeding process.

There are insufficient data to analyze changes in the spawning/breeding distribution of northern rockfish over time. Like other members of the genus *Sebastes*, northern rockfish bear live young, and parturition is believed to occur in the early spring (Clausen and Heifetz 2003). Because there are no NMFS GOA trawl surveys in the winter or early spring and no directed fisheries for northern rockfish in the winter or early spring, there is very little information available on northern rockfish reproductive behavior, habitat requirements, or distribution.

An analysis of northern rockfish trawl survey CPUE (used here as a proxy for spawning/breeding distribution) did not reveal any trends in the distribution of trawl survey CPUE over time. GOA northern rockfish are patchily distributed in the GOA and are not sampled effectively by NMFS (Courtney et al. 2003). Consequently, analysis of trawl survey CPUE in relation to commercial fishing intensity either in 5-by-5-km grids or smoothed into high, low, and no trawl zones also did not reveal any shifts in the distribution of trawl survey CPUE over time.

There are insufficient data to analyze changes in maturity at age. Age at 50 percent maturity (13 years) and size at 50 percent maturity (36.1-cm fork length) for northern rockfish in the GOA were estimated from a single sample of 77 females in the central GOA (Courtney et al. 2003).

Habitat Impacts Relative to Feeding
There is no evidence that links habitat features with northern rockfish accomplishing the feeding process.

Northern rockfish are generally planktivorous (eating mainly euphausiids and calanoid copepods by weight in both the GOA and the AI) (Yang 1993, 1996, 2003). There is no indication of a shift in diet over time or a difference in diet between the GOA and AI (Yang 1996, 2003). In the AI, calanoid copepods were the most important food of smaller-size northern rockfish, while euphausiids were the main food of larger sized fish (more than 25 cm) (Yang 1996). The largest size group also consumed myctophids and squids (Yang 2003). Arrow worms, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities (Yang 1993, 1996). Large offshore euphausiids are not directly associated with the bottom, but rather are thought to be advected onshore near the bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). Predators of northern rockfish are not well documented, but they likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

Habitat Impacts Relative to Growth to Maturity

Analysis of trawling effort (total number of trawl hauls, 1998 to 2002, 5-by-5-km blocks) in relation to northern rockfish catch showed that there is currently (1998 to 2002) little overlap between areas with high-intensity (more than 50 percent of the area swept per year) bottom trawling and adult northern rockfish habitat. This indicates that most bottom trawling is directed at catching other species. There is one high-intensity trawling effort area on Portlock Bank that is associated with high northern rockfish catches in the NMFS bottom trawl surveys.

A retrospective analysis of GOA rockfish targeted bottom trawling effort by year (1981 to 2002, similar to Conners et al. in press) showed that in the past (1981 to 1997) there may have been more trawling effort in areas that are not currently (1998 to 2002) trawled intensively or trawled at all. Some of these areas trawled more intensively in the past appeared to be on shallow (less than 100 m) offshore banks where older juvenile (more than 20 cm) northern rockfish occur. The effect of this past trawling on juvenile northern rockfish accomplishing the growth to maturity process is unknown.

Growth analyses of weight at length of northern rockfish caught in low (less than 50 percent of the area swept per year 1998 to 2002) trawl intensity areas versus high (more than 50 percent of the area swept) trawl intensity areas have been computed, but are inconclusive because of high variance associated with low sample size (123 individuals) in high trawl intensity areas. Growth analyses of length at age and weight at age were not conducted because of insufficient sample size (58 individuals) in high trawl intensity areas.

In a different approach, the average residuals at each length between weight and average weight for that length were compared at each length over survey years that had data in high and low fishing effort. Based on ANOVA with unequal sample size design, this approach yielded significant effects for fishing intensity during 1999 and 2001, but not 1987. In 1999 and 2001, the residuals were negative for high fishing effort and positive for low fishing effort, indicating that fish were smaller than average for a given length in high trawl intensity areas.

The results of the second analysis appear to indicate that fish in high-intensity areas are smaller than average for a given length. These results are based on fairly small samples in the high-intensity areas (123 individuals) and could also be caused by a number of confounding factors independent of habitat. Possible explanations are as follows: (1) the fishery in the high-intensity effort areas is removing the fastest growing component of the population and/or (2) the high-intensity effort areas are likely areas with the highest density of fish with intraspecific competition for food resources, resulting in slower growth.

There is no direct evidence that habitat disturbance affects the growth to maturity of northern rockfish. The growth analysis showed some significant differences in growth between high- and low-intensity trawl areas, but this is more likely a direct result of fishing or of intraspecific competition than of habitat degradation.

Stock Status and Trends

Stock status for the northern rockfish is assessed with an age-structured model. The model incorporates commercial catch, survey biomass, age data from the fishery and trawl survey, and length data from the fishery (Courtney et al. 2003).

Model estimates of spawning biomass increased during 1976 to 1991 as a result of two stronger than average year classes (1976 and 1984) and have slowly declined during 1991 to 2003 as a result of relatively low recruitment since 1984 (Courtney et al. 2003). There is evidence for a stronger than average recruitment in 1994, but this year class was not yet fully recruited during the last available survey year (2001). Recruitment varies greatly between years, which is typical of rockfish in the GOA. Most researchers agree that a climatic regime shift occurred around 1977 that reorganized the biotic community in Alaska waters (Francis et al. 1998), so recruitment estimates are generally compared after 1977. GOA northern rockfish spawning biomass has been above B_{MSY} ($B_{35\%}$) for all years modeled (1977 to 2003) and is not projected to fall below B_{MSY} under average recruitment (1977 to 1995) (Courtney et al. 2003).

Berkeley et al. (2004) suggest that maintenance of age structure and spatial distribution of recruitment are essential for long-term sustainability of exploited rockfish populations. Average age of northern rockfish from NMFS' trawl surveys in the GOA has increased from 13 (1984) to 18 (2001) (Courtney et al. 2003). While this is a result of two stronger than average year classes (1976 and 1984) moving through the population, it also indicates that, at least on a Gulf-wide scale, recent fishing effort (1984 to 2001) has not caused dramatic age truncation in northern rockfish. The commercial catch of northern rockfish is currently (1990 to 1998) concentrated on several geographically isolated relatively shallow (90 to 140 m) offshore banks (Clausen and Heifetz 2003). The concentrated nature of the northern rockfish fishery raises concern over localized depletion. However, there are insufficient survey age or length data from these offshore banks to conduct an analysis for localized depletion at this time.

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Although northern rockfish may eat some epifaunal prey, such as crabs and shrimp, the largest component of their diet is euphausiids; thus, the percent reductions in epifaunal prey would not be expected to have a significant impact on their feeding. There is no evidence that links habitat features with northern rockfish accomplishing the spawning/breeding process. Consequently, a reduction in living and non-living structure would not be expected to have an effect on spawning/breeding of GOA northern rockfish. A reduction in living and non-living structure may reasonably jeopardize growth to maturity due to a reduction of refuge habitat for juvenile GOA northern rockfish. However, no scientific studies have been conducted that specifically identify northern rockfish associations with living or non-living structures or the nature of those associations if they exist. Consequently, the effect of a reduction in living or non-living structures on northern rockfish accomplishing the growth to maturity process is unknown. Current stock status trends show no indications of fishing impacting the ability of the stock to maintain MSY, and there is no evidence to suggest that the potential reductions in living and non-living structure on growth and survival to maturity affects the ability of GOA northern rockfish to fulfill its role in a healthy ecosystem.

B.3.3.21 Pelagic Shelf Rockfish (GOA)

The pelagic shelf rockfish management group in the GOA comprises four species: dusky rockfish (*Sebastes variabilis*), dark rockfish (*S. ciliatus*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelas*). The forms of dusky rockfish commonly named light dusky rockfish and dark dusky rockfish are now officially recognized as two species (Orr and Blackburn 2004). *Sebastes ciliatus* applies to the dark shallow-water species with a common name dark rockfish, and *S. variabilis* applies to variably colored deeper-water species with a common name dusky rockfish.

Dusky rockfish is much more abundant in Alaska than the other three species, and it supports a valuable trawl fishery in the GOA. Because of the abundance and commercial importance of dusky rockfish in the GOA, this section will focus exclusively on the EFH for this species. They are, by far, the dominant species in this group, both in terms of biomass and harvest. Their habitat requirements are not expected to be so different from other species in this group as to require separate analysis.

Habitat Connections

Habitat preferences for the life stages of dusky rockfish are either unknown or very poorly known (Table B.3-1). Similar to all other species of *Sebastes*, the egg stage is completed inside the female. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is both expensive and labor-intensive. Post-larval dusky rockfish have not been identified; however, the post-larval stage for other *Sebastes* is pelagic, so it is also likely to be pelagic for dusky rockfish. The habitat of young juveniles is completely unknown. At some point they are assumed to migrate to the bottom and take up a demersal existence, but virtually no juveniles (less than 25-cm fork length) have been caught in bottom trawl surveys (Clausen et al. 2002) or with other sampling gear. Older juveniles have been taken only infrequently in the trawl surveys, but when caught are often found at more inshore and shallower locations that adults. For this reason, they are noted in Table B.3-1 as occurring on both the shallow and deep shelf, whereas adults are listed for only the deep shelf.

Adult dusky rockfish are concentrated on offshore banks and near gullies on the outer continental shelf at depths of 100 to 200 m (Reuter 1999); therefore, they are assigned to the deeper shelf area in Table B.3-1. Anecdotal evidence from fishermen and from biologists on the trawl surveys suggests that dusky rockfish are often caught in association with a hard, rocky bottom on these banks or gullies. Also, during submersible dives on the outer shelf of the eastern GOA, dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds where adults were seen resting in large vase sponges. Another study using a submersible in the eastern GOA observed small dusky rockfish associated with *Primnoa* spp. corals (Krieger and Wing 2002). A different submersible dive in the GOA observed 82 juvenile red rockfish closely associated with boulders that had attached sponges. No rockfish were observed near boulders without sponges (Freese and Wing 2004). Hence, Table B.3-1 shows both adults and older juveniles associated with living and non-living structure and older juveniles associated with corals.

Spawning/Breeding
There is no information on reproductive behavior for dusky rockfish, except that parturition is believed to occur in the spring, based on observations of ripe females sampled on a research cruise in April 2001 in

the central GOA. Because of this lack of knowledge, the effects of fishing on the habitat required for reproduction of dusky rockfish are unknown.

Feeding

The major prey of adult dusky rockfish appears to be euphausiids, based on the limited food information available for this species (Yang 1993). As euphausiids are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal or temporary effect on the availability of prey to adult dusky rockfish.

Growth to Maturity

As was previously discussed, habitat requirements for the various life stages of dusky rockfish are mostly unknown. Younger juveniles (less than 25-cm fork length) are almost never caught on any fishing gear, so it is likely that fishing does not occur (and thus has no direct effect) on whatever habitat they do occupy. However, older juveniles and adults have been observed in association with corals and sponges (Krieger and Wing 2002), and both life stages may prefer the rocky substrate inhabited by such epifauna. Although the importance of these associations is uncertain, bottom trawling is known to damage such living substrates and could have a negative impact on stocks of this species. Taking into consideration all these factors, a rating of unknown is given to the growth to maturity for dusky rockfish.

Evaluation of Effects

LEI Values Relative to Species Distribution

The habitat information that is available for dusky rockfish indicates they are associated with living structure, non-living structure, and hard corals (Table B.3-1). Dusky rockfish are present in the slope and shallows, but they are predominant in deep shelf habitat (Table B.3-3). The LEI indicates there may have been a 5 to 50 percent reduction in living structure features of habitat in areas where dusky rockfish are found (Figure B.2-3B, Table B.3-3). LEI maps in the GOA are difficult to interpret, however, because of the irregularity and patchiness in the distribution of habitat features. This is especially true for living substrate features such as sponges and soft corals that may be patchily distributed and occur on a finer scale than presented in this analysis. The reduction in non-living structure is likely quite low (less than 5 percent) because dusky rockfish appear to be associated with hard substrate such as rocks and boulders, which are not greatly affected by fishing (Figure B.2-4B, Table B.3-3). The LEI index for hard corals in areas where dusky rockfish occur is very high and in most areas is more than 50 percent (Figure B.2-6B, Table B.3-3). The extent of association between dusky rockfish and living and non-living substrate as habitat is unknown. If these substrates are desirable habitat features to these fish, there should be some concern considering the potential large reduction (more than 50 percent) in hard corals in the GOA, as indicated by the LEI index. This may be even more important because it is unknown how much coral there presently is in the GOA or, more important, how much there was prior to fishing effects. The loss of hard corals may be of even more importance if juvenile life stages are more dependent on coral than adults. Because most of the available data focuses on adult distribution, it is unknown what habitat features are important to juveniles. Further research investigating the importance of hard corals as dusky rockfish habitat is necessary to determine the effect of coral loss on these fish.

Habitat Impacts Relative to Spawning/Breeding

There is no information on reproductive behavior for dusky rockfish, except that parturition is believed to occur in the spring, based on observations of ripe females sampled on a research cruise in April 2001 in the central GOA.

Spawning behavior of dusky rockfish has not been documented. The rockfish fishery in the GOA and NMFS' trawl surveys occurs in the summer months. Information regarding distribution patterns in the winter and spring months when spawning is thought to occur comes from non-target fisheries, which do not offer accurate comparisons of distribution.

Only one study has estimated an age at maturity for dusky rockfish, and this consisted of 64 females collected near Kodiak. Additional collections are needed to discern any changes in maturity at age.

No direct evidence links habitat features with the ability of dusky rockfish to accomplish spawning/ breeding, but very little is known regarding the requirements for reproduction, so caution is warranted.

Habitat Impacts Relative to Growth to Maturity

The available data is limited and only describes the habitat requirements of adult dusky rockfish. Habitat requirements for the various life stages of dusky rockfish are mostly unknown. Younger juveniles (less than 25-cm fork length) are rarely caught on any fishing gear, so it is likely that fishing does not occur and, thus, has no direct effect on whatever habitat they do occupy. However, older juveniles and adults have been observed in association with corals and sponges (Krieger and Wing 2002, Freese and Wing 2004), and both life stages may prefer habitat created by such epifauna.

No direct evidence exists that indicates habitat disturbance affects the growth to maturity of dusky rockfish. However, the potential reduction of benthic habitat such as sponge and hard corals evidenced by the high LEIs in dusky rockfish habitat raises concern regarding the growth requirements of dusky rockfish. This is especially true because little information is available for younger juveniles that may be vulnerable to predation without adequate refugia. Juvenile survival is essential, but virtually nothing is known about it. If there are habitat impacts that would affect survival of juveniles to adults, then the reduction in coral and sponge as habitat is relevant. Growth analyses of length at age, weight at age, and weight at length of dusky rockfish caught in low trawl intensity areas versus high trawl intensity areas have been computed, but are inconclusive. The power of these tests is low due to the small sample sizes and must be improved to recognize any effects that might exist. Therefore, because the high LEI values for sponges and hard corals and the uncertainty surrounding their importance to dusky rockfish, it is unknown if growth to maturity has been affected by habitat disturbance.

Habitat Impacts Relative to Feeding

The major prey of adult dusky rockfish appears to be euphausiids, based on the limited food information available for this species (Yang 1993). As euphausiids are pelagic rather than benthic in their distribution and are too small to be retained by any fishing gear, fishing probably has a minimal or temporary effect on the availability of prey to adult dusky rockfish.

No direct evidence is available that indicates the feeding distributions have changed. Euphausiids are the major prey of dusky rockfish, and it is believed euphausiids are not directly associated with the bottom, but rather are thought to be advected onshore near bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). This would indicate that any change in feeding distribution is caused by oceanographic influences rather than habitat disturbance.

No direct evidence is available that indicates any change in the diet of dusky rockfish. Because euphausiid distributions are likely not affected by habitat disturbances and known to be widespread in the GOA, it is doubtful that diet changes would be detectable between heavily fished and lightly fished regions. In summary, there is no evidence that habitat disturbance has affected feeding success.

Stock Status and Trends

Stock status information for dusky rockfish is limited. Prior to 2003, average trawl survey biomass estimates were used to estimate abundance. In 2003, an age-structured model was introduced using all available data from 1977 to present. The model output provides trends of spawning biomass from 1977 to the present, but does not estimate anything prior to 1977. Therefore, there is little stock structure information prior to 1977, and the information from the model is limited by the amount of data that are available for model input.

Model estimates indicate spawning biomass increased slightly between 1977 and 1987 and has remained relatively steady since then (Lunsford et al. 2004). During this period, there have been no major declines in estimated abundance. Information is not available for years prior to 1977, however, and it is unknown what the stock trends were before this date or what influence long-term impacts to the habitat have had on dusky rockfish abundance.

Model estimates of recruitment vary greatly, which is typical of rockfish in the GOA. No obvious trend in recruitment is discernable since 1977. Several recent year classes appear to be strong. However, historical recruitments prior to 1977 are not available for comparison.

There is no evidence that the cumulative effects of fishing activities on habitat have impaired the stock's ability to produce MSY since 1977. Spawning biomass appears relatively stable from 1977 to 2004, and recruitments have been variable and strong in recent years. Because of the 1977 starting point and the limited input data to the model, however, a decrease in MSY over the long term is difficult to detect.

Summary

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Growth to Maturity	U (Unknown effect)
Feeding	MT (Minimal, temporary, or no effect)

Summary of Effects—The effects of fishing on the habitat of dusky rockfish are either unknown or negligible; however, caution is warranted. There is some information to suggest that bottom trawling may have a negative impact on the benthic habitat, especially corals and sponges. The LEI analysis indicates that there is a potential for large reductions in living substrates and hard coral habitats that dusky rockfish inhabit. The potential loss of these habitats would likely not have an effect on spawning/breeding of dusky rockfish or their feeding behavior. Very little information is available on these aspects of their life history, however, and further investigation may prove otherwise. A reduction in living structure and hard corals may impede these fishes' ability to reach growth to maturity. Several observations have shown rockfish to be associated with sponges and coral. The extent of this association is largely unknown, though, but may be of significance if these substrates increase survival rates by acting as refugia to juveniles or adults. An age-structured model has recently been developed for dusky rockfish and indicates no obvious trends in recruitment or spawning biomass. Data for this model are limited, however, and recruitment in the years prior to 1977 is not known, making long-term effects difficult to detect.

B.3.3.22 Thornyhead Rockfish (GOA)

While there was considerable new information to evaluate habitat effects for the major target groundfish species in Alaska, there were some species where information was either too sparse to evaluate, or simply did not exist. Such was the case for GOA thornyheads. Although thornyhead growth and catch per unit effort information was available from the NMFS surveys of the GOA, it was from habitats with the same type of impact (low); hence, it was impossible to evaluate differences in impact between areas. For this reason, the original GOA thornyhead evaluation described in the DEIS still represents the best available information, despite extensive inquiry to improve upon it.

Habitat Connections

Spawning/Breeding
Thornyheads spawn gelatinous pelagic egg masses. See Section 3.2.1.1.10.7 for further discussion and references.

Feeding
The adults feed mainly on epibenthic shrimp in the GOA; other prey includes small fish, benthic amphipods, and other benthic invertebrates and euphausiids. See Section 3.2.1.1.10.7 for further discussion and references.

Growth to Maturity
Larvae are pelagic for up to 15 months. Juveniles habits are generally unknown. Adults are demersal and are found in deep waters between 200 to 1,000 m. There is some evidence from studies of California and Oregon that younger individuals are found in shallower waters 200 to 600 m deep and that larger, older fish are found in deeper waters between 600 to 1,000 m. See Section 3.2.1.1.10.7 for further discussion and references.

Evaluation of Effects

Issue	**Evaluation**
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

GOA thornyhead eggs are presumed to be associated with pelagic habitats based on observations off the West Coast. GOA juveniles and adults are also associated with benthic habitats; specifically, on the deep shelf and slope in any type of non-living substrate, but they may prefer hard, non-living substrate according to limited studies in the eastern GOA. Overall, the GOA deep shelf and slope habitats comprise 33 and 22 percent, respectively, of the area designated as the thornyhead concentration distribution within the GOA (Table B.3-3). Of this 33 and 22 percent, 1 percent of the non-living substrate within the deep shelf and slope GOA habitat is projected to be reduced under status quo (Table B.3-3). It is assumed that this would have a negligible impact. Therefore, the ratings for the effects of spawning/breeding and growth to maturity for GOA thornyheads are no effect. The adults feed mainly on epibenthic shrimp and other benthic organisms which are included in epifaunal and infaunal features and are projected to be reduced by 1 percent in each habitat. It is assumed that the 1 percent reduction of epifauna and infauna within the GOA shallow and deep shelf habitats occupied by thornyheads would not have an impact and the rating for feeding is also no effect.

B.3.3.23 Other Rockfish Species (BSAI)

The other rockfish complex includes all species of *Sebastes* and *Sebastolobus* spp. other than Pacific ocean perch (*Sebastes alutus*) and those species in the other red rockfish complex (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; and shortraker rockfish, *S. borealis*). This complex is one of the rockfish management groups in the BSAI regions. Eight out of 28 species of other rockfish have been confirmed or tentatively identified in catches from the EBS and AI region; thus, these are the only species managed in this complex (Reuter and Spencer 2001, NMFS 2003). The two most abundant species for this complex are dusky rockfish (*Sebastes variabilis*) and shortspine thornyheads (*Sebastolobus alascancus*).

Dusky Rockfish

Habitat Connections

Habitat preferences for the life stages of dusky rockfish in the BSAI are either unknown or very poorly known (Table B.3-1). Adult dusky rockfish are thought to occur mainly in the middle and lower portions of the water column over areas of cobble, rock, and gravel along the outer continental shelf and upper slope region; thus, any adverse effects to this habitat type may influence the health of the dusky rockfish population. It is well documented that species under the genus *Sebastes* are viviporous, where the egg stage is completed within the female and the bears live larvae. In the larval stage, most *Sebastes* spp. can only be identified using genetics, but most, if not all, *Sebastes* larvae are pelagic until a certain age and then are believed to recruit to the bottom and become demersal. Most *Sebastes* have been documented to spend their early juvenile stages in depths shallower than the adult stage, but few juvenile dusky rockfish have been collected during the AFSC's trawl surveys. Table B.3-1 reflects this lack of data.

Spawning/Breeding
There is no information on the reproductive behavior of dusky rockfish in the BSAI. Thus, the effects of fishing on the habitat required for dusky rockfish reproduction are unknown.

Feeding
There is no information on the feeding behavior of dusky rockfish in the BSAI. In the GOA, though, they have been found to prey primarily on euphausiids (Yang 1993).

Growth to Maturity
Habitat requirements for the various life stages of dusky rockfish are unknown. In the BSAI, no juvenile specimens have been collected, and fishery data show that juveniles are not being caught (Reuter and Spencer 2004). Therefore, the habitat connections for dusky rockfish from growth to maturity are unknown.

Evaluation of Effects

LEI Values Relative to Species Distribution
Of the various BSAI habitats, only the AI deep and AI shallow habitats comprise 1 percent of the dusky concentrated distribution. Of this, living and non-living structures seem to be the most reduced habitat features for dusky rockfish in the BSAI, and hard coral is the most reduced in the AI (Table B.3-3). The LEI shows a 20 to 66 percent disturbance of the living and non-living habitat features within the concentrated distribution of dusky rockfish in the BSAI. The LEI shows that 55 to 63 percent of coral habitat is disturbed within the concentrated distribution area of dusky rockfish in the AI. The LEI maps and our current knowledge of the association of dusky rockfish with these habitats do not provide further information on the effect these proposed percentages of disturbance may have on the distribution of dusky rockfish. Given that only 1 percent of the area of dusky rockfish concentrated distribution is reflected in this analysis, the reductions in habitat features are probably no effect. The LEI model is intended to provide relative vulnerability of habitat features to fishing effort such that the absolute values of the estimated reductions are less important than their relation to each other.

Habitat Impacts Relative to Spawning/Breeding
The impacts of fishing on habitat relative to the spawning/breeding behavior of dusky rockfish are unknown.

Habitat Impacts Relative to Growth to Maturity
There is no information on the impacts of habitat disturbances to the growth to maturity of dusky rockfish. However, if information is gathered that strongly correlates growth to maturity of dusky rockfish to habitat such as living and non-living structure, then measures should be taken to limit the effects of fishing to those habitats. Currently, this impact is unknown.

Habitat Impacts Relative to Feeding
Although no studies have been conducted in the BSAI on the feeding behaviors of dusky rockfish, they feed mainly on euphausiids in the GOA. Being pelagic, it is more than likely that euphausiid distribution, thus availability of prey for dusky rockfish, is not affected by bottom habitat disturbances.

Stock Status and Trends
Stock status for dusky rockfish is unknown. Currently the other rockfish complex biomass is estimated mainly by the shortspine thornyheads (SST) biomass estimate.

Summary

Issue	**Evaluation**
Spawning/breeding	U (Unknown effect)
Feeding	MT (Minimal, temporary or no effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—In general the effects of fishing on the habitat of dusky rockfish are unknown or minimal. The main concern lies in the amount of habitat that has been estimated to be disturbed within the general distribution of dusky rockfish in the BSAI. If the loss of substrates, both living and non-living, is great due to the effects of fishing or as the result of a natural occurrence, then there is the potential that dusky rockfish growth to maturity may be affected. Many species of rockfish utilize rocky outcroppings and/or coral as a type of refugia during some or all of their life history stages. If this refugia is found to play an important role in the survival of this species, then loss of the substrate that makes up this refugia may decrease the survival rate of dusky rockfish.

BSAI Shortspine Thornyheads

Habitat Connections

Habitat preferences for the life stages of SST in the BSAI are either unknown or very poorly known (Table B.3-1). It is known that SST eggs are pelagic and float in masses of various sizes and shapes until larval stage is reached. The larval stage is also pelagic, and it is thought that after 14 to 15 months they begin settling to the bottom. Little information on the juvenile stage of SST is available. The juveniles and adults of this species are thought to occur over mud, sand, rock, cobble, and gravel substrate along the middle and outer continental shelf to the upper and lower slope of the EBS and AI; thus, any adverse effects to this habitat type may influence the health of the thornyhead rockfish population. Although the size of SST collected from both the AI survey and BS slope survey ranged from 15 to 50 cm, the majority of those collected were adults. Larger adults are found in deeper depths, suggesting that SST migrate deeper as they get older.

Spawning/Breeding
SST spawn gelatinous egg masses that are pelagic. No studies of SST spawning/breeding have been done for the BSAI.

Feeding
Analysis of SST stomach contents from the AI 1991 and 1994 trawl surveys showed that SST consume large amounts of fish (cottids, rajidae) and shrimp (pandalid) (Yang 2003, 1996). These prey items are mainly benthic and may be impacted by certain fishing gear such as bottom trawl. Yang 2003 noted that SST diet may be size-dependent, meaning that larger sized SST eat larger prey items; thus, those prey items large enough to be impacted by fishing gear may impact prey availability to SST.

Growth to Maturity
Larvae SST are thought to be pelagic for up to 15 months. Unfortunately, it is unknown when or how larvae recruit to the benthos. Adult SST are demersal and are found mainly at depths of 200 to 1,000 m. Similar to *Sebastes* spp., there is some evidence that younger/smaller SST are found shallower than the older/larger SST. It is not known whether SST prefer structured habitat, but they have frequently been collected from research surveys and fisheries using a variety of gear types (i.e., bottom trawl and longline).

Evaluation of Effects

LEI Values Relative to Species Distribution
Of the various BSAI habitat types, the AI deep comprised 23 percent of the concentrated distribution of SST (Table B.3-3). The BSAI slope comprised 12 percent of the SST concentrated distribution. The other habitat types comprised less than or equal to 5 percent of the concentrated distribution. Of the AI deep habitat, hard coral depletion was 9 percent in the areas where concentrated distribution of SST occurred, followed by living structure (4 percent of concentrated distribution). Given that no associations have been made to suggest that hard coral or living structures are the exclusive habitat type of SST, the projected depletion of these habitat types will have a minimal impact on SST species distribution.

Habitat Impacts Relative to Spawning/Breeding
Due to the pelagic nature of SST egg masses, impacts of habitat disturbances to the spawning/breeding behavior of SST are minimal.

Habitat Impacts Relative to Growth to Maturity
Impacts of habitat disturbances to the growth to maturity of SST are probably minimal. However, if information is gathered that strongly correlates survival success from growth to maturity of SST to habitat such as living and non-living structure, then measures should be taken to limit the effects of fishing to those habitats.

Habitat Impacts Relative to Feeding
SST prey are mainly epifauna, fish, and shrimp (Yang 2003, 1996). Table B.3-3 shows that a 14 percent reduction of epifauna is found in the BS sand habitat in the area of SST concentrated distribution. Fortunately, though, this habitat contributes to only 1 percent of the entire area where the concentrated SST distribution occurs. Therefore, habitat impacts relative to feeding are no effect.

Stock Status and Trends
Stock status for SST is good. The AI and BS slope bottom trawl surveys do a good job in assessing the biomass of SST. Currently, SST make up about 90 percent of the other rockfish complex. The average

survey biomass of all rockfish within the complex is used to estimate abundance. Although an economically valuable fish, there is no directed fishery for SST in the BSAI; thus, there are no areas where SST have been consistently fished since our domestic fisheries began back in 1977. The general trend in the SST biomass is positive, gaining 4,000 mt in the AI alone from the 2002 survey to the 2004 survey (Reuter and Spencer 2004).

Summary

Issue	Evaluation
Spawning/breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—In general, the relationship between habitat and SST survival rates has not been established. Given current information, however, impacts to habitat that may support various life stages of SST are minimal to no effect. The main concern is prey availability to SST. Because epifauna are the main prey items for SST, the impacts to those habitats that support their various life stages are also important. Unfortunately, there are no good data to determine which epifauna are the most important in SST diet along the large area of the BSAI.

B.3.3.24 Other Species

While there was considerable new information to evaluate habitat effects for the major target groundfish species in Alaska, there were some species where information was either too sparse to evaluate, or simply did not exist. For other species, especially nontarget species such as skates, sculpins, sharks, squids, and octopi, growth information has not been collected historically, and species-specific catch per unit effort information may be unreliable. Information on nontarget species is improving, but it is currently insufficient to evaluate habitat specific impacts. For these reasons, the original evaluations for the following species groups presented in the DEIS still represent the best available information, despite extensive inquiry to improve upon it.

B.3.3.24.1 BSAI Sharks (sleeper sharks and salmon sharks)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of sleeper sharks or salmon sharks. Sleeper sharks are thought to occur mainly in the middle and lower portions of the water column along the outer continental shelf and upper slope region; thus, any adverse effects to this habitat type may influence the health of the sleeper shark population. Salmon sharks are thought to occur in pelagic waters along the outer continental shelf and upper slope region of the EBS. Thus, any adverse effects to this habitat type, including disruption or removal of pelagic prey by fisheries, may influence the health of the salmon shark population.

B.3.3.24.2 GOA Sharks (dogfish, sleeper sharks, and salmon sharks)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of dogfish, sleeper sharks, or salmon sharks. Dogfish are thought to occur in the middle and lower portions of the water column and appear to concentrate in gullies along the continental shelf in the GOA. Sleeper sharks are thought to occur mainly in the middle and lower portions of the water column along the outer continental shelf and upper slope region, as well as in similar depths in Shelikof Strait and other gully habitats. Salmon sharks are pelagic throughout the GOA and appear to concentrate in Prince William Sound as well as in Shelikof Strait. Thus, any adverse affects to these habitat types may influence the health of GOA shark populations.

B.3.3.24.3 BSAI Skates (between 8 and 15 species in the genus *Bathyraja*)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of skates. Skates are benthic dwellers. The Alaska skate dominates the skate complex biomass in the EBS and is distributed mainly on the upper continental shelf. The diversity of the group increases with depth along the outer continental shelf and slope, with several new species likely to be described in the near future. Therefore, any adverse affects to the shallow shelf habitat may influence the health of the Alaska skate populations, while any adverse affects to outer continental shelf and slope habitats may influence the health of multiple species of skates.

B.3.3.24.4 GOA Skates (two Raja species, Big and longnose skate, and 8-15 Bathyraja species)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of skates. Skates are benthic dwellers. The big skate, a new commercial species in the GOA, comprises just under half of the skate complex biomass in the GOA and is distributed mainly on the upper continental shelf. However, other skate species are found throughout that habitat as well. The diversity of the group increases with depth in the gullies within the continental shelf and along the outer continental shelf and slope. Therefore, any adverse affects to the shallow shelf habitat may influence the health of the big skate populations as well as other skate species, while any adverse affects to outer continental shelf and slope habitats may influence the health of multiple species of skates.

B.3.3.24.5 BSAI Sculpins (over 60 species identified in BSAI trawl surveys)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of sculpins. Sculpins are benthic dwellers. Some sculpin species guard their eggs, and at least one species, the bigmouth sculpin, lays its eggs in vase sponges in the AI, although it is not known whether a particular type of sponge, or sponges in general, are essential to reproductive success. There are so many diverse species in this category that almost all benthic areas in the EBS and AI are likely to be inhabited by at least one sculpin species. Therefore, any adverse affects to habitat may influence the health of species in the sculpin complex.

B.3.3.24.6 GOA Sculpins (48 species identified in GOA trawl surveys)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of sculpins. Sculpins are benthic dwellers. Some sculpin species guard their eggs, and at least one species, the bigmouth sculpin, lays its eggs in vase sponges, although it is not known whether a particular type of sponge, or sponges in general, are essential to reproductive success. There are so many diverse species in this category that almost all benthic areas in the GOA are likely to be inhabited by at least one sculpin species. Therefore, any adverse affects to habitat may influence the health of species in the sculpin complex.

B.3.3.24.7 BSAI Squids (5 or more species)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of squid. Squid are thought to occur in pelagic waters along the outer continental shelf and upper slope region of the EBS and AI, and concentrate over submarine canyons; thus, any adverse effects to this habitat may influence the health of the squid populations.

B.3 3.24.8 GOA Squid (10 or more species)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of squid. Squid are thought to occur in pelagic waters along the gullies within the continental shelf and the outer continental shelf, in the upper slope region of the GOA, and to concentrate over submarine canyons; thus, any adverse effects to this habitat may influence the health of the squid populations.

B.3.3.24.9 BSAI octopi (5 or more species)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the EBS or AI to determine whether fishing activities have an effect on the habitat of octopi. Octopi occupy all types of benthic habitats, extending from very shallow subtidal areas to deep slope habitats; thus, any adverse effects to this habitat may influence the health of octopus populations. Knowledge of octopi distributions are insufficient to allow comparison with fishing effects.

B.3.3.24.10 GOA Octopi (5 or more species)

Habitat Connections, Evaluation of Effects

Issue	Evaluation
Spawning/breeding	U (Unknown effect)
Feeding	U (Unknown effect)
Growth to maturity	U (Unknown effect)

Summary of Effects—Essential habitat requirements for species in this category are unknown. No studies have been conducted in the GOA to determine whether fishing activities have an effect on the habitat of octopi. Octopi occupy all types of benthic habitats, extending from very shallow subtidal areas to deep slope habitats; thus, any adverse effects to this habitat may influence the health of octopus populations. Knowledge of octopi distributions are insufficient to allow comparison with fishing effects.

B.3.4 Effects of Fishing on Essential Fish Habitat of Forage Species

The forage species category was created by Amendments 36 and 39 to the BSAI and GOA FMP. This category includes eight families of fish (Osmeridae, Myctophidae, Bathylagidae, Ammodytidae, Trichodontidae, Pholidae, Stichaeidae, and Gonostomatidae) and one order of crustaceans (Euphausiacea). The aforementioned amendments prohibit the directed fishery of any forage species. The species included in this category have diverse life histories and it is impractical to analyze the group as a whole. Therefore, for the purpose of this document, each family and order will be analyzed separately.

B.3.4.1 Family Osmeridae

Habitat Connections

Spawning/Breeding
Most of the Alaska species of Osmerids (or smelt) spawn on beaches, rivers, or estuaries. There is little to no fishing pressure in the habitat needed for spawning/breeding. Hence, the effects of fishing are anticipated to have no impact on essential spawning, nursery, or settlement habitat.

Feeding
Adult smelt feed on pelagic zooplankton. Most of the smelt diet is composed of euphausiids and copepods, which are not likely to be affected by fishing.

Growth to Maturity
Osmerids have pelagic larval, juvenile, and adult life stages. During these stages, there is no evidence that survival of smelt is dependent on habitat that is affected by fishing.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Most of the Alaska species of smelt spawn on beaches, rivers, or in estuaries. Certain species of smelt, such as capelin, have been shown to have an affinity towards spawning grounds with specific substrate grain size (coarse sand or fine gravel). Therefore, non-living substrate is assumed to be very important for spawning/breeding. However, smelt spawning areas do not overlap with areas of intensive fishing. There is little to no fishing pressure in the nearshore environment needed by these species. Hence, the effects of fishing are anticipated to have little impact on the stock. The rating for the effects of fishing on spawning and breeding of smelt is MT.

Juvenile and adult smelt feed primarily on neritic plankton. There is little evidence that survival or prey availability of smelt is dependent on habitat that is disturbed by fishing. Therefore, the effects of fishing on the feeding and growth to maturity of smelt are rated MT.

B.3.4.2 Family Myctophidae

Habitat Connections

Spawning/Breeding
Myctophids (or lanternfish) are small bathypelagic species of fish. Myctophids are broadcast spawners, and their eggs are pelagic. Hence, the effects of fishing are anticipated to have little impact on essential spawning, nursery, or settlement habitat.

Feeding
Adult Myctophids feed on pelagic zooplankton. The Myctophid diet is composed largely of euphausiids and copepods, which are not species likely to be affected by fishing.

Growth to Maturity
Myctophids have pelagic larval, juvenile, and adult life stages. During these stages, there is no evidence that survival of Myctophids is dependent on habitat that is affected by fishing.

Evaluation of Effects

Issue	**Evaluation**
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Myctophids are pelagic throughout all life history stages. There is little evidence that Myctophid survival is dependent on habitat affected by fishing. Myctophids are broadcast spawners with pelagic eggs. Juvenile and adult Myctophids prey on neritic zooplankton and do not require physical structure for protection. Therefore, the effects of fishing on the spawning and breeding, feeding, and growth to maturity of Myctophids is rated MT.

B.3.4.3 Family Ammodytidae

Habitat Connections

Spawning/Breeding
Pacific sand lance (*Ammodytes hexapterus*) spawn on sand in shallow water. There is little to no fishing pressure in the nearshore habitat needed for spawning/breeding. Hence, the effects of fishing are anticipated to have no impact on essential spawning, nursery, or settlement habitat.

Feeding
Adult sand lance feed on pelagic zooplankton. Most of the sand lance diet is composed of copepods, which are not likely to be affected by fishing.

Growth to Maturity
Pacific sand lance have pelagic larval, juvenile, and adult life stages. During these stages, there is no evidence that survival of sand lance is dependent on habitat that is affected by fishing.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—The sole member of family Ammodytidae found in Alaska is the Pacific sand lance (*Ammodytes hexapterus*). Sand lance have been shown to have an affinity towards spawning grounds with specific substrate grain size (coarse sand). Therefore, non-living substrate is assumed to be very important for spawning/breeding. However, smelt spawning areas do not overlap with known areas of intensive fishing. There is little to no fishing pressure in the nearshore habitat needed by these species. Hence, the effects of fishing on the EFH of sand lance is rated MT.

Juvenile and adult sand lance feed primarily on copepods. There is little evidence that survival or prey availability of sand lance is dependent on habitat disturbed by fishing. Therefore, the effects of fishing on the feeding and growth to maturity of smelt are rated MT.

B.3.4.4 Family Trichodontidae

Habitat Connections

Spawning/Breeding
Pacific sandfish (*Trichodon trichodon*) lay demersal adhesive egg masses in rocky intertidal areas. There is little to no fishing pressure in the nearshore habitat needed for spawning/breeding. Hence, the effects of fishing are anticipated to have no impact on essential spawning, nursery, or settlement habitat.

Feeding
Pacific sandfish are ambush predators that lay in wait for prey buried under the sand. They have been shown to consume some epifauna prey, but more than 95 percent of their diet consists of small fish. It is unknown how these prey species are affected by fishing.

Growth to Maturity
Pacific sandfish larvae are pelagic, but juveniles and adults are demersal. Little is known about sandfish distribution in the BSAI and GOA. The effect of fishing on the survival of Pacific sandfish is unknown.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	U (Unknown)
Growth to maturity	U (Unknown)

Summary of Effects—Two members of the family Trichodontidae are found in the BSAI and GOA: the sailfin sandfish (*Arctoscopus japonicus*) and the Pacific sandfish (*Trichodon trichodon*). However, the sailfin sandfish is rarely encountered in Alaska waters. For the purposes of this document, attention will be focused on the Pacific sandfish.

Pacific sandfish lay demersal adhesive egg masses in rocky intertidal areas. The presence of the proper non-living substrate is important for the spawning/breeding of sandfish. However, there is little overlap of the spawning areas with known areas of intensive fishing. Hence, the effects of fishing on spawning/breeding of sandfish are rated MT.

Pacific sandfish are ambush predators that lay in wait for prey buried under the sand. They have been shown to consume some epifauna prey, but more than 95 percent of their diet consisted of small fish. It is unknown how these prey species are affected by fishing.

Pacific sandfish larvae are pelagic, but juveniles and adults are demersal. Little is known about sandfish distribution in the BSAI and GOA. The effect of fishing on the survival of Pacific sandfish is unknown due to lack of data.

B.3.4.5 Family Pholidae

Habitat Connections

Spawning/Breeding
There are several species of Pholids (or gunnels) found in Alaska waters. Most species of gunnels reside and breed in the shallow, nearshore habitat where there is little to no fishing effort. Hence, the effects of fishing are anticipated to have no impact on essential spawning, nursery, or settlement habitat.

Feeding
The diet of gunnels has been shown to rely heavily on epifaunal and infaunal prey. However, as stated above, there is little fishing in the shallow waters utilized by these species. For that reason, the effects of fishing are anticipated to have no impact on prey availability.

Growth to Maturity
There is little to no fishing pressure in the shallow, nearshore environment occupied by Pholids. Consequently, the effects of fishing are anticipated to have no impact on the survival of fish to maturity.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—There are several species of Pholids (or gunnels) found in Alaska waters. Most species of gunnels reside, feed, and breed in the shallow, nearshore habitat, where there is little to no fishing effort. Due to the lack of fishing pressure in the environs used by Pholids, the effects of fishing on the spawning/breeding, feeding, and growth to maturity are all rated MT.

B.3.4.6 Family Stichaeidae

Habitat Connections

Spawning/Breeding
There are many species of Stichaeids (or pricklebacks) found in Alaska waters. Most species of pricklebacks reside and breed in the shallow, nearshore habitat where there is little to no fishing effort. Hence, the effects of fishing are anticipated to have no impact on essential spawning, nursery, or settlement habitat.

Feeding
The diet of pricklebacks has been shown to rely heavily on epifaunal and infaunal prey. However, as stated above, there is little fishing in the shallow waters used by these species. For that reason, the effects of fishing are anticipated to have no impact on prey availability.

Growth to Maturity
There is little to no fishing pressure in the shallow, nearshore environment occupied by pricklebacks. Consequently, the effects of fishing are anticipated to have no impact on the survival of fish to maturity.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Due to the lack of fishing pressure in the environs used by pricklebacks, the effects of fishing on the spawning/breeding, feeding, and growth to maturity are all rated MT.

B.3.4.7 Family Gonostomatidae

Habitat Connections

Spawning/Breeding
Gonostomatids (or bristlemouths) are small bathypelagic species of fish. Bristlemouths are broadcast spawners, and their eggs are pelagic. Hence, the effects of fishing are anticipated to have little impact on essential spawning, nursery, or settlement habitat.

Feeding
Adult bristlemouths feed on pelagic zooplankton (mostly copepods). Bristlemouth prey species are not likely to be affected by fishing.

Growth to Maturity
Bathylagids have pelagic larval, juvenile, and adult life stages. During these stages, there is no evidence that survival of bathylagids is dependent on habitat that is affected by fishing.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Bristlemouths are pelagic throughout all life history stages. There is little evidence that bristlemouths survival is dependent on habitat that is affected by fishing. Bristlemouths are broadcast spawners with pelagic eggs. Juvenile and adult bristlemouths prey on neritic zooplankton and do not require physical structure for protection. Therefore, the effects of fishing on the spawning/breeding, feeding, and growth to maturity of bristlemouths are rated MT.

B.3.4.8 Order Euphausiacea

Habitat Connections

Spawning/Breeding
Euphausiids are broadcast spawners and their eggs are pelagic. Hence, the effects of fishing are anticipated to have little impact on essential spawning, nursery, or settlement habitat.

Feeding
Euphausiids feed on phytoplankton and zooplankton. Euphausiid prey species are not likely to be affected by fishing.

Growth to Maturity
Euphausiids have pelagic egg, larval, and adult life stages. During these stages, there is no evidence that survival of euphausiids is dependent on habitat affected by fishing.

Evaluation of Effects

Issue	Evaluation
Spawning/Breeding	MT (Minimal, temporary, or no effect)
Feeding	MT (Minimal, temporary, or no effect)
Growth to maturity	MT (Minimal, temporary, or no effect)

Summary of Effects—Euphausiids (or krill) are small, shrimp-like crustaceans which, along with copepods, make up the base of the food web in the BSAI and GOA. Euphausiids are pelagic throughout their entire life cycle and do not have a strong link to habitat that is affected by fishing. Euphausiids do not require habitat that is disrupted by fishing for spawning/breeding, feeding, or growth to maturity. Therefore, the effects of fishing for euphausiids is MT.

B.4 Conclusions

B.4.1 Species Evaluations

Evaluations were completed for 26 managed species (or species groups) and 8 forage species (Table B.4-1). See Sections B.3.2 to B.3.4 for more detailed information. Based on the available information, the analysis found no indication that continued fishing at the current rate and intensity would affect the capacity of EFH to support the life history processes of any species. In other words, the effects of fishing on EFH would not be more than minimal. Reasons for minimal ratings were predominantly either lack of a connection to affected habitat features, or findings from stock analyses that current fishing practices (including effects on habitat) do not jeopardize the ability of the stock to produce MSY over the long term. Other evaluations indicated that, even though a connection may exist between a habitat feature and a life-history process, the expected feature reductions were considered too small to make effects at the population level likely. There were also cases where the effects did not overlap significantly with the distribution of the species.

About one-third of the ratings were U (unknown effect). Most of unknown ratings were for species that have received relatively little study; hence, their life history needs and population status are poorly known. Most species with unknown ratings support small or no fisheries. Conversely, species that support significant fisheries have been studied more. In some cases, associations between the habitat features and life history processes were indicated, but the evaluator did not have enough information to assess whether the linkage and the amount of feature reduction would affect species welfare.

Even for well studied species, the knowledge to trace use of habitat features confidently for spawning, breeding, feeding, and growth to maturity to population level effects is not yet available. Several evaluators specifically cited uncertainty regarding the effect of particular noted linkages, and some urged caution. Most of these situations involved potential linkages between the growth-to-maturity of rockfish and Atka mackerel and habitat structure.

B.4.2 General Effects on Fish Habitat

While this evaluation identified no specific instances of adverse effects on EFH that were more than minimal and not temporary, the large number of unknown ratings and expressions of concern make it prudent to look for more general patterns across all of the species and habitat features (Table B.4-2).

Specific areas with high fishing effort, and hence high LEIs, were identified in the effects-of-fishing analysis. These included two large areas of the EBS, one north of Unimak Island and Unimak Pass and the other between the Pribilof Islands and Bristol Bay. Both of these areas have continued to be highly productive fishing grounds through decades of intensive fishing. While that may initially seem at odds with the LEI results, it is consistent with the evaluation that the habitat features affected by fishing either are not those important to the species fished in those areas, or are not being affected in a way that limits species welfare.

Fishing concentrations in other areas were smaller, but made up higher proportions of the GOA and EBS slopes. The largest effect rates were on living structure, including coral. The high reliance on limited areas for fishing production and their high estimated LEIs make it prudent to obtain better knowledge of what processes occur in those locations.

Table B.3-1 shows the habitat connections identified for each life stage of managed species and species groups. Each row represents a species life stage and each column one of the habitat types from the fishing-effects analysis. At their intersections, evaluators entered letters representing each of the habitat features (prey or structure classes) used by that life stage in that habitat. Most species of groundfish have pelagic larval and egg stages. Only one species, Atka mackerel, had a connection with a benthic habitat feature for its egg or larval stages. A combined tally at the bottom of the table notes how many species/life-stages were identified for each habitat feature in each habitat. Prey features represented about twice as many connections as structure features. The habitat feature/type combinations that had LEIs above 5 percent, outlined in the table, tended to have few connections. The highest number of connections (six) were for living structures on the GOA deep shelf, which had the lowest LEI of the outlined habitat feature/type combinations (6.2 percent). Connections with the highlighted blocks mostly involved rockfish species, with a few connections from Atka mackerel and blue king crab.

Cropping and summing effects on habitat features by distributions of the adults of each species (Table B.3-3) depicted how the fishing effects overlapped in the locations where each species is present. The general distribution values related to the broader areas occupied, while the concentration values related to areas of higher abundance. Concentration LEIs were generally higher than the estimates based on general distribution because adult species concentrations determine where fisheries operate. It is unfortunate that distributions were not available for juveniles because connections to the habitat feature with the highest LEIs (living structure) mostly involved the growth to maturity process. Characterizing juvenile distributions should be a high priority for future research.

Reductions across adult species distributions for the living structure were mostly between 10 and 17 percent. Higher values occurred for red king crab (29 percent for both coverages) and Atka mackerel (18 and 26 percent). The king crab evaluator noted that the distribution of juveniles was mostly outside of the affected areas. The evaluator for Atka mackerel emphasized use of non-living substrates by that species. Prey class effects by species distributions were all at or below 5 percent. In combination with negligible effects on habitat of forage species (Section B.3.5), this indicates that effects on availability of prey were minimal.

While LEIs for hard corals are subject to the limitations mentioned in Section B.2.6, they had the highest LEIs when considered by species distributions. Intersections where meaningful effects are most likely to occur are those between areas where hard corals are prevalent and species for which a significant portion of their distribution occurs in the same areas, including populations of golden king crab, Atka mackerel, sablefish, and the rockfish species. Coral LEIs at these points ranged from 23 to 59 percent. While few evaluators cited coral as specifically linked to life history functions, in some areas it may be an important component of the living structure that is potentially linked to growth to maturity for some of these species. Because of their very slow recovery, corals warrant particular consideration for protection and for the development of improved knowledge of their habitat functions and distribution.

B.5 Cumulative Effects of Fishing and Non-fishing Activities on EFH

This section discusses the cumulative effects of fishing and non-fishing activities on EFH. As identified in Section 4.4, historical fishing practices may have had effects on EFH that have led to declining trends in some of the criteria examined (Table 4.4-1). As described in earlier sections of Appendix B (Table B.4-2), the effects of current fishing activities on EFH are classified as minimal and temporary or unknown. Table B.4-2 identifies the rationale for the rating under each fishery.

A review of the effects of non-fishing activities on EFH is found in Appendix G and Table 3.4-37 of this EIS. Table 3.4-37 provides a summary of the detailed text descriptions found in Appendix G. The table identifies 29 non-fishing activities for which potential effects are described in Appendix G. However, the magnitude of these effects cannot currently be quantified with available information. Of the 29 activities, most are described as likely having less than substantial potential effects on EFH. Some of these activities such as urban/suburban development, road building and maintenance (including the placement of fill material), vessel operations/transportation/navigation, silviculture (including LTFs), and point source discharge may have potential cumulative impacts due to the additive and chronic nature of these activities. NMFS does not have regulatory authority over non-fishing activities, but frequently provides recommendations to other agencies to avoid, minimize, or otherwise mitigate the effects of these activities.

Fishing and each activity identified in the analysis of non-fishing activities may not significantly affect the function of EFH. However, the synergistic effect of the combination of all of these activities may be a cause for concern. Unfortunately, available information is not sufficient to assess how the cumulative effects of fishing and non-fishing activities influence the function of EFH on an ecosystem or watershed scale. The magnitude of the combined effect of all of these activities cannot be quantified, so the level of concern is not known at this point.

References

Abookire, A.A. In review. Reproductive biology, spawning season, and growth of female rex sole in the GOA.

Alaska Department of Fish and Game (ADF&G). 2000. A workshop examining potential fishing effects on population dynamics and benthic community structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaska waters. ADF&G Special Publication 14.

Allen, M.J., and G.B. Smith. 1988. “Atlas and zoogeography of common fishes in the BS and northeastern Pacific.” NOAA Technical Report, *NMFS 66*, U. S. Department of Commerce, NOAA. p. 151. *In* National Marine Fisheries Service 2001(a).

Andrews, A.H., E.E. Cordes, M.M. Mahoney, K. Munk, K.H. Coale, G.M. Cailliet, and J. Heifetz. 2002. Age, growth and radiometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the GOA. Hydrobiologia 471(1-3):101-110.

Ainley, D.G., W.J. Sydeman, R.H. Parrish, and W.H. Lenarz. 1993. Oceanic factors influencing distribution of young rockfish (Sebastes) in central California: A predator’s perspective. CalCOFI Report 34: 133-139.

Bailey, K.M. 2000. Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change. Mar. Ecol. Prog. Ser 198:215-224.

Bailey, K.M., T.J. Quinn II, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37: 179-255.

Ball, B.J., G. Fox, and B.W. Munday. 2000. Long- and short-term consequences of a Nephrops trawl fishery on the benthos and environment of the Irish Sea. ICES Journal of Marine Science. 57(5):1,315-1,320.

Balsiger, J.W. 1974. A computer simulation model for the EBS king crab population. Ph.D. dissertation, University of Washington. 198 p.

Balsiger, J.W. 1972. Standardization of BS red king crab fishery CPUE. INPFC Doc. No. 1514.

Barbeaux S., J. Ianelli, and E. Brown. 2004. Stock assessment of AI region pollock. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI regions. Prepared by the BSAI Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Barnhart, J. 2003. Personal communication, Alaska Department of Fish and Game, May 2003.

Bergman, M.J.N. and J.W. van Santbrink. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994 ICES Journal of Marine Science 57:1,321-1,331.

Berkeley, S.A., M.A. Hixon, R.J. Larson, and M.S. Love. Aug. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29:23-32.

Blood, D.M., A.C. Matarese, and M.S. Busby. In prep. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the GOA (based on research conducted 2001-2003).

Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (Sebastes alutus) in Priblof Canyon, Berring Sea. Continental Shelf Research. 21(3):207-224.

Brodeur, R.D., 1998. *In situ* observations of the association between juvenile fishes and *scyphomedusae* in the BS. Mar. Ecol. Prog. Ser. 163:11-20.

Brodeur, R.D., H. Sugisaki, and G.L. Hunt Jr. 2002. Increases in jellyfish biomass in the BS: implications for the ecosystem. Mar. Ecol. Prog. Ser. 233:89-103.

Brown, E. 2003. Effects of commercial otter trawling on EFH of the southeastern BS shelf. Master's Thesis, University of Washington.

Brylinsky, M., J. Gibson, and D.C. Gordon, Jr. 1994. Impacts of flounder trawls on the intertidal habitat and community of the Minas Basin, Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences. 51(3):650-661.

Carlson, H.R. 1994. Consistent yearly appearance of age-0 walleye pollock *Theragra chalcogramma* at a coastal site in southeastern Alaska, 1973-1994. Fish. Bull. 93:386-390.

Carlson, H.R. and Haight, R.E. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fjords of southeastern Alaska: Their environment, growth, food habits, and schooling behavior. Trans. Am. Fish. Soc 105: 191-201.

Carlson, H.R. and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of southeastern Alaska. Marine Fisheries Review 43(7):13-19.

Chikuni, S. 1975. Biological study on the population of the Pacific ocean perch in the North Pacific. Bull. Far Seas Fish. Res. Lab 12: 1-119.

Clark, M.R. and R. O'Driscoll. 2003. Deepwater fisheries and their impact on seamount habitat in New Zealand. Journal of Northwest Atlantic Fishery Science 31: 441-458.

Clausen, D.M. and J. Heifetz. 2003. The northern rockfish, *Sebastes polyspinis*, in Alaska: commercial fishery, distribution, and biology. Unpubl. manuscr. (submitted for publication to Mar. Fish. Rev. Available from NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau Alaska 99801).

Clausen, D.M. and J. Heifetz. 2002. The northern rockfish, *Sebastes polyspinus*, in Alaska: Commercial fishery, distribution, and biology. Mar. Fish. Rev 64(4):1-28.

Clausen, D.M., C.R. Lunsford, and J.T. Fujioka. 2002. Pelagic shelf rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 383-417. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D.M., J.T. Fujioka, and J. Heifetz. 2003. Shortraker/rougheye and other slope rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 531-572. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Collie, J.S., S.J. Hall, M.J. Kaiser, and I.R. Poiners. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology 69:785-798.

Connors, M. E., A.B. Hollowed, and E. Brown. 2004. Retrospective analysis of BS bottom trawl surveys: regime shift and ecosystem reorganization. Progress in Oceanography - in press.

Cote, D., S. Moulton, A. Scruton, and R.S. McKinley. 2001. Microhabitat use of juvenile Atlantic cod in a coastal area of Bonavista Bay, Newfoundland. Transactions of the American Fisheries Society. 130(6). Pp. 1217-1223.

Council. 2004. Stock Assessment and Fishery Evaluation report for the king and Tanner crab fisheries of the BSAI Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501. 238 p.

Council. 2003. Stock assessment and fishery evaluation report for the king and Tanner crab fisheries of the BSAI Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Council. 2000a. Environmental assessment for Amendment 11 to the Fishery Management Plan BSAI King and Tanner crabs. Rebuilding Plan for the Tanner Crab (*Chionoecetes bairdi*) Stock, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Council. 2000b. Environmental assessment for Amendment 14 to the Fishery Management Plan BSAI King and Tanner crabs. Rebuilding Plan for the Snow Crab (*Chionoecetes opilio*) Stock, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Council. 1999. Environmental assessment for Amendment 11 to the Fishery Management Plan BSAI King and Tanner crabs. Rebuilding Plan for the BS Tanner crab ©. *bairdi*) Stock, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Council. 1995. Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility analysis for red king crab bycatch in the BS trawl fisheries and alternatives for closure areas. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Courtney, D.L., D.M. Clausen, J. Heifetz, J.T. Fujioka, and J.N. Ianelli. 2003. GOA northern rockfish, p. 481-529. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Dew, C.B. 1990. Behavioral ecology of podding red king crab, *Paralithodes camtschatica*. Canadian Journal of Fisheries and Aquatic Science, 47(9), pp. 1994-1958.

Dew, C.B. and R.A. McConnaughey. in press. Did bottom trawling in Bristol Bay's red king crab broodstock refuge contribute to the collapse of Alaska's most valuable fishery? J. of Appl. Ecol.

Dew C.B. and R.A. McConnaughey. 2003. Did bottom trawling in Bristol Bay's red king crab broodstock refuge contribute to the collapse of Alaska's most valuable fishery? Proceedings of the symposium on effects of fishing activities on benthic habitats: linking, geology, biology, socioeconomics, and management, Tampa, FL, November 2002.

Dorn, M.W. 2004. Extending separable age-structured assessment models to evaluate trends in juvenile mortality of walleye pollock in the GOA. ICES CM 2004/FF:31.

Dorn, M.W., S. Barbeaux, S. Gaichas, M. Guttormsen, B. Megrey, K. Spalinger, and M. Wilkins. 2004. Assessment of the walleye pollock stock in the GOA. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the GOA. Prepared by the GOA Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Drinkwater, K. 2004. Summary Report: Review on evaluation of fishing activities that may adversely affect EFH in Alaska. Center for Independent Experts, Miami Florida.

Duffy-Anderson, J.T., L. Ciannelli, T. Honkalehto, K.M. Bailey, S.M. Sogard, A.M. Springer, and T. Buckley. 2003. Distribution of age-1 and age-2 walleye pollock in the GOA and EBS: sources of variation and implications for higher trophic levels. The Fish Big Bang. Proceedings of the 26th annual larval fish conference. Eds. H.I. Browman and A.B. Skiftesvik. Institute of Marine Research. Bergen, Norway.

Eno, N., D.S. Macdonald, J.A. Kinnear, S. Amos, C.J. Chapman, R.A. Clark, F.S. Bunker, and C. Munro. 2001. Effects of crustacean traps on benthic fauna. ICES Journal of Marine Science. 58(1):11-20.

Feder, H., and S. Jewett. 1981. Feeding interactions in the EBS with emphasis on the benthos. The Eastern Bering Sea Shelf: Oceanography and Resources, D.W. Hood and J.A. Calder, eds. OMPA/NOAA, University of Washington Press, Seattle, p. 69.

Fossa, J.H., P.B. Mortensen, and D.M. Furevik. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters distribution and fishery impacts. Hydrobiologia 471: 1-12.

Francis, R.C., S.R Hare, A.B. Hollowed, and W.S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fish. Oceanogr. **7**: 1-21.

Fredin, R. 1987. History of regulation of Alaska groundfish fisheries. NWAFC Processed Report 87-07.

Freese, J.L. 2001. Trawl induced damage to sponges observed from a research submersible. Marine Fisheries Review 63(3) 7-13.

Freese, L., P.J.Auster, J. Heifetz, and B.L. Wing. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the GOA. Marine Ecology Progress Series 182:119-126.

Freese, J.L. and B.L. Wing. 2004. Juvenile red rockfish, Sebastes sp., associations with sponges in the GOA. Mar. Fish. Rev. 65:38-42 (in press).

Fritz, L.W., A. Greig, and R.F. Reuter. 1998. Catch-per-unit-effort, length, and depth distributions of major groundfish and bycatch species in the BS, AI, and GOA regions based on groundfish fishery observer data. NOAA Tech. Memo. NMFS-AFSC-88. 179 p.

Fujioka, J. 2002. Presentation to the EFH Committee of the North Pacific Fisheries Management Council, Sitka Alaska.

Gharrett, A.J., Z. Li, C.M. Kondzela, and A.W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the GOA in 1998-2002. (Unpubl. manuscr. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801).

Gilkinson, K., M. Paulin, S. Hurley, and P. Schwinghamer. 1998. Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction Journal of Experimental Marine Biology and Ecology 224(2):291-312.

Gittings, S.R., T. J. Bright, A. Choi, and R.R. Barnett. 1988. The recovery process in a mechanically damaged coral reef community: Recruitment and growth. Proceedings of the Sixth International Coral Reef Symposium 2:225-230.

Grant, J. 2000. Modelling approaches to dredging impacts and their role in scallop population dynamics. Pages 27-36 in ADF&G, 2000. A workshop examining potential fishing effects on population dynamics and benthic community structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaska waters. ADF&G Special Publication 14.

Gunderson, D.R. 1997. Spatial patterns in the dynamics of slope rockfish stocks and their implications for management. Fish. Bull. 95: 219-230.

Gunderson, D.R. 1977. Population biology of Pacific Ocean perch, Sebastes alutus, stocks in the Washington-Queen Charlotte Sound region, and their response to fishing. Fish. Bull. 75: 369-403.

Gunderson, D.R., S.J. Westrheim, R.L. Demory, and M.E. Fraidenburg. 1976. The status of Pacific ocean perch (*Sebastes alutus*) stocks off British Columbia, Washington, and Oregon in 1974. Tech. Rep. Fish. Mar. Serv. Res. Dev. No. 690.

Gunderson, D.R. 1971. Evidence that Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound form aggregations that have different biological characteristics. J. Fish. Res Bd. Can. 29:1061-1070.

Gregory, R.S. and J.T. Anderson. 1997. Substrate selection and use of protective cover by juvenile Atlantic cod *Gadus morhua* in inshore waters of Newfoundland. Marine Ecology Progress Series. 146(1-3). pp 9-20.

Hanselman, D.H., Heifetz, J., Fujioka, J., and Ianelli, J. 2003. GOA Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA. North Pacific Fisheries Management Council. p. 429-479.

Hanselman, D.H., T.J. Quinn II, J. Heifetz, D. Clausen, and C. Lunsford. 2001. Spatial inferences from adaptive cluster sampling of GOA rockfish. *In* Spatial Processes and Management of Marine Populations. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040, [URL http //www.uaf.alaska.edu/seagrant/].

Hart, J.L. 1973. Pacific Fishes of Canada. Bulletin 180, Fisheries Research Board of Canada. 740 p.

Heifetz, J. 2002. Coral in Alaska: distribution, abundance, and species associations. Hydrobiologia 471: 19-28.

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

Hobson, E.S., J.R.Chess, and D.F. Howard. 2001. Interannual variation in predation on first-year Sebastes spp. by three northern California predators. Fish. Bull. 99: 292-302.

Hollowed, A., J. N. Ianelli, and P. Livingston. 2000. Including predation mortality in stock assessments: A case study for GOA pollock. ICES J. Mar. Sci 57(2):279-293.

Hunt, Jr., G.L., P. Stabeno, G. Walters, E. Sinclair, R.D. Brodeur, J.M. Napp, and N.A. Bond. 2002. Climate change and control of the southeastern BS pelagic ecosystem. Deep-Sea Res. Pt. II, 49(26), 5821–5853.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2004a. EBS Walleye Pollock Stock Assessment. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI regions. Prepared by the BSAI Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Ianelli, J. N., T. K. Wilderbuer, and T. M. Sample. 2004b. Greenland turbot. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

International North Pacific Fisheries Commission (INPFC; now the North Pacific Anadromous Fish Commission). 1968. INPFC document number 1148.

INPFC 1964. Condition of the king crab resource in the EBS. By K. Niwa and H. Fujita. Fisheries Agency of Japan. INPFC document number 765.

INPFC 1959. Progress report on king crab investigations - 1959. INPFC document number 316.

Ito, D.H. 1999. Assessing shortraker and rougheye rockfishes in the GOA: addressing a problem of habitat specificity and sampling capability. Ph.D. Dissertation, Univ. Washington, Seattle. 205 p.

Johnson, K.A. 2002. A review of national and international literature on the effects of fishing on benthic habitats. NOAA Technical Memorandum NMFS-FSPO-57. 72 pp.

Kenchington, E.L.R., J. Prena, K.D. Gilkinson, D.C. Gordon, K. MacIsaac, C. Bourbonnais, P.J. Schwinghamer, T.W. Rowell, D.L McKeown, and W.P. Vass. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences. 58(6):1043-1057.

Kendall, A.W. and W.H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. *Proceedings of the International Rockfish Symposium*, Anchorage, Alaska, pp. 99-117. *In* National Marine Fisheries Service 2001(a).

Kendall, A.W., Jr. 2000. An historical review of Sebastes taxonomy and systematics. Mar. Fish. Rev. 62: 1-16.

Kimura D.K. and L.L. Ronholt. 1988. In R.G. Bakkala (editor), Condition of groundfish resources of the EBS and AI region in 1987, p. 143-171. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-139.

Krieger, K. 2001. Coral impacted by fishing gear in the GOA. Proceedings of the First International Symposium on Deepwater Corals. (Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia 106-117).

Krieger, K. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fishery Bulletin 91(1):87-96.

Krieger, K. 1992. Shortraker rockfish, *Sebastes borealis*, observed from a manned submersible. Marine Fisheries Review. 54(4):34-37.

Krieger, K. J. 1997. Sablefish, *Anoplopoma fimbria*, observed from a manned submersible. *In* M. Saunders and M. Wilkens (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 115-121. NOAA Tech. Rep. 130.

Krieger, K.J. and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.

Krieger, K.J. and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, Sebastes borealis, and rougheye rockfish, S. aleutianus, determined from a manned submersible. Fish. Bull. 97: 264-272.

Laidig, T.E., P.B. Adams, and W.M. Samiere. 1997. Feeding habits of sablefish, *Anoplopoma fimbria*, off the coast of Oregon and California. *In* M. Saunders and M. Wilkens (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 65-80. NOAA Tech. Rep. 130.

Lang, G.M, C.W. Derrah, and P.A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the EBS from 1993 through 1996. AFSC processed report 2003-04. NMFS, NOAA, Dept. Commer., U. S., p. 351.

Laurel, B.J., Gregory, R.S. and J.A. Brown. 2003. Settlement and distribution of Age-0 juvenile cod, *Gadus morhua* and *G. ogac*, following a large-scale habitat manipulation. Marine Ecology Progress Series. 262. pp. 241-252.

Li, Z. 2004. Phylogenetic relationships and identification of juveniles of the genus Sebastes. University of Alaska-Fairbanks, School of Fisheries and Ocean Sciences. M.S. Thesis.

Leys, S.P. and N.R.J. Lauzon. 1998. Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges. J. Exper. Mar. Biol. and Ecol. 230(1): 111-129.

Loher, T. 2001. Recruitment variability in southeast BS red king crab (*Paralithodes camtschaticus*): the roles of early juvenile habitat requirements, spatial population structure, and physical forcing mechanisms. Ph.D. Dissertation, Univ. Washington, Seattle.

Loher, T. and D.A. Armstrong. 2000. Effects of habitat complexity and relative larval supply on the establishment of early benthic phase red king crab (*Paralithodes camtschaticus* Tilesius, 1815) populations in Auke Bay, Alaska. J. of Exp. Mar. Bio. And Ecol. 245(2000) 83-109.

Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, CA. 414 p.

Lowe, S. A. and R. Lauth. 2003. Assessment of GOA Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the GOA. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S., J. Ianelli, H. Zenger, K. Aydin, and R. Lauth. 2004. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S.A., D.M. Van Doornik, and G.A. Winans. 1998. Geographic variation in genetic and growth patterns of Atka mackerel, *Pleurogrammus monopterygius* (Hexagrammidae), in the Aleutian archipelago. Fish. Bull. U.S. 96:502-515.

Lyubimova, T.G. 1965. The main stages of the life cycle of Pacific ocean perch (*Sebastes alutus* Gilbert) in the GOA. *In* Soviet fisheries investigations in the northeast Pacific, Part 4: 85-111. (Transl. from Russian by Clearinghouse Fed. Sci. Tech. Inform., Springfield, VA, TT67-51206).

Lunsford, C.R. 1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the GOA. Master's Thesis. University of Alaska Fairbanks, Juneau, Alaska. p. 154.

Lunsford, C.R., D.H. Hanselman, S.K. Shotwell, and D.M. Clausen. 2004. Pelagic shelf rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 465-498. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501-2252.

Lunsford, C.R., L. Haldorson, J.T. Fujioka, and T. J. Quinn II. 2001. Distribution patterns and survey design considerations of Pacific ocean perch (*Sebastes alutus*) in the GOA. Spatial Processes and Management of Marine Populations, Alaska Sea Grant College Program. Lowell Wakefield Fisheries Symposium. Anchorage, Alaska., AK-SG-01- 02.

MacDonald, B.A. 2000. Potential impacts of increased particle concentrations on scallop feeding and energetics. Pages 20-26 in ADF&G, 2000. A workshop examining potential fishing effects on population dynamics and benthic community structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaska waters. ADF&G Special Publication 14.

Mackas, D.L., and A. Tsuda. 1999. Mesozooplankton in the eastern and western subarctic Pacific: community structure, seasonal life histories, and interannual variability. Prog. Oceanogr. 43: 335-363.

Major, R.L. and H.H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, *Sebastodes alutus*. FAO Fisheries Synopsis No. 79, NOAA Circular 347, p. 38.

Matarese, A.C., D.M. Blood, S.J. Picquelle, and J.L. Benson. 2003. Abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and BS ecosystems based on research conducted by the AFSC (1972-1996). NOAA Professional Papers 1:1 -281.

Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rep. NMFS 80, 652 p.

Matthews, K.R., J.R. Candy, L.J. Richards, and C.M. Hand. 1989. Experimental gillnet fishing on trawlable and untrawlable areas off northwestern Vancouver Island, from the MV Caledonian, August 15-28, 1989. *Can. Manuscr. Rep. Fish. Aquat. Sci. 2046*. p. 78.

McConnaughey, R.A. 2003. AFSC, personal communication.

McConnaughey, R.A., K.L. Mier, and C.B. Dew. 2000. An examination of chronic trawling effects on soft-bottom benthos of the EBS. ICES Journal of Marine Sciences. 57(5):1377-1388.

McConnaughey, R.A. and K.R. Smith. 2000. Association between flatfish abundance and surficial sediments in the EBS. Canadian journal of fisheries and aquatic sciences. 57(12):2410-2419.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. M.S. Thesis, Univ. Washington, Seattle. 76 p.

McDermott, S.F. and S.A. Lowe. 1997. The reproductive cycle of Atka mackerel, *Pleurogrammus monopterygius*, in Alaska waters. Fish. Bull. U.S. 95:231-333.

McFarlane, G.A. and W.D. Nagata. 1988. Overview of sablefish mariculture and its potential for industry. Alaska Sea Grant Report 88-4. PP. 105-120. University of Alaska Fairbanks, Fairbanks, Alaska 99775. Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda Maryland. 1037 p.

Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesa, Maryland. 1037 p.

Moiseev, P.A. and I.A. Paraketsov. 1961. Information on the ecology of rockfishes (family *Scorpaenidae*) of the northern part of the Pacific Ocean. Transl. from Russian by Fish. Res. Bd. Can., Pac. Biol. Sta., Nanaimo B.C., FRB Transl. Ser. 358).

Moles, A. and B.L. Norcross. 1995. Sediment preference in juvenile Pacific flatfishes. Neth. J. Sea Res. 34(1-3): 177-182 (1995).

Moore, P.G. 1999. Fisheries exploitation and marine habitat conservation: a strategy for rational coexistence. Aquatic Conserv: Mar. Freshw. Ecosyst. 9: 585-591.

Moran, M.J. and P.C. Stephenson. 2000. Effects of otter trawling on macrobenthos and management of demersal scalefish fisheries on the continental shelf of north-western Australia. 2000. ICES Journal of Marine Science. 57(3):510-516.

Nasby-Lucas, N.M., Embley, B.W., Hixon, M.A., Merle, S.G., Tissot, B.N., and Wright, D.J. 2002. Integration of submersible transect data and high-resolution multibeam sonar imagery for a habitat-based groundfish assessment of Heceta Bank, Oregon. Fishery Bulletin 100: 739-751.

National Marine Fisheries Service (NMFS). 2004. Website: Resources Assessment and Conservation Engineering Field Videos—Underwater Habitat Footage, AFSC. http://www.afsc.noaa.gob/race/media/videos/vids_habitat.htm.

NMFS. 2004. Final Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement. DOC, NOAA, National Marine Fisheries Service, Alaska Region, P. O. Box 21668, Juneau, Alaska 99802-1668. Volumes I-VII.

NMFS. 2003. Annual Report to Congress on the Status of U.S. Fisheries, 2002. U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD. 156 p.

NMFS. 2002. Report to industry on the 2002 eastern BS crab survey. AFSC Processed Report, 2002-05, U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-0070.

NRC (National Research Council). 2002. Effects of trawling and dredging on seafloor habitat. National Academy Press, Washington D.C. 126 pp.

Nichol, D.G. and E.I. Acuna. 2000. Annual and batch fecundities of yellowfin sole, *Limanda aspera*, in the EBS. Fish. Bull 99(1):108-122.

Nichol, D.G. and D.A. Somerton. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. Mar Ecol Prog Ser 239: 193-207.

Orensanz, J., B. Ernst, D. Armstrong, P. Stabeno, and P. Livingston. 2005. Contraction of the geographic range of distribution of snow crab (Chionoecetes opilio) in the Eastern Bering Sea-An Environmental Ratchet? (CALCOFI SCIENTIFIC REPORTS, accepted, 2005).

Orr, J.W. and J.E. Blackburn. 2004. The dusky rockfishes (Teleostei: Scorpaeniformes) of the north Pacific Ocean: resurrection of *Sebastes variabilis* (Pallas, 1814) and a redescription of *Sebastes ciliatus* (Tilesius, 1813). Fish. Bull., U.S. 102:328-348. Online. (.pdf, 569KB).

Pearcy, W.G., D.L. Stein, M.A. Hixon, E.K. Pikitch, W.H. Barss, and R.M. Starr. 1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. *Fishery Bulletin*, 87:955-965. *In* National Marine Fisheries Service 2001(a).

Prena, J., P. Schwinghamer, T.W. Rowell, D.C. Jr Gordon, K.D. Gilkinson, W.P. Vass, and D.L McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: Analysis of trawl bycatch and effects on epifauna. Marine Ecology Progress Series. 181:107-124.

Reuter, R.F. 1999. Describing dusky rockfish (*Sebastes ciliatus*) habitat in the GOA using historical data. M.S. Thesis, California State University, Hayward CA. 83 p.

Reuter, R.F., and P.D. Spencer. 2004. 2004 BSAI other rockfish *In* Appendix A stock assessment and fishery evaluation report for the groundfish resources of the BS and AI region, North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.

Richards, L.J., and N. Olsen. 1996. Slope rockfish assessment for the west coast of Canada in 1996 and recommended yeilds for 1997. Can. Tech. Rep. Fish. Aquat. Sci.: 91 p.

Rijnsdorp, A.D. and P.I. van Leeuwen. 1996. Changes in growth of North Sea plaice since 1950 in relation to density, eutrophication, beam-trawl effort and temperature. ICES J. Marine Science, 53: 1199-1213.

Rijnsdorp, A.D., A.M. Buys, F. Storbeck, and E.G. Visser. 1998. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the seabed and the impact on benthic organisms. ICES Journal of Marine Science 55:403-419. (B-5)

Rooper, C. and Boldt, J. 2004. Distribution of juvenile Pacific ocean perch (*Sebastes alutus*) in the AI. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI region as projected for 2005. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

Rose, C.S. 2002. An analysis of the effects of fishing on fish habitats of the waers off of Alaska. White paper prepared for the EFH Committee of the North Pacific Management Council. (B-3).

Rutecki, T.L. and E.R. Varosi. 1997. Distribution, age, and growth of juvenile sablefish, *Anoplopoma fimbria*, in Southeast Alaska. *In* M. Saunders and M. Wilkens (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 45-54. NOAA Tech. Rep. 130.

Ryer, C.H., A.W. Stoner, and R.H. Titgen. 2004. Behavioral mechanisms underlying the refuge value of benthic habitat structure for two flatfishes with differing anti-predator strategies. Marine Ecology Progress Series, Vol. 268:231-243.

Sasaki, T. 1985. Studies on the sablefish resources in the North Pacific Ocean. Bulletin 22, (1-108), Far Seas Fishery Laboratory. Shimizu, 424, Japan.

Schnute, J.T., R. Haigh, B.A. Krishka, and P. Starr. 2001. Pacific Ocean Perch Assessment for the West Coast of Canada in 2001. DFO Research Document 2001: 96 pp.Scott, B. 1995. Oceanographic features that define the habitat of Pacific Ocean perch, Sebastes alutus. Fish. Oceanogr. 4: 147-157.

Schwinghamer, P., D.C. Gordon, Jr., T.W. Rowell, J.P. Prena, D.L McKeown, G. Sonnichsen, and J.Y. Guignes. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Conservation Biology 12: 1215-1222.

Scott, B. 1995. Oceanographic features that define the habitat of Pacific ocean perch, *Sebastes alutus*. Fish. Oceanogr. 4:147-157.

Shima, M., A.B. Hollowed, and G.R. VanBlaricom. 2002. Changes over time in the spatial distribution of walleye pollock (*Theraga chalcogramma*) in the GOA, 1984-1996. Fish. Bull. 100:307-323.

Seeb, L. W. and A.W. Kendall Jr. 1991. Allozyme polymorphisms permit the identification of larva and juvenile rockfishes of the genus *Sebastes*. Environ. Biol. Fish. 30:191–201.

Shester, G. 2004. Letter dated April 13, 2004 to Dr. James Balsiger, Alaska Regional Administrator, National Marine Fisheries Service re: Comments on Alaska Region EFH Draft Environmental Impact Statement. 24 p.

Siegel, V. 2000. Krill (Euphausiacea) demography and variability in abundance and distribution. Can. J. Fish. Aquat. Sci. 57 (Sup. 3): 151-167.

Sigler, M.F., C.L. Lunsford, J.T. Fujioka, and S.A. Lowe. 2004. Sablefish *in* November 2004 Stock Assessment and Fishery Evaluation Report. NPFMC.

Sigler, M.F., C.R. Lunsford, J.T. Fujioka and S.A. Lowe. 2002. Alaska sablefish assessment for 2003. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA as projected for 2003. Available from North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, Alaska 99501-2252.

Sigler, M. F., T. L. Rutecki, D.L. Courtney, J.F. Karinen, and M.S.Yang. 2001. Young-of-the-year sablefish abundance, growth, and diet. Alaska Fisheries Research Bulletin 8(1): 57-70.

Sigler, M. 2003. Personal observation. AFSC, Auke Bay Laboratory.

Smith, C.J., K.N. Papadopoulou, S. Diliberto. 2000. Impact of otter trawling on eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science 55:1340-1351. (B-16).

Smith, K.R. and R.A. McConnaughey. 1999. Surficial sediments of the EBS Continental Shelf: EBSSED Database Documentation.

Sogard, S.M. and B.L. Olla. 1993. The influence of predator pressure on utilization of artificial seagrass habitats by juvenile walleye pollock, *Theragra chalcogramma*. Env. Biol. Fish. 37:57-65.

Sparks-McConkey, P.J. and L. Watling. 2001. Effects on the ecological integrity of a soft-bottom habitat from a trawling disturbance. Hydrobiologia. 456(1-3):73-85.

Spencer, P.D. and J.N. Ianelli. 2004. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI region as projected for 2005, pp. 675-746. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

Spencer, P.D. and J.N. Ianelli. 2003. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI region as projected for 2004, pp. 563-610. North Pacific Fishery Management Council, Anchorage, AK.

Spencer, P.D. and J.N. Ianelli. 2002. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the BSAI region, pp. 515-558. North Pacific Fishery Management Council, Anchorage, AK.

Spencer, P.D., G.E. Walters, and T.K. Wilderbuer. 2002. Flathead sole. *In* Appendix A Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI Region. P 361-408. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Spencer, P., T.K. Wilderbuer, and T.M. Sample. 2004a. Flathead sole. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Spencer, P., T.K. Wilderbuer, and T.M. Sample. 2004b. Alaska plaice. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Stevens, B.G., and J. Kittaka. 1998. Postlarval settling behavior, substrate preference, and time to metaorphosis for red king crab *Paralithodes camtschaticus*. Marine Ecology Progress Series, 167, pp. 197-205.

Stokesbury, K.D.E. 2000. Physical and Biological Variables Influencing the Spatial Distribution of the Giant Scallop, Placopecten magellanicus. *In* A Workshop Examining Potential Fishing Effects on Population Dynamics and Benthic Community Structure of Scallops with Emphasis on the Westhervane Scallop, *Patinopecten caurinus*, in Alaskan Waters. Alaska Department of Fish and Game Special Publication 14.

Stone, R. and B. Wing. 2001. Growth and recruitment of an Alaskan shallow-water gorgonian. In Proceedings of the First International Symposium on Deep-Sea Corals. Willis on et al. Eds. p 88-94.

Stone, R. 2004. Depth distribution, fisheries interactions, and habitat of deep-sea corals in the AI off of Alaska-Preliminary research data presented at American Association for the Advancement of Science. Seattle Washington. NOAA Fisheries. AFSC. Auke Bay Laboratory.

Stoner, A.W. and A.A. Abookire. 2002. Sediment preference and size-specific distribution of young-of-the-year Pacific halibut in an Alaska nursery. J. Fish Biology (2002) 61, 540-559.

Stoner, A.W. and M.L. Ottmar. 2002. Relationships between size-specific sediment preferences and burial capabilities in juveniles of two Alaska flatfishes. J. Experimental Marine Biology and Ecology 282 (2002) 85-101.

Stoner, A.W. and R.H. Titgen. 2003. Biological structures and bottom type influence habitat choices made by Alaska flatfishes. J. Experimental Marine Biology and Ecology 292(2003) 43-59.

Straty, R.R. 1987. Habitat and behavior of juvenile Pacific rockfish (*Sebastes* spp. and *Sebastolobus alascanus*) off southeastern Alaska. NOAA Symp. Ser. Undersea Res. 2(2):109-123.

Tanasichuk, R.W. 1997. Diet of sablefish, *Anoplopoma fimbria*, from the southwest coast of Vancouver Island. *In* M. Saunders and M. Wilkens (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 93-98. NOAA Tech. Rep. 130.

Thompson, G.G. and M.W. Dorn. 2004. Assessment of the Pacific cod stock in the EBS and AI Area. *In* Plan Team for Groundfish Fisheries of the BSAI (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the BSAI regions, p. 185-302. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G.G., H.H. Zenger, and M.W. Dorn. 2004. Assessment of the Pacific cod stock in the GOA. *In* Plan Team for Groundfish Fisheries of the GOA (editor), Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 131-232. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thrush S.F. and P.K. Dayton. 2002. Disturbance to marine benthic habitats by trawling and dredging: Implications for marine biodiversity. A nnu. Rev. Ecol. Syst. 33:449-473.

Turk, T. 2000. Distribution, Abundance, and Spatial Management of the Weathervane Scallop Fishery in Alaska. Masters Thesis, University of Washington. 231p.

Turnock, B.J. 2004. BS snow crab. *In* 2004 Stock Assessment and Fishery Evaluation report for the king and Tanner crab fisheries of the BSAI Region. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK, 99501.

Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2004. GOA arrowtooth flounder. In stock assessment and fishery evaluation report for the groundfish resources of the GOA. North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501-2252.

Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2003a. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Report for the 1997 GOA Groundfish Fishery. GOA Groundfish Plan Team, North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2003b. GOA flatfish. In Stock Assessment and Fishery Evaluation Report for the 2004 GOA Groundfish Fishery. GOA Groundfish Plan Team, North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

Turnock, B.J., T.K. Wilderbuer, and E.S. Brown. 2002. Arrowtooth flounder. *In* Appendix B Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the GOA Region. P 199-228. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Turnock, B.J. and Z.T. A'mar. 2004a. GOA Dover Sole. In Stock Assessment and Fishery Evaluation Report for the 2004 GOA Groundfish Fishery. GOA Groundfish Plan Team, North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

Turnock, B.J. and Z.T. A'mar. 2004b. GOA Rex Sole. In Stock Assessment and Fishery Evaluation Report for the 2004 GOA Groundfish Fishery. GOA Groundfish Plan Team, North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

Umeda, Y., T. Sample, and R.G. Bakkala. 1983. Recruitment processes of sablefish in the EBS. In Proceedings of the International Sablefish Symposium March 1983, Anchorage, Alaska. Alaska Sea Grant Report 83-8.

Van Dolah, R.F., P.H. Wendt, and N. Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research 5: 39-54.

Wahl, M. 1985. *Metridium senile*: distribution and small scale colonization by the combined strategy of locomotion and asexual reproduction (laceration). Mar. Ecol. Prog. Ser. 26:271-277.

Walters, C.J. and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Can. J. Fish. Aquat. Sci. 38:704-710.

Walters, G.E. and T.K. Wilderbuer. 2000. Decreasing length at age in a rapidly expanding population of northern rock sole in the EBS and its effect on management advice. J. Sea Ressearch 44(2000) 17-26.

Westrheim, S.J. 1970. Survey of rockfishes, especially Pacific ocean perch, in the northeast Pacific Ocean, 1963-66. *J. Fish. Res. Bd. Can.*, 27:1,781-1,809.

Westrheim, S.J. and W.R. Harling. 1975. Age-length ralationships for 26 scorpaenids in the Northeast Pacific Ocean. Tech. Rep. Environ. Can. Fish. Mar. Serv. no. 565.

Wilderbuer, T.K, A.B. Hollowed, W.J. Ingraham Jr., P.D. Spencer, M.E. Conners, N.A. Bond, and G.E. Walters. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the EBS. Prog. Oceanog. 55 (2002) 235-247.

Wilderbuer, T.K. and D. Nichol. 2004a. Yellowfin sole. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wilderbuer, T.K. and T.M. Sample. 2004b. Arrowtooth flounder. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wilderbuer, T.K. and G.E. Walters. 2004c. Northern rock sole. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the BSAI Region as Projected for 2005. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wing, B.L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the Eastern GOA. *In* M. Saunders and M. Wilkens (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 13-26. NOAA Tech. Rep. 130.

Witherell, D. 2002. A preliminary evaluation of fishery effects on EFH off Alaska. North Pacific Fishery Management Council, Anchorage, AK. Unpublished draft manuscript.

Witherell, D. 1997. A brief history of bycatch management measures for EBS groundfish fisheries. Marine Fisheries Review

Witherell, D, D. Ackley, and C. Coon. 2002. An overview of salmon bycatch in Alaska groundfish fisheries. Alaska Fishery Research Bulletin (9)1:53-64.

Witherell, D. and C. Pautzke. 1997. A brief history of bycatch management measures for EBS groundfish fisheries. Marine Fisheries Review, 59(4), pp. 15-22.

Withler, R.E., T.D. Beacham, A.D. Schultze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, Sebastes alutus, in Queen Charlotte Sound, British Columbia. Mar. Biol. 139:1-12.

Yang, M.S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1997. AFSC Proc. Rep 2003-07. 233 p. (Available from National Marine Fisheries Service, AFSC, 7600 Sand Point Way NE, Seattle WA 98115).

Yang, M.S. 1999. The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the AI area. Fishery Bulletin, 97(4):1047-1057.

Yang, M.S. 1996. 1996. Diets of the important groundfishes in the AI in 1991. U.S. Dept. of Commer., NOAA Tech Memo. NMFS-AFSC-60, 105 p.

Yang, M.S. 1993. Food habits of the commercially important groundfishes in the GOA in 1990. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M.S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. NOAA Tech. Memo. NMFS-AFSC-112. 174 p.

Yoklavich, M.M., H.G. Greene, G.M. Cailliet, D.E. Sullivan, R.N. Lea, and M.S. Love.. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin 98: 625-641.

Yoon, W.D., Cho, S.H., Lim, D., Choi, Y.K., and Lee, Y. 2000. Spatial distribution of *Euphausia pacifica* (Euphausiacea: Crustacea) in the Yellow Sea. J. Plankton Res. 22: 939-949.

Zenger, H.H., Jr. and M.F. Sigler. 1992. Relative abundance of GOA sablefish and other groundfish based on National Marine Fisheries Service longline surveys, 1988-90. U. S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-216, 103 p.

Zhang, C.I., T.K. Wilderbuer, and G.E. Walters. 1998. Biological characteristics and fishery assessment of Alaska plaice, *Pleuronectes quadrituberculatus*, in the EBS. Mar. Fish. Rev. 60(4): 16-27.