PACIFIC COAST GROUNDFISH FISHERY MANAGEMENT PLAN

FOR THE CALIFORNIA, OREGON, AND WASHINGTON GROUNDFISH FISHERY

APPENDIX B
PART 5

Research Needs and Data Gaps Analysis for Groundfish Essential Fish Habitat

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November 2005

Table of Contents

List of Tables

1.0 INTRODUCTION

The material in this part of the Groundfish fishery management plan (FMP) appendices is adapted from the description of research needs originally incorporated into the FMP as section 11.10.6 by Amendment 11 (Section 2.0) and the data gaps analysis (Section 3.0) in the *Risk Assessment for the Pacific Groundfish FMP* prepared by MRAG Americas, Inc.; National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center, FRAM Division; NMFS Northwest Regional Office; and TerraLogic GIS, Inc. The Risk Assessment describes the essential fish habitat (EFH) Model used to identify and describe EFH, an Impacts Model developed to evaluate anthropogenic impacts to EFH, and a data gaps analysis.

2.0 RESEARCH NEEDS

Many data gaps and research needs are readily apparent as a result of the efforts to identify EFH, fishing and nonfishing impacts to EFH, and conservation measures to protect, restore, and enhance EFH. These findings reinforce and complement habitat research needs previously identified in the FMP and other documents such as the Council's Research and Data Needs document. For example, a very comprehensive list of research needs has been identified as a significant component of Oregon's Ocean Resources Management Plan (State of Oregon 1991); they often are applicable throughout the EEZ and most have not been met. Several recommended research needs for EFH are taken from this list and contributions received from the technical team and others interested in marine fish, fishery, and habitat issues.

The following recommendations for research needs directly support implementation of the proposed recommendations in this amendment and provide for improved protection, restoration, and enhancement of EFH for a healthy ecosystem and productive fisheries over the long term. The Council will integrate these recommendations into the Research and Data Needs document. The Council will emphasize research needs to better identify and preserve EFH for populations whose productivity may be seriously impaired as a result of habitat loss or degradation and for populations whose habitat needs are very poorly or not known. These recommendations are also based on the assumption that ongoing EFH activities will continue to gather and incorporate existing information that could not be incorporated to date. Also, research studies often can address multiple needs simultaneously and the list below is not intended to represent independent research efforts. Further, habitat is meant in the broad context of its physical, chemical, and biological characteristics.

- Specifically identify habitat areas of particular concern: those rare, sensitive, and vulnerable habitats (to adverse fishing and nonfishing effects). Identify associated life stages and their distributions, especially for species and life stages with level 1 (or no) information. Develop appropriate protection, restoration, and enhancement measures.

- Identify any existing areas that may function as "natural" reserves and protection measures for these areas.

- Map benthic habitats on spatial scales of the fisheries and with sufficient resolution to identify and quantify fish/habitat associations, fishery effects on habitat, and the spatial structure of populations. Mapping of the rocky areas of the continental shelf is critical for the identification of the rocky shelf and nonrocky shelf composite EFHs.

- Explore merits of harvest refugia as a potential management tool. Determine candidates, sites, and criteria for refugia; develop quantitative and qualitative methods to assess the effectiveness of the refugia; and develop methods to protect refugia from anthropogenic impacts.

- Conduct experiments to assess the effects of various fishing gears on specific habitats on the West Coast and to develop methods to minimize those impacts, as appropriate. From existing and new sources, gather sufficient information on fishing activities for each gear type to prioritize gear research by gear, species, and habitat type.

- Explore and better define the relationships between habitat, especially EFH, and productivity of groundfish species. Improved understanding of the mechanisms that influence larval dispersal and recruitment is especially important.

- Evaluate the potential for incentives as a management tool to minimize adverse effects of fishing and nonfishing activities on EFH.

- Standardize methods, classification systems, and calibrate equipment and vessels to provide comparable results in research studies and enhance collaborative efforts.

- Develop methods, as necessary, and monitor effectiveness of recommended conservation measures for nonfishing effects. Develop and demonstrate methods to restore habitat function for degraded habitats.

Reference:

Oregon Ocean Resources Task Force. 1991. Oregon's Ocean Resources Management Plan. State of Oregon. Portland, Oregon. 202p.

3.0 DATA GAPS ANALYSIS

3.1 Data Gaps for Identifying EFH

3.1.1 Groundfish habitat

3.1.1.1 Geological substrate

The Comprehensive Risk Assessment has provided the first coastwide compilation of geological substrate for the West Coast of the U.S. This is a major achievement of the project, but although the coverage of the resulting map is "continuous", it is not complete and the quality of the data varies from place to place. There are many areas where the substrate data need to be improved. Both the OSU Active Tectonics Laboratory and the Moss Landing Marine Laboratory (MLML) are continuing to work on updating the substrate data. However, it has not been possible to incorporate the most recent updates into the assessment process at this stage due to time constraints.

Data quality information can be explicitly incorporated into the EFH Model so that the advice on identification of EFH reflects the degree of confidence in the identification of habitat type. However, there is currently a mismatch between the substrate polygons and the data quality polygons, which caused some artifacts in the HSP output when data quality data were included in the model. This issue could not be resolved in the time available for the preparation of the assessment.

Available data quality data are based on measurement error only; genuine data quality depends also on:

- transition zones (e.g., between two substrate types, or areas where depth changes sharply)

- genuine mixtures within a parcel of habitat identified as a single substrate type (e.g., gradual changes in depth or latitude)

No data quality information is currently available for California.

In some cases, interpretive decisions had to be made when stitching together data from different sources. To facilitate this process, in the time available, automated procedures were used in lieu of more time-consuming manual editing procedures. Future work may provide interpretations that are different to those used in this analysis. However, it is not expected that this will substantially change the results, or have major implications for the identification of EFH.

Detailed geological substrate data are missing for some areas of the EEZ. The two major gaps are the estuaries, which are currently delineated from the rest of the map, but have no geological characterization at all, and the area between the current western limit of the substrate map and the outer edge of the EEZ. There is a smaller physical gap in the map between the end of OSU's interpretation in Straits of Juan de Fuca and the NWI Estuaries boundary.

Certain benthic features are not identified separately in the substrate classification system; for example, seamounts are lumped together with ridges and banks. Therefore, there may be some benthic features of importance to groundfish that are not mapped separately.

Substrate type information for the seabed off California is classified only into hard and soft substrates. Off Washington and Oregon there is a much more detailed breakdown into categories such as mud, sand, gravel, rock, etc.

The shoreline is not consistent along the entire coast. The standard adopted by the two laboratories (OSU and MLML) are not the same. In addition, the boundaries of the estuaries are not aligned with the shoreline, resulting in gaps and overlaps.

Table 1. Summary of Data Gaps for Geological Substrate.

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
Data quality is highly variable across the existing substrate map. New data exist that have not yet been incorporated into the assessment, due to time constraints.	HSP maps assume habitat type is recorded in the GIS without error irrespective of the true level of uncertainty Identification of EFH may miss important areas of substrate, and/or areas may be mis-identified as EFH for some species and life stages.	The most recent data on benthic substrate need to be processed and incorporated into the EFH Model.
Data quality data do not currently reflect the full range of uncertainty in benthic substrate type and are not used in the EFH Model.	As above.	Enhanced measures of data quality need to be developed and their use in the EFH Model investigated further.
No data quality data are currently available for California (Section 2.2.5.1).	As above.	Data quality information for California could be developed by Moss Landing Marine Lab.
Detailed geological substrate data are missing for some areas of the EEZ.	No EFH can be identified offshore of the area of the current benthic substrate map to the edge of the EEZ. Some important features, such as seamounts may not be properly represented; estuaries are	Benthic substrate data for areas not covered by the substrate map should be collected, processed, and incorporated into the assessment.

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
	defined as a single substrate "type" irrespective of the actual substrate; there can be no subdivision of areas within estuaries based on substrate type.	
The classification system does not separate out some benthic features that may be important to groundfish.	The importance of some specific areas of seabed as EFH for groundfish may not be properly identified.	The classification system needs to be re-examined from a groundfish ecological perspective.
Off California, substrate type is divided only into hard and soft.	Habitat preferences are recorded in the HUD to a finer classification than just hard and soft substrates, but this information is lost when projecting these preferences onto the substrate map off California. The information is used in a risk averse way such that some areas may be mis-identified as EFH for some species/life stages.	More detailed substrate type data should be compiled for California.
The shoreline is not set to a consistent standard and does not align with the estuary data.	Identification of EFH at the shoreline boundary may be inaccurate when projected onto some maps. It may appear that some small areas of land have been identified as EFH, or some small areas of the seashore may not be properly mapped as EFH.	The shoreline must be set to a common standard along the entire coast and must be aligned with all other relevant GIS datasets, such as estuaries.

3.1.1.2 Bathymetry

Bathymetry data for Oregon and California were provided by OSU and MLML respectively. Additional data were acquired for Washington, which were already compiled and continuous. This limits the range of contours that can be used to identify EFH to depth to 10 m intervals.

Depth zones are discontinuous at the boundaries between data sources, due to the disparate nature of the bathymetry sources. No manual adjustments were made to the compiled bathymetry data to remove these discontinuities.

A small data gap exists between Oregon and Washington, approximately 100 to 200 meters across. This was bridged by extending the contour lines to meet the shared boundary.

Table 2. Summary of Data Gaps for Bathymetry.

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
The bathymetry dataset is not of a consistent level of detail across the West Coast.	Data for Washington limit the range of contours that can be used to identify EFH to depth to 10 m intervals.	Compile data sets to develop a continuous bathymetric grid of the best available data for the entire West Coast which could be used to generate contours at any required interval.
Discontinuities exist in bathymetry data at the boundaries between data sources.	Given the scale of the bathymetry data used in the EFH Model, this data gap is unlikely to be of major significance to the assessment.	Targeted surveys to collect bathymetry data in the relevant boundary areas.

3.1.1.3 Biogenic habitat

There is limited information on both the distribution of biogenic habitat and its importance as a habitat for groundfish on the West Coast. These habitats are, however, known to be vulnerable to physical impacts caused by fishing gears, with, in some cases, protracted recovery times of ten years or more. Mapping of vulnerable biogenic habitats should be given a high priority.

In addition to mapping current extent, it is particularly important in the case of biogenic habitats to obtain information on their historical extent. These habitats may respond rapidly to short and long term shifts in oceanographic conditions and anthropogenic disturbance, including coastal development. Historical data are therefore important to give an indication of both the current status and extent relative to the past and the potential future extent, in the event that conditions change. No historical data have been obtained to date.

Table 3. Summary of Data Gaps for Biogenic Habitats.

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
Limited understanding of the importance of biogenic habitats for groundfish species.	Biogenic habitat may not be identified as an important habitat for groundfish species, or conversely may be wrongly identified as an important habitat for groundfish.	Visual observation of the association between groundfish and biogenic habitats. Sampling and analysis of groundfish life stages in known areas of biogenic habitats.
Limited mapping of the occurrence of organisms that form biogenic habitats, in terms of shape files delineating metrics, such as levels of density of organisms that can be related to the importance of the location as habitat for groundfish.	Areas of habitat of importance to groundfish that are particularly vulnerable to impacts and may have very long recovery times may not be correctly identified as EFH and may not receive protection from potentially damaging activities. Note that areas of biogenic habitat may still be identified as EFH by virtue of their non-biogenic characteristics and the presence of groundfish in those areas.	Visual survey of seabed to determine the density of organisms that represent important biogenic habitat for groundfish. Some structure-forming invertebrates are found primarily on soft bottom, and would be sampled effectively in the NMFS trawl surveys. Example include sea whips and perhaps sponges. For these soft bottom invertebrates, maps of relative CPUE by station should be produced (SSC Feb 2004). Collection of all available data on historical extent of biogenic habitats.

3.1.2 Use of Habitat by Groundfish

The identification of EFH is based almost entirely on Level 1 (distribution) data, either from the NMFS trawl surveys or inferred from the Habitat Use Database (HUD). The NMFS trawl survey data were modeled using a general additive model (GAM) of presence/absence in survey samples. This approach ignores information on relative density from trawl surveys (based on catch per unit effort), which may provide a more accurate picture of the importance of specific habitat for groundfish. A species may have a broad depth or geographic distribution, but may only reach high densities in a limited area. However, catch-per-unit-effort data from surveys may provide an overly distorted picture of relative density depending on the statistical techniques used to analyze them. Further investigation is needed to explore the use of catch-per-unit-effort from the surveys as a means of identifying habitat suitability from Level 2 (density) data.

Out of the 328 possible profiles of Habitat Suitability Probability (HSP), it was only possible to produce 36 from the NMFS trawl survey data (including those completed with additional expert opinion), all of which were for adults. A further 124 profiles were developed from data organized in the HUD. HSP profiles for 168 species/life stage combinations could not be developed due to lack of data describing their habitat requirements. Data are lacking particularly for egg and larval stages.

The relative levels of precision achieved by the two main methods of calculating HSPs based on depth and latitude (the NMFS trawl survey data and the HUD) need to be investigated further so that uncertainty in the outputs can be properly expressed in the EFH Model, and hence reflected accurately in the decision-making process.

EFH is mapped on the basis of benthic habitat characteristics. The characteristics of pelagic habitat have not been considered to date. The features of the water column that are likely to be of importance include biological, physical, and chemical oceanographic processes that are hard to map. Frontal boundaries, temperature regimes, and biological productivity all vary on seasonal and inter-annual scales that make identification of a static two dimensional designation of a boundary such as is required for EFH problematic. We have not attempted to map these features in the GIS in the same way as for the benthic substrate at this stage. EFH for species and life stages residing in the water column is mapped instead on the basis of latitudinal and depth ranges reported in the literature.

The only true measure of habitat suitability is obtained through measurement of demographic parameters, i.e., production, mortality, growth, and reproductive rates. EFH could then be defined as areas with above-average survival, growth, or recruitment. There are, however, no data currently available for identifying EFH at Levels 3 (habitat specific growth, reproduction, or survival rates) and 4 (habitat specific production rates).

Table 4. Summary of data gaps for habitat use data.

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
The analysis of NMFS survey data for distribution of fish by depth and latitude does not take into account relative densities as indicated by catch per unit effort. The limitations of presence/absence information to infer EFH should not be ignored (SSC Feb 2004).	The use of presence/absence data in the EFH Model treats the data in a risk averse way. A species may have a broad depth or geographic distribution, but may only reach high densities in a limited area. However, catch per unit effort data from surveys may provide an overly distorted picture of relative density depending on the statistical techniques used to analyze them.	GAMs and Generalized Linear Models (GLMs) that can accommodate zero catches have been commonly used to obtain indices of abundance using West Coast trawl survey data for stock assessment and could be used in a re-examination of the data for the purposes of identifying EFH.
168 species/life stage combinations have no HSP profile developed for them. Only six species in the FMP have depth/latitude profiles developed for all life stages. All species in the Groundfish FMP have at least one HSP profile developed (all adults are covered).	EFH cannot be identified for species/life stage combinations without an HSP profile. EFH identified for species with less than the full complement of four profiles may not represent the full extent of EFH. However, when all areas identified as EFH are added together for the FMP, the likelihood than an area for a particular species is missed will be reduced.	Conduct an extensive, worldwide literature review to investigate whether more data can be obtained for filling out the HUD, particularly for eggs and larvae. Undertake exploratory data analyses of ichthyoplankton survey data such as the CalCOFI and NMFS datasets for areas off California to investigate the utility of these type of data for identifying EFH.
Only 36 HSP profiles were developed from NMFS trawl	EFH will likely be described less precisely from HUD-based HSP	Obtain information from specialists with expert knowledge of the

Data Gap	Significance for the Identification of EFH	Potential Means of Filling Data Gap
survey data. A further 20 profiles could be developed with the help of expert opinion to complete the shallow part of the depth/latitude profile.	profiles than they would be from survey-based profiles for these species and life stages.	distributions of the species involved, using the same technique as used during this study.
The NMFS trawl survey data are used to support identification of EFH only for adult life stages.	Many species occupy different habitats at different life history stages. Information about these ontogenetic shifts present in the trawl data is not being utilized in the present analysis.	Size composition data are available for many groundfish from the NMFS trawl surveys. In many cases, juveniles can be reliably distinguished from adults on the basis of size.
The characteristics of pelagic habitat have not been mapped and are not used in the identification of EFH.	The important features of habitat for species and life stages that are not associated with benthic habitats are not taken into consideration. For the most part these habitats are not at risk from the actions of fishing gears, however, they may be at greater risk from nonfishing activities that cause modification of the chemical composition and physical characteristics of the pelagic environment.	Pelagic habitat characteristics could be mapped in the GIS and incorporated into the EFH Model.
No data are available for identifying EFH at Levels 3 (habitat specific growth, reproduction, or survival rates) and 4 (habitat specific production rates)	In a spatially heterogeneous system, in which source-sink dynamics are likely to be occurring, EFH should be protecting source areas, and not inadvertently protecting sink areas. There is a risk that the latter can occur if population density is used as a proxy for growth potential.	Conduct tagging (growth) studies and study fecundity by area; develop spatially discreet stock/recruitment relationships; and bio-energetics models. Conduct *In situ* physiological experiments and mortality experiments and develop life history-based meta-population models.

3.2 Data gaps for Assessing Impacts

3.2.1 Groundfish Habitat

The data gaps described above for the identification of groundfish habitat under the headings of geological substrate, bathymetry, and biogenic habitat apply equally to the assessment of impacts. Data on habitat are one of the main inputs into the assessment of impacts on EFH. They provide the framework for the development of spatially explicit habitat-based mitigation measures.

Within areas identified as EFH, if we assign sensitivity and recovery values by habitat type, but habitat type is misidentified, then some areas may receive less, or more, protection than they require. For these reasons, as well as those discussed above, it is important to address the data gaps in the identification of groundfish habitat.

3.2.2 The Effects of Fishing on Habitat

3.2.2.1 Sensitivity and Recovery

There is a general lack of West Coast specific studies on the effects of fishing gears on habitat. The risk assessment developed a review of gear impacts from which were developed the sensitivity and recovery indices for gear types used on the West Coast. At the same time as noting the paucity of West Coast specific studies, we do not think that this invalidates the relevance of the assessment that has been undertaken. Nevertheless, it would be preferable to undertake specific studies on the West Coast to reduce the level of uncertainty in the analysis that arises from having to use the results of studies conducted elsewhere.

The sensitivity index provides a relative measure of the likely changes to habitat caused by interactions with various fishing gears. However, it is not explicit that the changes described in the index result from a single contact with the gear, nor what happens with subsequent contacts. The process of recovery is similarly difficult to quantify. The relationship between fishing effort and habitat change (impact) is likely to be complex and almost certainly non-linear. At this stage, however, we have no empirical data from which to develop such relationships. This data gap is at the heart of the problem of interpreting the output of the Impacts Model for trawl gears developed during this study. If data could be collected that would relate a specific quantum of fishing effort to a specific change in habitat condition (i.e., an impact), then it might be possible to develop a calibration of the model in terms of a value for *k*.

It has been suggested that there exists underwater video taken during surveys for laying underwater cables across areas that may have been subject to past fishing activity. Such visual observation records would be particularly useful if they could be overlaid spatially with detailed location-specific fishing effort data that would give an indication of the number of times observed areas had been contacted by fishing gear.

There is also no quantitative link between change in habitat structure and consequent change in its utility for managed species. For example, for a habitat/gear combination with a sensitivity level of 2, the index tells us that contact with the gear will cause substantial changes in the habitat, such as deep furrows on the bottom, with differences between impact and control sites being 25 to 50% in most metrics measured. What the index does not tell us, however, is what this change implies in terms of the functionality or utility of the habitat for the species that occupy it. We don’t know, therefore, if habitat impacts are limiting to the status of groundfish.

Qualitative information is available in the literature on the likely effects of habitat change in specific cases; for example physical disturbance of spawning areas at spawning times is likely to cause some disruption of the process, and hence threaten reproductive success. However, no quantitative metrics are currently available to incorporate into a large scale statistical analysis of risk. This issue is linked closely to the lack of information at Levels 3 (habitat specific growth, reproduction, or survival rates) and 4 (habitat specific production rates) for identifying EFH. If we have no measure of these rates in specific habitats, we cannot yet hope to measure changes in these rates caused by specific changes in habitat structure and composition.

Substantial new research, probably involving laboratory experiments and in-situ studies of unprotected and protected areas of habitat, is required to develop metrics of sensitivity and recovery with all the desired characteristics for modeling impacts. However, before embarking on this research, there should be a detailed theoretical statistical modeling of the impacts-recovery process and an exploration of the sensitivity of the outputs of that model to different assumptions about functional relationships between habitat-gear contacts and the utility of habitat for groundfish. Such a process should be undertaken with the aim of providing clear guidance for future studies of impacts on habitat.

The sensitivity and recovery matrices categorize habitat types using the methodology adopted for the GIS. This distinguishes implicitly, to some extent, between habitats in high and low energy environments (e.g., shelf, slope, basin floor), but this distinction is limited. Currently there is no explicit accounting for natural disturbance in the evaluation of the significance of fishing impacts in terms of effects on the utility of EFH for groundfish. Existing data on natural physical disturbance, such as wave height and storm frequency could be collected and incorporated into the GIS. The sensitivity of habitats (stratified by depth) to various impacts could then be modified based on predicted levels of natural physical disturbance by area.

3.2.2.2 Fishing Effort Data

One of the most significant constraints to assessment of habitat impacts from fishing is the fishing effort data. There are no reliable spatial data available for fixed gears, nor for recreational gears, for the whole West Coast. There are also limitations in the logbook data themselves. The PacFIN logbook database contains information on the start position of each haul, and the duration of the haul. There is no information on the speed and direction of the tow, nor the estimated width of the ground gear. At this stage, it is therefore not possible to plot the footprint of the trawl gear in the GIS. Regarding speed and direction, the logbooks themselves do contain end position of tows, but these data have not been entered into the database. Regarding the width of the gear, it is possible to estimate this information for different gear types, but it is quite variable, depending on the specific rigging of the trawl, and the way in which it is fished.

The PacFIN database contains the following gear codes for bottom trawls:

Gear Name	CODE
Bottom Trawl	
ALL TRAWLS EXCEPT SHRIMP TRAWLS	TWL
BEAM TRAWL	BMT
BOTTOM TRAWL	BTT
FLATFISH TRAWL	FFT
GROUNDFISH TRAWL (OTTER)	GFT
GROUNDFISH TRAWL FOOTROPE > 8 in.	GFL
GROUNDFISH TRAWL FOOTROPE < 8 in.	GFS
ROLLER TRAWL	RLT

However, the database contains only three codes for groundfish trawls: flatfish trawl (FFT), groundfish trawl (GFT), or roller trawl (RLT). This limits the extent to which reliable gear width estimates could be applied to the tows in the database because of the wide range of variability within each of the gear categories actually used. It has not been possible within the scope of the current project to undertake additional work to develop alternative approaches to characterizing the fishing effort which would provide a more accurate picture of fishing impacts and the effects of management alternatives.

Entering trawl end points into the PacFIN database would be a useful first step in developing a better spatial record of trawl fishing effort. However, there are additional problems when trying to plot spatial changes in fishing effort over time based on this database. Coastwide, trawl start points and duration are recorded from 1987 to the present. However, prior to 1997 position data for trawls off California were provided by logbook block (10 nm x 10 nm) only, not by precise haul location. There are additional anecdotal reports that some other start points may not be accurately recorded in the database. Also, prior to 1998, date was recorded as year only, making tracking of seasonal patterns impossible. Completing the focus group assessment of fishing effort for the entire West Coast would be a highly worthwhile undertaking to provide spatial information on non-trawl gears, as well as a calibration for trawl gears. However, this would be rendered more useful if the information collected could include meaningful metrics of fishing intensity.

In terms of future monitoring of fishing effort, the most likely way in which detailed data on locations of gears will be obtained is through the use of an electronic vessel monitoring system (VMS) that logs position at suitably fine scale intervals. We note, however, that such systems record the position of the transceiver, and not necessarily the location where the fishing gear contacts the habitat. Detailed calibration studies would need to be undertaken for each gear to develop ways of interpreting VMS data for the purposes of monitoring gear impacts on habitat. For the historical record it may be possible to obtain detailed fishing location data from fishermen. For example, many satellite navigation systems store location data of previous fishing activities for future reference. Similar calibration of these data would be necessary.

3.2.3 Effects of Nonfishing Activities on Habitat

There is information available on nonfishing impacts, but the spatial and temporal resolution of these data are limited. Different types of impacts can be overlaid in the GIS to show their spatial overlap, but it is not possible at present to develop any quantitative evaluation of the relative importance and/or cumulative effects of fishing and nonfishing impacts on EFH. Data for some kinds of nonfishing activities are lacking.

Improvement in the data on nonfishing impacts would require a substantial data collection exercise from a wide variety of sources outside of fisheries. The greatest challenge to this data collection effort is the lack of centralized spatial data storage at the agency level. Although many individuals were contacted, identifying the right individual is critical or a potentially useful dataset may be overlooked. In addition, data incorporating nonfishing impacts often reside with the states. If data are located in Oregon, equivalent data must be located for Washington and California. If available, data developed independently by state agencies are often collected at different scales or degrees of accuracy. Stitching together these disparate data into a unified, coherent database requires reconciliation of data sets to make them usable in a coast wide database. This reconciliation of data will be possible for some data sets and impossible for others.

3.3.3 Measuring Cumulative Impacts

The Groundfish FMP, as with all others, must be amended, as necessary, to prevent, mitigate, or minimize to the extent practicable adverse effects from fishing on EFH (600.815(a)(2)(ii)).[1] In addition, Federal agencies must consult with NMFS on Federal projects that may adversely impact EFH. These requirements recognize that both fishing and nonfishing actions may adversely affect fisheries productivity through a variety of impacts on EFH.

To the extent feasible and practicable, therefore, FMPs should analyze how fishing and nonfishing activities influence habitat function on an ecosystem or watershed scale (§ 600.815 (a) (6) (i)). This is being achieved for West Coast groundfish through the development of an EIS, of which this risk assessment is part. The EIS must include a description of the ecosystem or watershed; the dependence of the managed species on the ecosystem or watershed, especially EFH; and how fishing and nonfishing activities, individually or in combination (cumulatively), impact EFH and the managed species; and how the loss of EFH may affect the ecosystem. Cumulative impacts are defined as the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions (CEQ regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. An assessment of the cumulative and synergistic effects of multiple threats should also include the effects of natural stresses such as storm damage or climate-based environmental shifts.

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[1] The EFH provisions at 16 U.S.C. §§ 1853(a)(7) state that each FMP shall identify EFH and "minimize to the extent practicable adverse effects on such habitat caused by fishing…."

Measuring the cumulative impacts of different types of fishing gear in a quantitative sense requires the development of a common metric. Currently this is not possible for a number of reasons; primarily the lack of spatially explicit effort data and the need to better interpret the sensitivity and recovery scales for different gear types. Nevertheless, with better effort data from which to develop gear footprints, and better calibration of impacts through the sensitivity and recovery indices, it should be possible to achieve a quantitative assessment of the combined impacts of several gears operating in the same area, and their relative contributions.

There is perhaps an even bigger problem, however, when we consider the cumulative impacts of fishing and nonfishing activities. Fishing gears have a primarily physical impact on habitat, although other less obvious effects, such as the selective removal of portions of the food chain also occur. Nonfishing impacts, however, range from similar kinds of physical disturbance to sedimentation and chemical alteration of the seawater, among many other things. Evaluating the cumulative effects of all of these potentially impacting processes is an immensely complicated task, for which we currently have a major lack of data.

3.3.4 Economics Analysis: Evaluating Practicability

A large gap left by the Comprehensive Risk Assessment is the evaluation of the economic effects of alternatives, and specifically the ways in which fishermen respond to regulation intended to mitigate identified problems. The risk assessment was never intended to address this issue; however, it is obviously vitally important to the success of the EFH mandate. It is also useful to consider how the analysis undertaken in this study could be expanded to incorporate socio-economic and economic factors. It may be possible, through such a study to develop the kind of common metric needed to consider impacts in a cumulative sense.

In the context of the EFH mandate described in the previous section, “practicable” was interpreted to mean “reasonable and capable of being done in light of available technology and economic considerations.” In other words, a gear modification, time/area closure, or other management measure is “practicable” if the technology is available and effective, and will not impose an unreasonable burden on the fishers. Councils must therefore evaluate alternatives to prevent, mitigate, or minimize the adverse effects of fishing in this context.

The EFH regulations at 50 CFR 600.815(a)(2)(iii) provide guidance on evaluating the practicability of management measures:

> In determining whether it is practicable to minimize an adverse effect from fishing, Councils should consider the nature and extent of the adverse effect on EFH and the long and short-term costs and benefits of potential management measures to EFH, associated fisheries, and the nation, consistent with national standard 7.

The costs of fishery management measures can be estimated on a gross, relative scale given expected changes in allowable catch and effort, and hence economic condition of the fishery. However, such an estimate will mask an underlying picture of complex ways in which individual fishers and fishing communities are affected by, and respond to management measures that are likely to either change the way they use fishing gear, change the gear itself, or simply ban some gears from fishing in some areas or at certain times of the year. In addition, economic costs are not only related to how fishers respond to management measures. Measures to prevent, mitigate, or minimize the adverse effects of fishing on EFH are intended to restore, or prevent declines in the productivity of the organisms that rely on those habitats. Hence taking no action might have associated economic consequences in the future, and the action itself might, in the longer term lead to improvements in productivity and hence catches, even if some areas can no longer be fished with certain gears.

The EFH regulations at 50 CFR 600.815(a)(2)(iii) also state that "In determining whether management measures are practicable, Councils are not required to perform a formal cost/benefit analysis." However, in order to effectively evaluate practicability in an objective way, it is necessary to develop an integrated analysis that enables consideration of both sides of the cost/benefit equation in some form of common currency. On the cost side, this would involve consideration of the economic consequences of management measures that change human behavior (including both fishing and nonfishing activities), and also the potential consequences of no action in terms of economic losses resulting from habitat degradation.

On the benefit side, this would involve consideration of economic gains arising from habitat restoration that results in, for example, improved productivity of fisheries, or perhaps eco-tourism. The benefits of fishery management measures would need to be evaluated in the context of impacts arising from nonfishing activities, which themselves may or may not be mitigated once identified.[2] However, the benefits of specific actions to protect or restore habitat are not all readily quantifiable in the same units as the costs. This is in part due to uncertainty in the direct effects of fishing gears and nonfishing impacts on habitat function and the lack of information on the relationships between habitat function and productivity. This uncertainty and lack of information is both a consequence of and exacerbated by the complexities of the ecological relationships and processes involved.

This problem has been recognized and studied by several authors (e.g., Costanza et al. 1997) and attempts have been made to estimate the value of various "ecosystem services," including those provided by EFH. Such studies tend to agree that this type of valuation is very difficult to do and fraught with uncertainties. It also seems likely that any estimates that are calculated will be at best minimum estimates, or more likely under estimates. Costanza et al. (1997), however, agree that quantification of the value of the ecosystem is a worthwhile objective, citing among other benefits, the value of such estimates in project appraisal, i.e., in the preparation of EISs.

The EFH EIS for the Gulf of Mexico FMPs[3] used six specific practicability factors relevant to EFH Final Rule requirements to evaluate the concepts discussed in the previous section (see table below). These factors were chosen to help identify the costs and benefits to EFH, the fisheries, and the nation. Factors 1 and 2 address burdens on fishers, and the remaining four address availability and effectiveness of technology.

Practicability Factor	Relevance to 50 CFR 600.815(a)(2)(iii)	Description
1. Net economic change to fishers	The long and short-term costs and benefits of potential management measures to: • associated fisheries • the nation	Changes in short-term and long-term economic conditions of fishers as a result of fishing impacts alternatives

[2] The Council and NMFS cannot take direct action to mitigate impacts on EFH other than those caused by fishing. For impacts arising from non-fishing activities, the EFH mandate makes provision for a written, public consultation process between NMFS and the agency responsible for the non-fishing activity. Such a consultation exercise may result in action by that agency to modify the non-fishing activity, in which case the economic consequences of such modification may need to be considered in an integrated model to evaluate practicability.

[3] Prepared by MRAG Americas under contract to the Gulf of Mexico Fishery Management Council

Practicability Factor	Relevance to 50 CFR 600.815(a)(2)(iii)	Description
2. Equity of potential costs among communities	The long and short-term costs and benefits of potential management measures to: • fishing communities	Changes in short-term and long-term economic conditions for communities that are dependent on fisheries or vulnerable to fishing impacts alternatives
3. Effects on enforcement, management, and administration	The long and short-term costs and benefits of potential management measures to: • associated fisheries • the nation	Changes in requirements or effectiveness of enforcement, management, and administration as a result of fishing impacts alternatives
4. Changes in EFH	The nature and extent of the adverse effect on EFH and The long and short-term costs and benefits of potential management measures to: • EFH	Future improvement or degradation in the extent, quality and/or function of EFH resulting from fishing impacts alternatives
5. Population effects on FMU species from changes in EFH	The nature and extent of the adverse effect on EFH and The long and short-term costs and benefits of potential management measures to: • EFH • associated fisheries	Magnitude and direction of productivity changes resulting from changes in EFH
6. Ecosystem changes from changes in EFH	The long and short-term costs and benefits of potential management measures to: • EFH • associated fisheries	Improvement or degradation of ecosystem function resulting from changes in EFH

This current project has focuses on biological impacts to EFH caused by fishing. We have therefore investigated only a part of the cost/benefit equation. A program of work is needed that will provide a precursor to developing a functional economics component of the Impacts Model. The overall aim should be to move towards the development of a fully integrated Impacts Model that can be used to objectively evaluate trade offs and practicability to assist Councils and NMFS in decision making with respect to mitigating impacts on EFH. Such a model would need to treat the socioeconomic behavior of fishers and the options open to them in terms of responding to new measures, in order to develop a framework of probabilistic rules of behavior that can be expressed in a Bayesian Network. The economic consequences of those fishers' decisions and behavior will be based on expectations of catch and catch value, operational costs (e.g., for new gears, learning new techniques, switching to other target species), etc. Existing models of fishers' responses to management for the West Coast and elsewhere could be used in developing the model. If successful, there is a broad potential for expanding the application and principles of Bayesian Network models to other aspects of fishery management in an ecosystem context.