Pacific Coast Groundfish Fishery Management Plan

for the California, Oregon, and Washington Groundfish Fishery

APPENDIX B
PART 1

Assessment Methodology for Groundfish Essential Fish Habitat

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1.0 INTRODUCTION

In response to a court directive and settlement agreement to complete new National Environmental Policy Act (NEPA) analyses for Amendment 11 to the Pacific Coast Groundfish fishery management plan (FMP), the National Marine Fisheries Service (NMFS) developed an Essential Fish Habitat (EFH) Designation and Minimization of Adverse Impacts Environmental Impact Statement (EIS). Council action based on this EIS led to the Groundfish FMP being amended with new EFH provisions.

This document describes the rigorous assessment of groundfish habitat on the West Coast that supported the Council's decision on how groundfish EFH would be identified and described. This document is adapted from the *Risk Assessment for the Pacific Groundfish FMP* prepared by MRAG Americas, Inc.; NMFS Northwest Fisheries Science Center, FRAM Division; NMFS Northwest Regional Office; and TerraLogic GIS, Inc. The Risk Assessment describes the EHF Model used to identify and describe EFH, an Impacts Model developed to evaluate anthropogenic impacts to EFH, and a data gaps analysis.

Developing these components of the Risk Assessment was intended to answer the following fundamental questions:

- What areas could qualify as essential pursuant to section 303(a)(7) of the Magnuson-Stevens Act (MSA)?
- Given past inputs (anthropogenic and environmental), what is the probability that the condition of Pacific coast groundfish habitat has been degraded to an extent that function has been impaired?
- Given foreseeable inputs (anthropogenic and environmental) and regulatory regimes, how are trends in Pacific coast groundfish habitat expected to respond? What areas are at risk of impaired function and of particular concern?
- How might trends in habitat function be affected by altering anthropogenic inputs and regulatory regimes?
- What types of fisheries management alternatives could be applied to mitigate the effects of fishing on habitat? What are the likely impacts to habitat of specific fisheries management alternatives?
- What are the scientific limitations of assessing habitat?

The data analysis undertaken to address these questions has included spatial and temporal analysis of the distribution of habitat types, distribution of fish species, habitat use by fish, sensitivities of habitat to perturbations, and the dynamics of fishing effort.

The three parts of the Risk Assessment referenced above have been adapted as parts of the appendices to the Groundfish FMP. The description of the EFH Model for identifying and describing groundfish EFH comprises this document, part of Appendix B to the FMP.

The Risk Assessment proceeded along three major tracks: data consolidation and infrastructure development, proof of concept, and assessment modeling and review. The results of the data consolidation phase are discussed in Section 2. Proof of concept ended in February 2003 with the endorsement of the preliminary assessment methodology. Section 3 describes the EFH assessment model and outputs.

Five main types of data were available for the risk assessment: habitat use, habitat characteristics, fishing effects, nonfishing effects, and existing habitat protection. These data feed into the analytical parts of the decision-making framework, which the development team termed the Comprehensive Risk Assessment, reflecting the integrated use of the best scientific information available in the development of guidance for the policy development process.

First and foremost, many of these data types can be analyzed and presented in GIS maps and overlays to indicate where the most important and vulnerable habitats are distributed in relation to the activities that may be impacting them (fishing and non-fishing). This information was developed to support the Impacts Model.

Thorough and responsible analysis of these data, however, involves substantially more than creating maps and spatial overlays in the GIS. To better represent the processes that make a particular piece of habitat more or less "essential" for managed species, and the risks posed to that habitat by fishing and non-fishing activities, the development team created a sophisticated modeling framework. As mentioned above, two models were developed; the EFH Model and the Impacts Model. While these components are clearly integrated, it was more practical to develop the models separately due to the complex and wide-ranging scope of the issues they address.

The first step in the process was the identification and description of EFH described in this document. The second step is an assessment of the risk to EFH from both fishing and non-fishing activities, which if fully developed, could assist the Council in developing measures to prevent, mitigate, or minimize, to the extent practicable, the adverse effects of fishing and fishing gear on EFH. As stressed above, the Impacts Model forms only part of this process. In a previous version of the decision-making framework, it was envisioned that all of the data elements from the data consolidation phase might feed into the Impacts Model. However, in practice this has not proved possible at this stage. The Impacts Model, is described in Appendix C to the Groundfish FMP.

The comprehensive risk assessment is, of necessity, a part quantitative and part qualitative procedure supporting EFH-related actions. It is hoped that in the future it will be possible to gather the necessary data and information to allow further development of the Impacts Model so that it can integrate these other data sources into an overarching quantitative model for risk analysis.

2.0 DATA CONSOLIDATION

To consolidate the available data and set the stage for the identification of EFH and risk assessment, NMFS in cooperation with the Pacific States Marine Fisheries Commission (PSMFC) implemented a multi-faceted project, which includes: (1) a GIS database that displays habitat types in comparison with known groundfish distribution/abundance and fishing effort; (2) a literature review and database of groundfish habitat associations; (3) a literature review of fishing gear impacts to habitat; (4) literature review of non-fishing impacts to habitat; and (5) analysis of information on fishing effort.

The various GIS and other databases that have been compiled for this project were organized into five major categories:

1. West Coast fish habitat
2. Use of habitat by groundfish
3. Effects of fishing on groundfish habitat
4. Non-fishing activities that affect groundfish habitat
5. Existing habitat protection measures

Within all of these categories, GIS has been a pivotal tool in compiling, analyzing, and presenting data. The first two categories form the backbone of the EFH Model, while the first and third are the principal inputs into the Impacts Model. In this section we provide a description of the data collection and processing procedures in the first four categories.

2.1 GIS Deployment in the EFH Process

This project has launched a major GIS effort to synthesize and generate spatial information previously unavailable at the Pacific Coast scale. Whether creating new GIS data (i.e., groundfish fishing regulations) or mining existing data and using it in innovative ways (i.e., invertebrate data from trawl surveys), this EFH process has been the driving force behind compiling disparate biological, regulatory, and catch data into a single GIS. The completed GIS seamlessly interacts with the Bayesian Belief Network models and is an invaluable tool for data visualization and regulatory decision-making.

2.1.1 Challenges Encountered While Compiling EFH GIS

Compiling comprehensive datasets covering the range of West Coast groundfish has proven to be an enormously complex and time-consuming task. Listed below are the issues and constraints encountered repeatedly while developing the EFH GIS data layers.

Locating Quality Data. Every GIS undertaking of this magnitude faces longstanding challenges to data sharing and integration. Compiling a GIS for an 822,000 km^2 study area requires navigating a complex web of federal, state, and local agencies in an effort to locate the best available data. Ideally, data sets sought out for inclusion were comprehensive for the West Coast where possible, already in GIS format, free, readily available, and redistributable. However, more often than not, meeting all these criteria proved impossible. Balancing cost and time requirements to meet the EIS schedule required prioritization of efforts to locate data. It is important to note that elements that received a lower priority in this round can be collected and incorporated in later versions to support future decision-making processes.

Uniting Disparate Data Sets. Reconciling data from disparate sources into a unified, coherent database presents a multitude of technical challenges, requiring decisions about seemingly arcane, yet critical, details. Almost all EFH data was available only as geographic subsets to the study area. Ideally, these data would be “stitched” together at their edges using straightforward GIS commands. In practice, however, combining these geographic subsets into one comprehensive GIS layer required additional processing including: (1) modifying attribute definitions to make them identical; (2) eliminating overlapping areas by determining which subset has priority; (3) filling in data gaps between subsets; (4) understanding and reconciling different source scales and spatial extents; (5) validating coding; (6) updating coding as new information is provided; and (7) projecting data to a common West Coast projection. During these procedures, the goal has been to remain as consistent as possible with the intent of the source data while also creating comprehensive data coverage for the area of interest. To facilitate this process, automated procedures were used in lieu of more time-consuming manual editing procedures.

Scale and Detail Exceed Software Capacity. The large spatial extent of this project combined with the need for highly detailed GIS data has resulted in the creation of GIS datasets that exceed the capacity of essential software algorithms. To address this issue, alternative processing procedures were required to process and recompile these datasets into usable a format.

2.1.2 GIS Modeling and Management

The scale, scope, and complexity of this project have repeatedly pushed the limits of standard GIS technologies and existing spatial data, which required the project team to use innovative tools and multiple programming languages to develop the best possible GIS on which to base the EFH and Impact models. Relying on their expertise in the marine sciences, the team developed the spatial framework upon which these models are based. The result is a system that easily moves baseline data into the modeling process, facilitates model validation through results visualization, and displays the model outputs. In addition, the GIS allows for the mapping of management alternatives to allow decision makers and the public to identify preferred alternatives.

2.2 West Coast Fish Habitat

The EFH model uses information on habitat preferences of species and life stages in the Groundfish FMP for three habitat characteristics—benthic habitat (including biogenic habitat), depth, and latitude—to support the development of alternatives for identifying EFH. Accordingly, the following sections describe the data collected and processed in these three main categories. We also discuss more briefly the role of pelagic habitat in the identification of and assessment of risk to EFH.

2.2.1 Benthic Habitat

2.2.1.1 Summary

Benthic habitat is characterized primarily on the basis of the physical substrate. Marine geologists worked closely with fish ecologists to develop GIS data delineating bottom-types and physiographic features associated with groundfish habitats. Benthic habitat data for Washington and Oregon were developed by the Active Tectonics and Seafloor Mapping Lab, College of Oceanic and Atmospheric Sciences at Oregon State University. Data for California were developed by the Center for Habitat Studies at Moss Landing Marine Laboratories. TerraLogic GIS, Inc. was responsible for merging and cleaning these two data sources to create a seamless West Coast coverage. All lithologic and physiographic features were classified according to a deepwater benthic habitat classification system developed by (Greene, *et al.* 1999).

Information on the distribution of biogenic structures and other organisms, which may form an essential, and potentially sensitive, component of habitat is less readily available, but is included to the extent possible at this stage. Biological organisms may play a critical role in determining groundfish habitat use and preference. Structure-forming invertebrates, such as sponges, anemones, and cold water corals, can be an important and component of fish habitat. An example within the US EEZ is the Oculina Bank on the Atlantic coast of Florida. On the West Coast, however, assessment of the significance of associations between structure-forming invertebrates and groundfish species is limited by available literature.

GIS data have been compiled for several essential biological habitat components; canopy kelp, seagrass, and benthic invertebrates. Limited information is available to spatially delineate these biological habitats coastwide. However, because these habitats are so important, the project team felt that incomplete coverage was preferable to leaving these data out of the GIS.

Estuaries are known to be important areas for some groundfish species, such as kelp greenling, starry flounder, and cabezon. However, estuarine seafloor types were generally not mapped by the marine geologists during the initial data consolidation phase of the project. They are included as a separate mapped category of their own for inclusion in modeling efforts.

2.2.1.2 Physical Substrate

Marine geology experts have developed GIS data delineating bottom-types and physiographic features associated with groundfish habitats. Benthic habitat data for Washington and Oregon were developed by the Active Tectonics and Seafloor Mapping Lab, College of Oceanic and Atmospheric Sciences at Oregon State University (Appendix 2 to the Risk Assessment). Data for California were developed by the Center for Habitat Studies at Moss Landing Marine Laboratories (Appendix 3 to the Risk Assessment). TerraLogic was responsible for merging and cleaning these two data sources to create a seamless West Coast coverage. All lithologic and physiographic features were classified according to a deep-water benthic habitat classification system developed by (Greene, *et al.* 1999). Detailed documentation about the classification system and mapping methods are included in Appendix 3.

In general, the benthic habitat is classified according to its physical features in several levels of a hierarchical system. The levels, in order, are; megahabitat, seafloor induration, meso/macrohabitat, and modifier(s). For the West Coast, the following types have been delineated:

<u>Level 1: Mega Habitat</u>:

Continental Rise/Apron;
Basin Floor;
Continental Slope;
Ridge, Bank, or Seamount;
Continental Shelf.

<u>Level 2: Seafloor Induration</u>:

Hard Substrate;
Soft Substrate.

Table 1. Unique benthic habitat types delineated in the West Coast EFH GIS.

Habitat Code	Habitat Type	Mega Habitat	Habitat Induration	Meso/Macro Habitat	Modifier
Ahc	Rocky Apron Canyon Wall	Continental Rise	hard	canyon wall	
Ahe	Rocky Apron	Continental Rise	hard	exposure	
As_u	Sedimentary Apron	Continental Rise	soft		unconsolidated
Asc/f	Sedimentary Apron Canyon Floor	Continental Rise	soft	canyon floor	
Asc_u	Sedimentary Apron Canyon Wall	Continental Rise	soft	canyon	unconsolidated
Asg	Sedimentary Apron Gully	Continental Rise	soft	gully	
Asl	Sedimentary Apron Landslide	Continental Rise	soft	landslide	
Bhe	Rocky Basin	Basin	hard	exposure	
Bs_u	Sedimentary Basin	Basin	soft		unconsolidated
Bsc/f_u	Sedimentary Basin Canyon Floor	Basin	soft	canyon floor	unconsolidated
Bsc_u	Sedimentary Basin Canyon Wall	Basin	soft	canyon wall	unconsolidated
Bsg	Sedimentary Basin Gully	Basin	soft	gully	
Bsg/f_u	Sedimentary Basin Gully Floor	Basin	soft	gully floor	unconsolidated
Fhc	Rocky Slope Canyon Wall	Slope	hard	canyon wall	
Fhc/f	Rocky Slope Canyon Floor	Slope	hard	canyon floor	
Fhe	Rocky Slope	Slope	hard	exposure	
Fhg	Rocky Slope Gully	Slope	hard	gully	
Fhl	Rocky Slope Landslide	Slope	hard	landslide	
Fs_u	Sedimentary Slope	Slope	soft		unconsolidated
Fsc/ f_u	Sedimentary Slope Canyon Floor	Slope	soft	canyon floor	unconsolidated
Fsc_u	Sedimentary Slope Canyon Wall	Slope	soft	canyon wall	unconsolidated
Fsg	Sedimentary Slope Gully	Slope	soft	gully	
Fsg/f	Sedimentary Slope Gully Floor	Slope	soft	gully floor	
Fsl	Sedimentary Slope Landslide	Slope	soft	landslide	
Rhe	Rocky Ridge	Ridge	hard	exposure	
Rs_u	Sedimentary Ridge	Ridge	soft		unconsolidated
Shc	Rocky Shelf Canyon Wall	Shelf	hard	canyon wall	
She	Rocky Shelf	Shelf	hard	exposure	
Shi_b/p	Rocky Glacial Shelf Deposit	Shelf	hard	ice-formed feature	bimodal pavement
Ss_u	Sedimentary Shelf	Shelf	soft		unconsolidated
Ssc/f_u	Sedimentary Shelf Canyon Floor	Shelf	soft	canyon floor	unconsolidated
Ssc_u	Sedimentary Shelf Canyon Wall	Shelf	soft	canyon wall	unconsolidated
Ssg	Sedimentary Shelf Gully	Shelf	soft	gully	
Ssg/f	Sedimentary Shelf Gully Floor	Shelf	soft	gully floor	
Ssi_o	Sedimentary Glacial Shelf Deposit	Shelf	soft	ice-formed feature	outwash

Level 3: Meso/macrohabitat:

- Canyon Wall;
- Canyon Floor;
- Exposure, Bedrock;
- Gully;
- Gully Floor;
- Ice-formed Feature;
- Landslide.

Level 4: Modifier:

- Bimodal Pavement;
- Outwash;
- Unconsolidated Sediment.

Each unique combination of these four characteristics defines a unique benthic habitat type. For the West Coast EFH project, 35 unique benthic habitat types have been delineated.

In addition, for Oregon, marine geologists delineated areas on the continental slope that were "predicted rock." These predicted rock areas were determined using multibeam bathymetry data having slopes greater than 10 degrees. Areas meeting this criterion "have been found from submersible dives, camera tows, and sidescan sonar data to nearly always contain a high percentage of harder substrates" (Goldfinger, *et al.* 2002). Predicted rock areas are included with other rocky habitats in the classification, but retain an additional identifier indicating that it was predicted.

2.2.1.3 Estuaries

Estuaries are known to be important areas for some groundfish species, such as kelp greenling, starry flounder, and cabezon. However, estuarine seafloor types were generally not mapped by the marine geologists during the initial data consolidation phase of the project. Only those habitats that are specifically mapped can be incorporated into the EFH model. Specific substrates within estuaries are not mapped; however, because of their significance as groundfish habitat, estuaries are included as a separate mapped category of their own, so that they can form part of the area identified as EFH. The only drawback of this approach is that an entire estuary is either identified as EFH or not. It is not presently possible to identify only part of an estuary, because there is no information in the GIS to distinguish between one part of an estuary and another. As information becomes available in GIS format this will change.

GIS boundaries for West Coast estuaries were compiled during the 1998 EFH process. The boundaries were derived primarily from the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI). Where digital data for the NWI were unavailable, data from NOAA's Coastal Assessment Framework were used. Because these data were readily available, it was decided to merge them with the existing seafloor habitat data. In most cases, the areas delineated as estuaries do not overlap the areas that have geological substrate and/or bathymetry mapped, so the depths and bottom types are currently undescribed within the GIS.

The project team encountered some challenges during the merging process due to the differences in shoreline boundaries used for the seafloor habitat and estuaries. There were both gaps and areas of overlap between the two data sets. Often these gaps or overlaps are not real, but artifacts of the mis-alignment between the layers. Because we did not have the resources for extensive manual editing to align these boundaries, we developed some decision rules for dealing with data inconsistencies in the areas of overlap. Gaps between the data sets remain because there was not an acceptable automated method for either filling or removing them.

Various combinations of seafloor habitat and estuary habitat codes occur once the two data sets are combined. In a couple situations, one data set delineates an area as land (indicated by the code "Island"), and the other data set delineates the same area as potential EFH (either estuary or benthic habitat). Because terrestrial areas are not potentially EFH, land areas are removed prior to input to the EFH model. However, any areas that were ambiguous (i.e., at least one of the datasets identified them as potential EFH) were retained.

2.2.1.4 Biogenic Habitat

Biological organisms also play a critical role in determining groundfish habitat use and preference. In some cases, the biological component of the habitat is the most important feature that makes the habitat suitable for a particular species/life stage. GIS data has been compiled for canopy kelp, seagrass, and benthic invertebrates.

Limited information is available to spatially delineate these biological habitats coastwide. However, because these habitats are so important, the project team felt that incomplete coverage was preferable to leaving these data out of the GIS. Therefore, presence of a biological habitat polygon is a good indicator that the particular feature is there, or was there in the past. However, lack of a biological habitat polygon could mean two things: (1) the habitat type does not occur in that location; or (2) GIS data was not available for that area.

<u>Canopy Kelp Beds</u>

Kelp beds have been shown to be important to many groundfish species, including several rockfish species. GIS data for the floating kelp species, *Macrocystis* spp. and *Nereocystis* spp., are available from state agencies in Washington, Oregon, and California. These data have been compiled into a comprehensive data layer delineating kelp beds along the West Coast. The kelp source data were provided for each state by the following agencies; Washington Department of Natural Resources (WDNR), Oregon Department of Fish and Wildlife (ODFW), and California Department of Fish and Game (CDFG). Source data were collected using a variety of remote-sensing techniques, including aerial photos and multispectral imagery. Because kelp abundance and distribution is highly variable, these data do not necessarily represent current conditions. However, data from multiple years were compiled together with the assumption that these data would indicate areas where kelp has been known to occur. Washington State has the most comprehensive database, covering 10 years (1989-1992 and 1994-2000) and annual surveys of the Straits of Juan de Fuca and the Pacific Coast. Oregon did a coastwide survey in 1990, and then surveyed select reefs off southern Oregon in 1996-1999. A comprehensive kelp survey in California was performed in 1989, and additional surveys of most of the coastline occurred in 1999 and 2002.

<u>Seagrass</u>

Despite their known importance for many species, seagrass beds have not been as comprehensively mapped as kelp beds. An excellent coastwide assessment of seagrass has been recently published by Wyllie-Echeverria and Ackerman, (2003). This assessment identifies sites known to support seagrass and estimates of seagrass bed areas, however, it does not compile existing GIS data. Therefore, GIS data for seagrass beds had to be located and compiled for the EFH project.

Potential data sources for seagrass were identified through internet database searches as well as initial contacts provided by NMFS EFH staff and Sandy Wyllie-Echeverria at the University of Washington. Twenty-eight individuals or organizations were contacted for seagrass data or to provide further contacts.

Seagrass species found on the West Coast of the U.S. include eelgrass (*Zostera* spp., *Ruppia sp*.) and surfgrass (*Phyllospadix* spp.). Eelgrass is found on soft-bottom substrates in intertidal and shallow subtidal areas of estuaries. Surfgrass is found on hard-bottom substrates along higher energy coasts.

Eelgrass mapping projects have been undertaken for many estuaries along the West Coast. These mapping projects are generally done for a particular estuary, and many different mapping methods and mapping scales have been used. Therefore, the data that have been compiled for eelgrass beds are an incomplete view of eelgrass distribution along the West Coast. Data depicting surfgrass distribution are very limited—the only GIS data showing surfgrass are in the San Diego area.

In order to complete the EFH model by the required deadlines, acquisition of data on seagrass was ended in March 2004. Any data that were not made available by this date could not be included in the coastwide seagrass GIS layer. Table 2 lists the geographic coverage, time period, and sources of the seagrass data sets that were compiled.

Structure-forming Invertebrates

Structure-forming invertebrates—such as sponges, anemones, and cold water corals—can be an important and potentially vulnerable component of fish habitat. On the West Coast the significance of associations between structure-forming invertebrates and groundfish species, in terms of being EFH, has not been clearly identified.

Information recorded in the habitat use database (see Section 2.3.4.2) indicates that one or more species in the Groundfish FMP have been recorded as occurring with 10 separate categories of invertebrates that could be regarded as structure forming, or habitat creating. These are basketstars, brittlestars, mollusks, sea anemones, sea lilies, sea urchins, sea whips, sponges, tube worms, and vase sponges. This does not imply that fish use these structure-forming invertebrates as habitat. It also does not assume that ALL species in the various groups form structure or that those that do form structure do so all the time. Further, this is most certainly only a partial list and is incomplete—some significant groups are missing, e.g., cold water corals, including gorgonians and antipatharians, and other octocorals that form structure to an elevation of four meters above the seafloor.

Data on the presence of sponges, anemones, and cold water corals (including gorgonians, black corals, and sea pens) are available from the NOAA Fisheries bottom trawl surveys on the West Coast shelf and slope. These data form the basis for the only coast-wide source of distributional information for structure-forming invertebrates (see Morgan and Etnoyer, 2003). However, there are some serious limitations to this information. First, only presence data could be plotted; those trawl samples without structure-forming invertebrates (i.e., absence data) have not been plotted. Second, the trawl samples are notoriously biased toward trawlable soft bottom, low relief habitats. Therefore complex rock structure, which is known to be important habitat for many structure-forming invertebrates, is not well represented. The coral category includes both soft-bottom sea pen species and also species that occur primarily on complex rocky substrata.

Given the dearth of existing information on systematics, distribution, and abundance of structure-forming invertebrates (particularly in deep water) on the West Coast, a number of investigators have initiated relatively comprehensive surveys of these organisms. Notably, habitat-specific studies of structure-forming invertebrates and associated fish assemblages are underway both in the Southern California Bight and off the Oregon Coast (Heceta Bank and Astoria Canyon). The association between fishes and these invertebrates, and more importantly what might be considered essential aspects of these associations, remains to be demonstrated.

Table 2. Summary of seagrass data sets compiled as of February 2004.

State	Geographic Coverage	Time Period	Description	Source
WA	all coastal and estuarine areas	1994-2000	Shorezone Inventory – aerial video interpretation	Washington Department of Natural Resources
WA	Skagit, Whatcom Counties	1995 1996	Nearshore Habitat Inventory – multispectral image analysis	Washington Department of Natural Resources
WA	Hood Canal	2000	multispectral image analysis	Point No Point Treaty Council
OR	coastal estuaries	1987	Oregon Estuary Plan Book maps	Oregon Department of Land Conservation and Development
OR	Tillamook Bay	1995	multispectral image analysis	Tillamook Bay National Estuary Program and Tillamook County
CA	Northern and Southern California, and San Francisco Bay	1994 1995 1998	Environmental Sensitivity Index data – compilation of various existing data sets	NOAA, National Ocean Service (NOS), Office of Response and Restoration (ORR)
CA	Tomales Bay	1992 2000-2002	aerial photo interpretation	California Department of Fish and Game and NOAA, NOS, ORR
CA	San Diego region, Dana Point to Mexican border	2002	multispectral image analysis and multibeam acoustic backscatter data	San Diego Nearshore Habitat Mapping Program
CA	Alamitos Bay	2000	SCUBA and boat-based GPS survey	NMFS, Southwest Region (data developed by Wetlands Support)
CA	Morro Bay	1998	aerial photo interpretation	Morro Bay National Estuary Program (data provided by NMFS, SWR)
CA	San Diego Bay	2000	single-beam sonar interpretation	U.S. Navy and Port of San Diego (data provided by NMFS, SWR)

2.2.2 Bathymetry

Water depth is one of the three habitat characteristics used in the EFH Model to calculate habitat suitability probability values (Section 3.4). A single West Coast bathymetric data layer was therefore developed. After collecting bathymetry from numerous sources, each was individually contoured to 10-meter depth intervals. Using an innovative technique, these contour lines were converted to polygons to facilitate analysis with additional polygonal datasets. This process proved exceptionally challenging, surpassing the limitations of the GIS software. A split and stitch approach was adopted to clip the universal coverage down to manageable regions and recompile the data after the polygons were formed. The resulting GIS coverage contains polygons with 10-meter depth ranges. The geographic extent of the final bathymetry data was set to the same extent as the benthic habitat data, including using the same shoreline delineated by the benthic habitat data (i.e., 0-meter depth contour) for the bathymetry data.

Moss Landing Marine Lab provided 10-meter depth contours for California. These contours were derived from a publicly-available, 200-meter bathymetry grid from the California Department of Fish and Game, Marine Region GIS Unit. For Oregon, up to 46° N. latitude, Oregon State University provided 10-meter depth contours. These contours were generated from a 100-meter bathymetry grid developed by combining and resampling multiple in-house data sets. Data sources and processing procedures for these contours are described in Appendix 2 (Goldfinger, *et al.* 2002). Bathymetry data for the remaining areas, (Washington and the southernmost portion of the EEZ), were developed from free, publicly-available sources. For most of Washington, a 20-meter bathymetry grid was acquired from Washington Department of Fish and Wildlife and contoured to 10-meter depths. The remaining data gaps were filled with 10-meter contours developed from the gridded Naval Oceanographic Digital Bathymetric Data Base–Variable Resolution (DBDB-V). A small data gap between Oregon and Washington, approximately 100 to 200 meters across, was bridged by extending the contour lines to meet the shared boundary.

Due to the disparate nature of the bathymetry sources, the depth zones are discontinuous at the boundaries between data sources. No manual adjustments have been made to the compiled bathymetry data to remove these discontinuities. Due to software processing constraints and the extremely large size of the contour data files for California, these contours were algorithmically smoothed to remove extra vertexes within a maximum distance of 150 meters. By visual assessment, this generalization process had minimal impact on the contour locations.

2.2.3 Latitude

Along with depth and substrate type, latitude is the third habitat characteristic used in the EFH Model to calculate habitat suitability probability values (Section 3.4). Initially, boxes delineating one-minute latitudinal zones were created and overlaid with bathymetry and benthic habitat data to create a set of unique physical habitat polygons. During the development of the EFH model, it was concluded that species distributions change more gradually over latitude, and that 10-minute latitudinal zones would be a more appropriate level of detail. Therefore, a new GIS coverage depicting 10-minute latitude zones was developed and merged with other habitat components.

2.2.4 Pelagic Habitat

There are a number of species and life stages in the Groundfish FMP that occur in the water column, but do not have any association with benthic substrate. While the water column is likely to be much less sensitive to fishing impacts than benthic substrate, it is still necessary to identify EFH for these components of the groundfish assemblage. For example, there may be non-fishing impacts, such as pollution, that have adverse effects. However, mapping EFH in the pelagic zone is even more difficult and less exact than for the seabed. 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, as is required for EFH, problematic. The project team did not attempt 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.

2.2.5 Data Quality

An important component to the modeling of habitat suitability probability is the level of uncertainty in data inputs. While we have observations of habitat features such as the physical substrate and the depth, these are not known with certainty, and depending on how the observations were made the quality of the data will vary. The information available on data quality is described in the following sections.

2.2.5.1 Physical Substrate

The maps of physical substrate have been interpreted and compiled from various types of source data, including existing geologic maps, sediment samples, sidescan sonar imagery, seismic reflection data, and multibeam bathymetry. As with any type of mapping, there is some uncertainty involved in mapping benthic habitats. Each data source has its own strengths and weaknesses, as well as a specific spatial resolution. In general, when more than one source of information is available, or the data source is highly detailed, the interpretation will be of higher quality and accuracy.

A data quality GIS layer was developed to indicate the degree of certainty that the mapped seafloor type represents the "real" seafloor type. For the Washington and Oregon benthic habitat maps, the Active Tectonics and Seafloor Mapping Lab at OSU provided a data quality layer created by developing four separate 100-meter grids for each data type (bathymetry, sidescan sonar, substrate samples, seismic reflection) and ranking the data sources on a scale of 1 to 10. OSU geologists created an overall substrate data quality layer by summing the values from the four individual data quality layers, creating a new layer with values from 1 to 40. Detailed documentation of the Washington/Oregon data quality layer is provided as Appendix 4 to the Risk Assessment. No data quality layer is available for benthic habitat in California.

2.2.5.2 Bathymetry

Bathymetric data quality is affected by the source data's spatial resolution, spatial accuracy, and attribute accuracy and precision. A general data quality layer for bathymetry has been developed by TerraLogic GIS. The boundaries for each bathymetry data source have been delineated and the overall quality of each data source can be ranked on a relative scale. The bathymetry data from Oregon are the highest quality, the data from California are second best quality, the third quality level are the data from Washington (WDFW), while the lowest quality data is from the Naval Oceanographic Office used to fill gaps off Washington and Southern California. Within each data source, there are also variations in data quality. However, other than Oregon, there is not adequate information to delineate these within-source variations. Therefore, the project team used a single quality rank for each source.

Discussion at the Pacific Fishery Management Council's SSC Groundfish Sub-Committee review meeting in February 2004 suggested that the influence of the bathymetry data quality on the outcome of the modeling process would be limited, because of the scale on which depth was being considered in the model generally exceeded the scale of the error in even the worst data areas. At the March 2004 Council meeting, the SSC therefore recommended that work on the bathymetry data quality layer should be suspended. The data quality layer for bathymetry was therefore not included in modeling process.

2.3 Use of Habitat by Groundfish

2.3.1 NMFS Trawl Surveys

Trawl surveys can provide valuable information on fish distribution, and hence provide source data for estimating the suitability of habitat within the area covered by the FMP. Bottom trawl surveys have been conducted on the continental shelf and upper slope off the West Coast (Washington, Oregon, and California) since 1977. These surveys provide the primary source of abundance and trend information for most stock assessments conducted on West Coast groundfish. Three survey series in the study area are described below. A summary comparison of the details of these surveys in 2001 is provided in Table 3.

The shelf survey (30-200 fathoms) by the Alaska Fisheries Science Center (AFSC) uses larger (120 to 130 ft) chartered fishing vessels and has been conducted triennially since 1977. This is commonly known as the triennial shelf survey. The ninth and final survey in the series was conducted in 2001.[1] From 1977 through 1986, the surveys were aimed at estimating rockfish abundance. The five latter surveys from 1989 to 2001 shifted the emphasis more toward better assessments of a broader range of groundfish species. From 1987 to 1992, the depth range of the survey was 55 to 366 m. In 1995, the lower depth was increased to 500 m in order to cover the habitat of slope rockfish more completely. The final 2001 survey encompassed the coastal waters from Point Conception, California, to central Vancouver Island, British Columbia (34° 30' N. latitude–49° 06' N. latitude). A total of 527 stations were occupied, of which 506 were successfully sampled. Catches included over 166 fish species representing more than 57 families (Weinberg, *et al.* 2002).

A second survey series also conducted by AFSC was initiated in 1984. This survey aimed at covering the slope (100-700 fathoms) and was motivated by the need for information on the commercially important species inhabiting that region (Lauth et al. 1998). These species, comprising the “deepwater complex,” include Dover sole, sablefish, shortspine thornyhead, and longspine thornyhead. The survey has been conducted annually since 1988 using primarily the 225 ft NOAA Research Vessel Miller Freeman. The spatial coverage of the surveys has varied. In 1997, for the first time, the entire West Coast from Point Conception to the US-Canada border was surveyed.

In 1998 the Northwest Fisheries Science Center (NWFSC), initiated a new bottom trawl survey of the commercial groundfish resources in the slope zone (100–700 fathoms). Conducted in the summer months, this survey uses chartered local West Coast trawlers ranging in size from 60 to 100 ft. In 1998, the survey covered the area from Cape Flattery, Washington (48° 10' N. latitude), to Morro Bay, California (35° N. latitude), between August 20 and October 16. This survey has been conducted annually since 1998. Although the survey aims to sample the slope, in 2001 the design was changed for one year to cover the shelf. The survey in all other years (1998-2000 and 2002) has been a segmented transect design that divides the US Pacific coast into 10-degree equidistant sections north to south and 10 east-west segments based on depth. The area covered in 1998-2000 was 34° 15’ N. latitude to 48° 15’ N. latitude. In 2002, the area covered expanded at the southern margin to 32° 30’ N. latitude (south of Point Conception) and contracted very slightly at the northern margin to 48° 10’ N. latitude.

For all these surveys, haul locations are stored both as points indicating the vessel’s start position and trawl mid-point, as well as straight lines connecting the vessel’s start and end point. The tabular data associated with each haul, such as species code and species weight, are stored in related database tables. The information in these related tables can be queried geographically, or tabular queries can be performed and then the results displayed geographically.

The data from these trawl surveys have been compiled and converted to GIS format. They can be used in geographic overlays with other information, such as fishing effort or habitat, to validate model outputs or assess the relationship between various layers.

[1] The triennial shelf survey years were 1977, 1980, 1983, 1986, 1989, 1992, 1995, 1998, and 2001.

The survey data also can be analyzed to characterize the preferences of species and life stages for different components of the habitat. For example, it is possible to explore the relationships between catch per unit effort (CPUE) and habitat attributes such as latitude and depth.

Table 3. Comparison of the three trawl survey series covering the West Coast of the US. Information provided by NOAA Fisheries.

Item (year=2001)	NWFSC Slope Survey	AFSC Triennial Shelf Survey	AFSC Slope Survey
Vessel type	Chartered West Coast trawler	Chartered Alaska trawler	Fisheries research vessel
Period	1998-ongoing	1977-2001	1984-ongoing
Frequency	Annual	Triennial	Annual since 1988
Survey type and depth	Slope (100-700 fathoms)	Shelf (30-200 fathoms)	Slope (100-700 fathoms)
LOA vessel	68-92 ft	125-128 ft	225 ft
Survey design	Stratified by lat & depth, random by depth & proximity	Stratified by lat & depth, somewhat fixed stations	Stratified by lat & depth, somewhat fixed stations
Yearly use of same survey vessels	Yes in some instances, but not intent of design	Yes, if possible	Yes
Survey time of the year	Summer	Summer	Fall
No. of vessels available for hire	Approx. 40 (have used 9 vessels to date)	At least 100	1
No. of scientists on board	3	6	12
No. of hours vessel worked/day fishing (daytime or round the clock)	14 (daytime only sampling)	14 (daytime only sampling)	24 (round the clock sampling)
Days at sea (2001)	166	130	28
Average no. of tows/day (2001)	2.01	3.89	7.43
Number of attempted tows (exclude experimental)	408	539	216
Number of valid tows*	334	506	208
Net mensuration	Yes	Yes	Yes
All fish species identified	Yes	Yes	Yes
Invertebrate species ID	No, only crab identified	Yes, all invert spp.	Yes, all invert spp.
No. of different length spp.	4 primary, 15 total	28 primary, 77 total	9 primary and total
Average no. of lengths collected/tow	196	510	545
Average no. otoliths collect/haul/vessel	18	15	40
Commercial fish retained?	Yes	No	No
Targeted tow duration	15 mins	30 mins	30 mins
Average lift off-lag time (minutes)	4.5	0.4	"almost immediately"
Range of lift off-lag times	1-20 minutes	0-2 minutes	NA
Average no. of weather days	0.5	0.75	0

* Difference in number of valid tows is highly correlated to whether tow location is fixed or random from year to year.

2.3.2 Ichthyoplankton Surveys

This section describes surveys that could provide some information on the distribution of planktonic phases of groundfish species. Data from these surveys have not been used in the EFH model. They do not provide comprehensive coastwide coverage. Where possible, fish habitat in the water column has been described using information on the latitude and depth ranges of the species and life stages in question (see Section 3.4.2.1).

2.3.2.1 CalCOFI Ichthyoplankton Surveys

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) unit has conducted standardized ichthyoplankton surveys, primarily offshore of California and Baja California, since 1951. Survey methods and results are described by Moser, *et al*. (1993). GIS maps of egg and larval distributions of managed species have been developed from data collected during these surveys (NMFS 1998).

2.3.2.2 NMFS Icthyoplankton Surveys

Research surveys extending from the Strait of Juan de Fuca to northern California and offshore to the boundary of the EEZ were conducted periodically during the 1980s. They were intended to complement the egg and larval data obtained from the CalCOFI ichthyoplankton surveys. NMFS conducted these surveys cooperatively with the Soviet Pacific Research Institute. Survey methods and their results are described by Doyle (1992). Data on egg and larval distribution were used to develop the GIS maps of NMFS ichthyoplankton survey results in the 1998 EFH Appendix.

2.3.3 NOAA Atlas

In the late 1980s, NOAA compiled information about several commercially-valuable groundfish species on the West Coast. This information was synthesized into a hand-drawn map atlas format showing the species' distribution for various life stages (NOAA 1990). The source data for these maps included NMFS' RACEBASE, commercial and recreational catch statistics, state or regional agency data, and expert review. The scale of these maps is generally 1:10,000,000. In the 1990s these atlas maps were converted to GIS format. This conversion included clipping the species polygons with a 1:2,000,000 land polygon. The 13 groundfish species and life stages that are available in GIS format are listed in Table 4.

Table 4. Groundfish distributions mapped in the NOAA Atlas (1990).

NAME	Life History Stage							
	adult	juvenile	mating	old juvenile	young juvenile	spawning	release of young	range
arrowtooth flounder (*Atheresthes stomias)*	x	x						
Dover sole (*Microstomus pacificus)*	x	x				x		
English sole (*Parophrys vetulus (=Pleuronectes vetulus)*)	x			x	x	x		
flathead sole (*Hippoglossoides elassodon*)	x	x				x		
lingcod (*Ophiodon elongates*)	x	x				x		x
Pacific cod (*Gadus macrocephalus*)	x			x	x	x		
Pacific hake (*Merluccius productus*)	x				x	x		
Pacific ocean perch *(Sebastes alutus*)	x		x	x			x	
petrale sole (*Eopsetta jordani*)	x			x	x	x		
sablefish (*Anoplopoma fimbria*)	x	x				x		
spiny dogfish (*Squalus acanthias*)	x		x	x	x			
starry flounder (*Platichthys stellatus*)	x			x	x	x		
widow rockfish (*Sebastes entomelas*)	x	x	x				x	

2.3.4 Fish/habitat Functional Relationships

Using habitat distribution information to identify EFH requires some knowledge of the functional relationships between the species of interest (in this case the Pacific Coast Groundfish Fishery Management Unit) and the habitats they use. This section describes the information available to describe these relationships.

2.3.4.1 The Updated Life Histories Descriptions

In 1998, A Life Histories Appendix to Amendment 11 to the Pacific Coast Groundfish FMP described the life histories and EFH designations for 83 of the individual species that the FMP manages. The primary sources of information for the life history descriptions and habitat associations were published reports and gray literature. GIS maps of species and life stage distributions generated were included.

The Life Histories Appendix was intended to be a living document that could be changed as new information on particular fish species became available, without using the cumbersome FMP amendment process. The EFH regulations state that the Councils and NMFS should periodically review and revise the EFH components of FMPs at least once every five years. In response to this requirement for periodic review, the life history descriptions were recently updated and included in Groundfish FMP Appendix B.2. The update was compiled by conducting literature searches using the *Cambridge Scientific Abstracts Internet Database Service* and by reviewing recently completed summary documents, such as the California Department of Fish and Game's Nearshore Fishery Management, the Oregon Department of Fish and Wildlife's Nearshore Fisheries Management Plan, and *The Rockfishes of the Northeast Pacific* by Love *et al*. (2002).

The life history descriptions included in Groundfish FMP Appendix B.2 provide an extensive and detailed reference on species/life stage and habitat interactions. However, detailed bathymetry information for all species' life stages is incomplete at present. Furthermore, the information on substrate is somewhat patchy, and the classification of substrates and habitats is inconsistent across species. Some of these problems are unavoidable. For example, although most groundfish species are demersal, some life stages (for example, eggs and larvae) are sometimes pelagic. It is therefore difficult in some instances to associate these life stages with a particular habitat.

2.3.4.2 The Habitat Use Database (HUD)

The life history descriptions also provide a valuable compilation of information on the habitat preferences of all the species and life stages in the Pacific Coast Groundfish FMP to the extent known. However, the text format in which the information is presented does not lend itself well to analysis of habitat use across many habitat types or many species and life stages.

A Pacific Coast Groundfish Habitat Use Relational Database was therefore developed to provide a flexible, logical structure within which information on the uses of habitats by species and life stages could be stored, summarized, and analyzed. The database is designed primarily to capture the important pieces of information on habitat use by species in the Pacific Groundfish FMP as contained in the life history descriptions compiled by NMFS (see Section 2.2.2.1). Some of this information needs to be captured in a database format so that habitat use data can be analyzed both by species and habitat to provide input into various components of the analysis of EFH, habitat areas of particular concern (HAPCs), and fishing impacts (See Appendix 6 to the Risk Assessment- Manual of the Habitat Use Database).

3.0 DESCRIBING AND IDENTIFYING EFH

3.1 Guidance from the EFH Final Rule

The Magnuson-Stevens Act (MSA) defined EFH to mean “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (MSA § 3(10)). This defines EFH, but does not specify how to distinguish among various parts of a species’ range to determine the portion of the range that is essential. The EFH Final Rule (50 CFR Part 600) elaborates that the words “essential” and “necessary” mean EFH should be sufficient to “support a population adequate to maintain a sustainable fishery and the managed species’ contributions to a healthy ecosystem.”

The EFH Final Rule provides regulations and guidance on the implementation of the EFH provisions of the MSA. It includes guidance on the types of information that can be used for describing and identifying EFH.

3.1.1 EFH Description for the Fishery

According to the MSA, EFH must be described and identified for the fishery as a whole (16 U.S.C. §1853(a)(7)). The EFH Final Rule clarifies that every FMP must describe and identify EFH for each life stage of each managed species. As further clarification, NOAA General Counsel has stated that “Fishery” as used in the MSA in reference to EFH refers to the fishery management unit (FMU) of an FMP. Therefore, a single EFH designation for Pacific Coast Groundfish EFH must aggregate individual species/life stages EFH identifications. In the groundfish FMP a single map is used to describe and identify EFH for the fishery. However, the analysis that produces that map will include the preparation of maps of EFH for as many species and life stages as possible.

Designation of EFH for a fishery is therefore achieved through an accounting of the habitat requirements for all life stages of all species in the FMU. Prior to designating EFH for a fishery, the information about that fishery needs to be organized by individual species and life stages. If data gaps exist for certain life stages or species, the EFH Final Rule suggests that inferences regarding habitat use be made, if possible, through appropriate means. For example, such inferences could be made on the basis of information regarding habitat use by a similar species or another life stage (50 CFR Pt. 600.815(a)(iii)). All efforts must be made to consider each species and life stage in describing and identifying EFH for the fishery and to fill in existing data gaps using inferences prior to determining that the EFH for the fishery does not include the species or life stage in question.

While identification of EFH is carried out at the fishery (FMP) level, the determination of whether an area should be EFH depends on habitat requirements at the level of individual species and life stages. Potentially, only one species/life stage in the FMU may be required to describe and identify an area as EFH for the FMP. Many areas of habitat, however, are likely to be designated for more than one species and life stage. The composite habitat requirements for all the species in the Pacific Coast Groundfish FMP are likely to result in large areas of habitat being described and identified as EFH, due to the overlay of multiple species habitat needs. Descriptions of groundfish fishery EFH for 82 of the species in the groundfish FMP and their life stages resulted in over 400 EFH identifications in the 1998 EFH Amendment. When these individual identifications were taken together, EFH for the groundfish FMP included all waters from the mean higher high water line, and the upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon, and California seaward to the boundary of the U.S. Exclusive Economic Zone.

The identification of substantial portions, if not all of the EEZ, as EFH has been seen as a weakness in the EFH mandate, because if "everything" is EFH then the designation process apparently fails to focus conservation efforts on habitats that are truly "essential". However, this conclusion does not take into consideration that the distinction between all habitats occupied by a species and those that can be considered "essential" is made at the species and life stage level. The designation of EFH at the FMP level delineates a static two dimensional boundary for consultation purposes. A consultation process will be triggered when an agency plans to undertake an activity that potentially impacts habitat within the boundary of the area designated as EFH. The resulting consultations will consider how the proposed action potentially impacts EFH. The detailed characteristics of the habitat in the relevant location will be an important part of this analysis. In this context, it is possible to envision that an area of EFH that has been designated as such for a particularly large number of species and life stages, or is particularly rare, or stressed, or vulnerable might be of particular concern. In recognition of this, the Final Rule encourages regional Fishery Management Councils to identify HAPC within areas designated as EFH (600.815(a)(8)).

The process of distinguishing between all habitats occupied by managed species and their EFH requires one to identify some difference between one area of habitat and another. In essence, there needs to be a characterization of habitats and their use by managed species that contains sufficient contrast to enable distinctions to be drawn, based on available information. This needs to be a data-driven exercise, and the methodology we have developed aims to use all available data with which to make such a determination.

In this context, the project team noted that if a species is overfished and habitat loss or degradation may be contributing to the species being identified as overfished, all habitats currently used by the species may be considered essential. However, fish stocks depleted by overfishing, or by other factors, are likely to use less of the available habitat than a virgin stock or a stock at "optimum" biomass would use. Indeed, other species may have expanded their range to fill some of these ecological niches. Certain historic habitats that are necessary to support rebuilding the fishery and for which restoration is technologically and economically feasible may also be considered as essential. Once the fishery is no longer considered overfished, the EFH identification should be reviewed and amended, if appropriate (EFH Final Rule CFR 600.815(a)(1)(iv)(C)).

3.1.2 Levels of Information for Identifying EFH

The EFH Final Rule explains that the information necessary to describe and identify EFH should be organized at four levels of detail, Level 4 being the highest and Level 1 the lowest detail:

<u>Level 4</u> Production rates by habitat are available.
Overall production rates can be calculated from growth, reproduction, and survival rates. However, using this information to describe and identify EFH requires not only that production rates have been calculated, but also that they have been calculated for different patches of habitat that can then be distinguished from each other. According to the EFH Final Rule, at this level, data are available that directly relate the production rates of a species or life stage to habitat type, quantity, quality, and location. Essential habitats are those necessary to maintain fish production consistent with a sustainable fishery and the managed species' contribution to a healthy ecosystem.

<u>Level 3</u> Growth, reproduction, or survival rates within habitats are available.
Similar to information on overall production rates, it can be used to describe and identify EFH. Growth, reproduction, and survival rates would need to have been calculated for different patches of habitat that can then be distinguished from each other. According to the EFH Final Rule, at this level, data are available on habitat-related growth,

reproduction, and/or survival by life stage. The habitats contributing the most to productivity should be those that support the highest growth, reproduction, and survival of the species (or life stage).

<u>Level 2</u> Habitat-related densities of the species are available.
Relative density information may be available from surveys, or it could perhaps be inferred from catch per unit effort data, although only for those areas that have been fished. According to the EFH Final Rule, at this level, quantitative data (i.e., density or relative abundance) are available for the habitats occupied by a species or life stage. Because the efficiency of sampling methods is often affected by habitat characteristics, strict quality assurance criteria should be used to ensure that density estimates are comparable among methods and habitats. Density data should reflect habitat utilization, and the degree that a habitat is utilized is assumed to be indicative of habitat value. When assessing habitat value on the basis of fish densities in this manner, temporal changes in habitat availability and utilization should be considered.

<u>Level 1</u> Distribution data are available for some or all portions of the geographic range of the species.
Distribution information is available from surveys, catch/effort data, and evidence in the biological literature, including ecological inferences (e.g., a habitat suitability index, HSI). According to the EFH Final Rule, distribution data may be derived from systematic presence/absence sampling and/or may include information on species and life stages collected opportunistically. In the event that distribution data are available only for portions of the geographic area occupied by a particular life stage of a species, habitat use can be inferred on the basis of distributions among habitats where the species has been found and on information about its habitat requirements and behavior. Habitat use may also be inferred, if appropriate, based on information on a similar species or another life stage.

3.2 Habitat Characteristics of Importance for Fish

Habitat characteristics comprise a variety of attributes and scales, including physical (geological), biological, and chemical parameters, location, and time. It is the interactions between environmental variables that make up habitat that determine a species' biological niche. These variables include both physical variables—such as depth, substrate, temperature range, salinity, dissolved oxygen—and biological variables—such as the presence of competitors, predators, or facilitators.

Species distributions are affected by characteristics of habitats that include obvious structure or substrate (e.g., reefs, marshes, or kelp beds) and other structures that are less distinct (e.g., turbidity zones, thermoclines, or fronts separating water masses). Fish habitat utilized by a species can change with life history stage, abundance of the species, competition from other species, environmental variability in time and space, and human induced changes. Occupation and use of habitats by fish may change on a wide range of temporal scales; seasonally, inter-annually, inter-decadal (e.g., regime changes), or longer. Habitat not currently used but potentially used in the future should be considered when establishing long-term goals for EFH and species productivity.

Fish species rely on habitat characteristics to support primary ecological functions comprising spawning, breeding, feeding, and growth to maturity. Important secondary functions that may form part of one or more of these primary functions include migration and shelter. Most habitats provide only a subset of these functions. The type of habitat available, its attributes, and its functions are important to species productivity and the maintenance of healthy ecosystems.

In developing a process for identifying EFH the project team built a model that expresses the probability that a particular location contains suitable habitat for species in the groundfish FMP, based on our knowledge of the habitat conditions at that location and of the habitat preferences of those species. As recognized in the EFH Final Rule, the only true measure of habitat suitability is obtained through measurement of demographic parameters (production, mortality, growth, and reproductive rates—Levels 4 and 3 described above). For example, EFH could be defined as areas with above-average survival, growth, or recruitment (which for ease of exposition we will refer to as areas of high growth potential). However, data on these parameters across a range of habitats are extremely difficult to obtain. Fish population density, or even presence/absence in data-poor situations (Levels 2 and 1 respectively), are often used as a proxy for growth potential. However, growth potential and density are not necessarily well correlated. For example, in source-sink systems, source populations may have lower densities than sink populations (because they are exporting propagules), even though they are the basis for the overall population's growth potential (Lundberg and Jonzen 1999a; Lundberg and Jonzen 1999b).

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 this can occur if population density is used as a proxy for growth potential. The risk is further exacerbated under harvesting pressure, if source populations are being more heavily fished than sink areas (Tuck and Possingham 1994). Similarly, in a heavily perturbed system, in which external factors such as pollution may be distorting the natural spatial patterns of growth potential, current population density may be a poor proxy for EFH under protected conditions. The question then is whether EFH or HAPC designations should be acting to protect areas that would have high growth potential if protected, or whether they should be protecting areas that currently have higher growth potential regardless of their intrinsic value as EFH. By using data on presence/absence or population density that are collected in a perturbed system under current conditions, the project team attempted the latter, but without a clear understanding of the relationship between density and growth potential.

The EFH Final Rule requires using the highest level of information (production rates) first if it is available, followed by the second highest level (growth, reproduction, or survival rates) and so on. Information at Levels 2 through 4, if available, should be used to identify EFH as the habitats supporting the highest relative abundance; growth, reproduction, or survival rates; and/or production rates within the geographic range of a species. The guidelines also call for applying this information in a risk-averse fashion to ensure adequate areas are protected as EFH. The most complete information available should be used to determine EFH for the FMP, accounting for all species and their life stages that it contains. If higher level information is available for only a portion of the species/life stage range, then it should be used for at least that portion. A decision also needs to be made regarding if and how the information could be used to extrapolate to the rest of the range. Information at lower levels should be used only where higher-level information is unavailable and cannot be validly extrapolated.

There is an implicit link between the level of information available for species and life stages and the extent of EFH that is likely to be designated for that species/life stage. Figure 1 illustrates the expectation that on a relative scale. If information is available at level 4, it is easier to identify a smaller portion of the overall range of a species as EFH, than if we are relying on less precise or proxy information at lower levels. For example, an identification of EFH based on areas where production rates are highest is likely to result in a smaller area than one based on basic distribution data, because production rates are unlikely to be at their highest level throughout the species range. Rather, they will be highest where habitat conditions are optimal for the species and life stage in question.

Figure 1 is, however, an oversimplification. It is not always the case, for example, that the EFH identified based on the higher level of information will be entirely within the area identified based on the lower level. As indicated above in the discussion of source-sink dynamics, EFH identified on the basis of areas of highest density (Level 2) might not necessarily encompass the areas of highest productivity for some life stages. It does demonstrate, however, that if we are relying on information at lower levels, it is important to use that information in such a way that it does provide sufficient contrast to offer a range of alternatives for identifying as EFH those that are believed to be the most important parts of the range of each species and life stage in the FMP. Although identifying a large area as EFH would seem to be the most risk averse approach, it is not sufficient to do this without adequate justification. As mentioned previously, the EFH Final Rule (600.815(a)(1)(iv)(A)) requires that FMPs explain how EFH for a species is distinguished from all habitats potentially used by that species, in order to improve understanding of the basis for the designations.

If only Level 1 information is available, distribution data should be evaluated (e.g., using a frequency of occurrence or other appropriate analysis) to identify EFH as those habitat areas most commonly used by the species. FMPs should explain the analyses conducted to distinguish EFH from all habitats potentially used by a species. Such analyses should be based on geo-referenced data that show some areas as more important than other areas, to justify distinguishing habitat and to allow for mapping. The data must at least show differences in habitat use or in habitat quality that can be linked to habitat use.

If no information for a species/life stage is available at the lowest level (distribution) and it is not possible to infer distribution from other species or life stages, then EFH cannot be identified for that species designated (600.815(a)(1)(iii)(B)).

3.3 Available Information for Identifying EFH

There are two main categories of available information to describe and identify EFH:

- Empirical geo-referenced data on species distributions, densities, and/or productivity rates derived from analyses of surveys and commercial catches. These data are essentially independent of the underlying habitat.

- Information about associations and functional relationships between species/life stages and habitat that can be used to make inferences about species distributions, density and/or productivity rates, based on the distribution of habitat.

Information at all four levels of detail described in the EFH Final Rule may exist in both of these categories. Examples of such are provided in Table 5. Only the shaded cells of Table 5 contain information that is currently available for identifying EFH under the Groundfish FMP. Virtually no information exists at Levels 3 and 4 and none of the information that does exist at these levels could be used to distinguish between different areas of habitat with sufficient contrast to indicate that one should be identified as EFH and another should not.

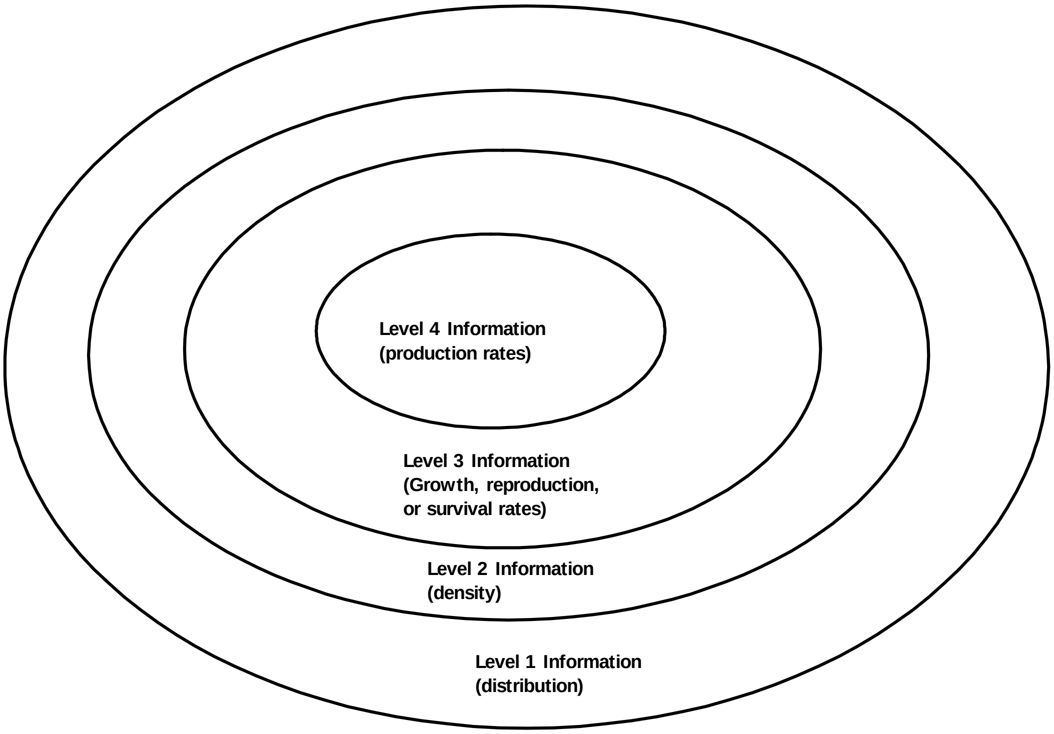

Figure 1. Diagrammatic representation of the effect of levels of information and the relative extent of the area of EFH likely to be identified for an individual species/life stage (not to scale).

Table 5. Types of information that could be used at the four levels of detail described in the EFH Final Rule (only the shaded cells contain information that is currently available for identifying EFH).

	Empirical Geo-referenced Information	Species-Habitat Relationship Modeling
Level 4: production rates by habitat	*In situ* physiological experiments and mortality experiments	Life history-based meta-population models
Level 3: growth, reproduction, or survival rates within habitats	Tagging data (growth); Fecundity data by area	Spatially discreet stock/recruitment relationships; Bio-energetics models
Level 2: habitat-related densities of the species	Survey/fishery related CPUE as proxy for density	Spatial modeling of habitat suitability probability, based on cpue (proxy for density)
Level 1: distribution data	Trawl survey data and the NOAA Atlas (Sections 2.2.1 and 2.2.2)	Habitat-species associations (Section 2.2.3); Spatial modeling of habitat suitability probability, based on presence/absence

3.4 The EFH Model

3.4.1 Introduction

Robust methods need to be devised for identifying EFH in a climate of uncertainty. In this study, the project team developed a modeling approach (called the EFH Model) for assessing the likely importance of habitats for each species and life stage in the FMP, to the extent that data are available to do so. This is done by evaluating the probability that particular habitats are suitable for particular species and life stages, based on available data sources; the NMFS groundfish surveys (Section 2.3.4.2) for as many species and life stages as possible, and information on habitat associations from the habitat use database (Section 2.3.4.2) for other species and life stages. The model provides a scientific method for assessing Pacific Coast groundfish habitat and identifying EFH.

A Bayesian Belief Network (BBN), a particular type of network model, was chosen as a suitable analytical tool for developing the EFH Model.

The EFH model takes information about the preferences of species/life stages for certain habitat conditions, and uses this to plot habitat suitability probabilities across the habitat parcels mapped in the GIS. Three habitat attributes or parameters are used to describe habitat conditions: depth, latitude, and benthic substrate (from the GIS). Taken together, these three parameters are considered to provide a reasonable basis for predicting the HSP for all species and life stages in the groundfish FMP.

Of the various types of data that can be used for identifying EFH, the approach adopted in the EFH Model falls under the heading of spatial modeling of HSP (Levels 1 and 2 under species-habitat relationship modeling in Table 5). The model has been designed to take advantage of the GIS data and available information on species distribution and habitat preferences. It was recognized at the outset that this assessment was occurring in a data-poor environment and therefore output had to be expressed in terms of probabilities rather than absolute numbers.

3.4.2 Calculating HSP

The EFH Model requires suitability indices for depth, latitude, and habitat type, taking into account any interactions that might exist between them (for example, a species' preferred depth range may vary with latitude).

HSP is a measure of the likelihood that a habitat with given characteristics is suitable for a given fish species/life stage or species/lifestage assemblage. It represents the quantitative link between habitat characteristics (habitat type, depth, and latitude) and the probability of occurrence of species in the FMP.

The overall HSP is calculated from separate probabilities for each habitat characteristic, which can be derived from various sources. To date, most approaches have been based on linear regression modeling of abundance data (Brown, *et al.* 2000; Christensen, *et al.* 1997; Clark, *et al.* 1999; Rubec, *et al.* 1999; Rubec, *et al.* 1998). However, the association between fish abundance and quantitative habitat characteristics is typically non-linear, and possibly quite complex.

National Ocean Service (NOS) scientists have developed draft habitat suitability models for 18 fishes and one invertebrate for the biogeographic assessment of the three central California marine sanctuaries. Bathymetry (meters) and bottom substrate were used as the habitat parameters to examine habitat quality for benthic species. Mean sea surface temperature and bathymetry were used to model pelagic species. At the February 2004 meeting of the Ad Hoc Groundfish Habitat Technical Review Committee (GHTRC), the possibility of using the NOS HSI data directly in the BBN model was discussed. Although these data do provide a useful guide for the BBN model, substantial additional work has been needed to develop a complete model of EFH for the FMP. The NOS HSI data cover only a few of the species in the FMP and the study was for a limited geographic area, and hence does not include the effect of latitude. Some concerns have also been expressed regarding the methodology used in the NOS model. The models of the relationships between abundance and habitat characteristics are somewhat rudimentary (e.g., a polynomial regression curve fit of mean log abundance [survey data] by categorical bathymetric class) and not always well represented by the data. Also, the combined HSI values are calculated using the geometric mean, which gives potentially unintended results when one of the individual indices is very low.

In recent years, there has been increasing interest in generalized additive models (GAMs) (Hastie and Tibshirani 1990) which have been particularly useful in modeling fish abundance and related parameters (Augustin, *et al.* 1998; Borchers, *et al.* 1997a; Borchers, *et al.* 1997b; Swartzman, *et al.* 1992). The basic idea of a GAM is to fit a regression model in which the explanatory variables are modeled by smooth curves; the fitting algorithm actually estimates the functional form (shape) of these curves.

The NMFS surveys provide a valuable source of data on the occurrence and density (measured as catch per area swept by the net) of fish at sampled locations (stations). The survey data routinely record depth and latitude at sampling stations, but not substrate. Hence they cannot be used directly to describe the effect of all three habitat characteristics of interest in the BBN model. A way around this problem would be to use the GIS to overlay the survey stations on the bottom substrate layer and thereby allocate a substrate type to each sample station. This would enable substrate type to be used as a third explanatory variable alongside latitude and depth in a GAM. However, there are several potential problems with this approach that would take some time to resolve. Some of these problems are:

- individual tows cover an area large enough to have a variety of different substrate characteristics;
- the survey records the location of the vessel, not the trawl, and the variability in towing conditions makes it very difficult to estimate the actual position of the net on the bottom; and

- the location of sampling stations is not random with respect to substrate because the trawl cannot operate over some substrates (e.g., rocky terrains).

It was therefore decided to use the survey data to develop a model incorporating depth and latitude only and to add in the effect of substrate separately within the network model, based on information recorded in the habitat use database, and other expert opinion (see below). The basic relationships in the EFH Model are shown, in a slightly simplified form, in Figure 2.

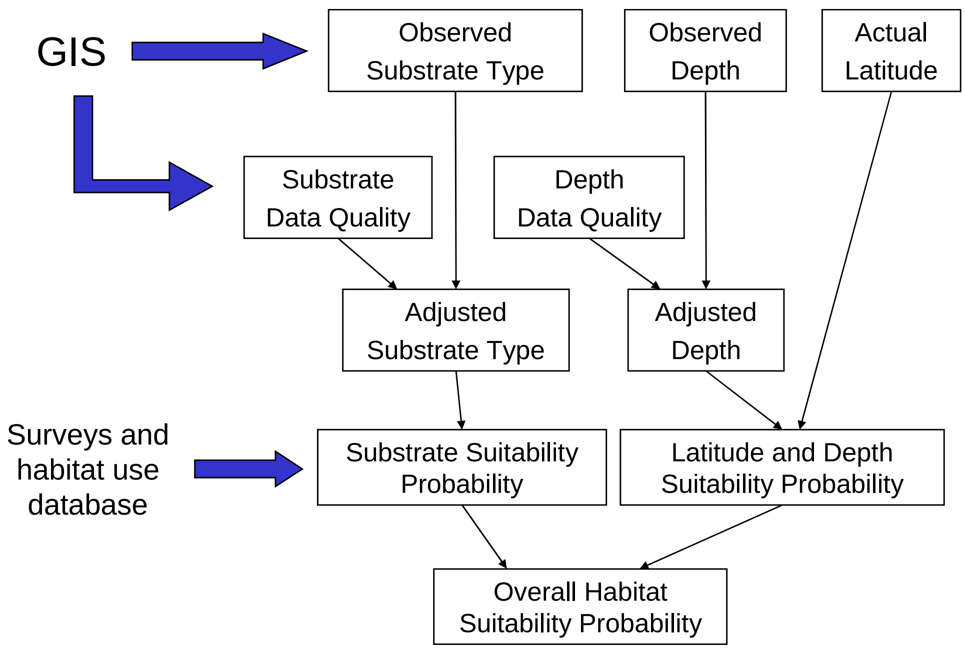

Figure 2. Simplified relationships in the BBN model to identify EFH.

3.4.2.1 Depth and Latitude

NMFS Survey Data

An extensive exploratory data analysis was undertaken to investigate the best approach to analyzing the NMFS survey data for the purpose of identifying EFH through the BBN model. Initial runs involved using GAMs to model the effects of depth and latitude on relative abundance (CPUE)[2]; however, a number of problems were encountered. The first few species analyzed revealed a problem with over dispersion in the CPUE data, which are often characterized by a large number of zero values and a very few large values. As described in Section 3.1.2, population density may in fact be a poor proxy for growth potential. Rather than pursue the analysis of the CPUE data, it was therefore decided to model the effects of habitat on the presence/absence of fish species in the FMP. In addition to avoiding the problems of over-dispersion in CPUE data that were present for some species, this approach was preferred because fitted values are directly interpretable as probabilities that the habitat is suitable for the fish (based on the likelihood that the fish are present), and hence directly applicable to the identification of EFH.

[2] There was also an expectation that there would be an interaction between the effects of depth and latitude, which was also investigated.

Following discussion with the Council's SSC, it was noted that 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. There are limitations in using presence/absence information to infer the locations of EFH habit. For example, a species may have a broad depth or geographic distribution, but may only reach high densities in a limited area. The project team agreed, but had previously concluded that the use of presence-absence from a large number of surveys would provide the most robust result at this stage, even though technically it means that the model essentially discarded Level 2 data in favor of Level 1 data. While noting also that the analysis of depth and latitude ranges is only part of the input into the EFH model (it uses information on substrate preference also), EFH designations resulting from this analysis can be considered to be reasonable approximations that will need to be refined as additional information becomes available and more sophisticated analyses become possible.[3]

Preliminary results using GLMs to model presence/absence resulted in an over-smoothing of the data, giving insufficient contrast in the probability profiles. It was therefore decided to use GAMs rather than GLMs due to the GAMs greater smoothing flexibility. A GAM incorporating a cubic smoother with six degrees of freedom was found to smooth the data most adequately.[4]

The response was modeled as a Binomial variable (0 = non-present and 1 = present) and the data were fitted by a GAM with a logit link function (See Appendix 18 for details of the development of the modeling approach):

$$P_{(\Pr esent))} = \begin{cases} 0 & ;\text{no fish are present in haul} \\ 1 & ;\text{one or more fish are present in haul} \end{cases}$$

In addition to describing the exploratory data analyses, Appendix 18 to the original Risk Assessment description (MRAG Americas Inc., *et al.* 2004, from which this document is adapted) provides a report on the GAM analysis conducted for the 20 species that were completely covered by the survey data A further 40 species required additional expert opinion to complete their profiles, because the surveys did not sample in the 0-30 meters depth range. Spreadsheets for these species were developed and sent out to experts requesting them to provide data independently for the 0-50 meters depth interval. The columns for 40 and 30 meters were compared to the output from the model and the data in the 20, 10, and 0 columns were incorporated in the partially completed profiles. In the time available, this procedure was completed for a further 16 species, thereby increasing the number of completed habitat suitability profiles for adults from 20 to 36.

[3] We also note that the NMFS survey data were used for only a minority of the species and life stages mapped.

[4] These decisions regarding the modeling approach were taken by MRAG Americas in consultation with NMFS following discussions at the August 4 meeting of the TRC and subsequent discussions between MRAG Americas and NMFS.

An example of one of the spread sheets filled out by an expert, is shown below. The grayed area is that filled out by the expert.

Latitude (degrees)	Depth in 10 m intervals 70	60	50	40	30	20	10	0	
49	0.96023	0.97329	0.98212	0.98	0.98	0.7	0.3	0.1	Washington
48	0.95263	0.9681	0.97861	0.98	0.98	0.7	0.3	0.1	Washington
…	…	…	…	…	…	…	…	…	…
34	0.94459	0.96258	0.97486	0.75	0.5	0.2	0.1	0.1	So.Calif. Bight
32-33	0.75	0.75	0.5	0.5	0.2	0.2	0.1	0.1	So.Calif. Bight

The other 24 species for which only a small portion of the profile was missing could not be completed, because the experts could not provide the necessary information in the time available.

An example of the modeling output (HSP) for depth and latitude is provided in Figure 3. In all cases, the interaction terms between these two explanatory variables proved to be statistically non-significant. This analysis therefore provides values of HSP given depth and latitude. The addition of the effect of physical substrate and biogenic habitat to the model is described in the next section.

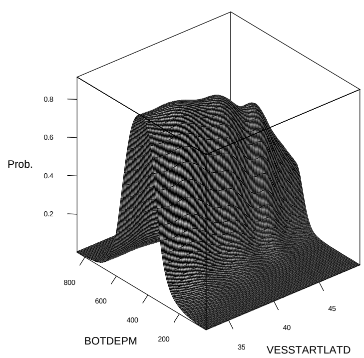

Figure 3. HSP for aurora rockfish.

Habitat Use Database (HUD)

The habitat preferences of the 82 species are broken down by four life stages: eggs, larvae, juveniles, and adults and the identification of EFH needs to account for all of these stages to the extent possible. This makes a theoretical total of 328 possible HSP profiles (82 x 4).

As described in the previous section, out of these 328 possible profiles it was only possible to produce 36 complete profiles from the NMFS trawl survey data (including those completed with additional expert opinion).[5]

[5] Note that the 36 profiles from the survey data were considered to be indicative of the HSP for only the adult life stages of the 36 species covered, because of the type of sampling gear used on the surveys. Size

The Habitat Use Database (HUD) contains absolute and preferred depth and latitude values for the four life stages of most of the species in the FMP. No data are recorded in the HUD for a total of 74 of the 328 possible species/life stage combinations. Of the 74 combinations, 56 are eggs and 17 are larvae. A further 94 combinations (mainly larvae and juveniles) have so little data in the HUD that it is not possible to develop profiles. This leaves 124 combinations for which profiles could be developed from the HUD. We therefore developed a method to convert the information on depth and latitude preferences in the HUD into HSP profiles that could be used in the EFH model.

There are up to 4 different values recorded for depth and latitude in the HUD. These are:

AbsMinDepth	Absolute minimum depth
PrefMinDepth	Preferred minimum depth
PrefMaxDepth	Preferred maximum depth
AbsMaxDepth	Absolute maximum depth
AbsMinLat	Absolute minimum latitude
PrefMinLat	Preferred minimum latitude
PrefMaxLat	Preferred maximum latitude
AbsMaxLat	Absolute maximum latitude

Assuming that the habitat will be most suitable somewhere between the preferred minimum and preferred maximum values, a fifth value, termed the optimum, was created for both depth and latitude.

For simplicity, the discussion below will examine the depth observations since the same principle will be applied to the latitude observations. The case with Pacific ocean perch (adults) is used to illustrate the approach, because it is a species for which we have both the survey data results and a full complement of data in the HUD. The optimum value in

Table 6 is calculated as:

$$Optimum_{depth} = \frac{\text{PrefMinDepth} + \text{PrefMaxDepth}}{2}$$

This results in a mean value between PrefMinDepth and PrefMaxDepth. An index value, which is a proxy for the habitat suitability probability calculated from the survey data, is then assigned to each of the five depth points. This has the value of 0.0 at AbsMinDepth and AbsMaxDepth. The optimum is given the value of 1 (the maximum possible value). It then remains to assign index values for the PrefMinDepth and PrefMaxDepth. Following discussions with the SSC's Groundfish Sub-Committee, it was decided to calculate these values from the 36 profiles completed from the survey data. We have the actual habitat suitability probability values at the PrefMinDepth and PrefMaxDepth for these species. We took the averages of these values and used those for the HUD species. These values were 0.19 at PrefMinDepth and 0.236 at PrefMaxDepth.

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composition data are available for many groundfish from the surveys and these could be used to distinguish juveniles from adults in the survey hauls, however, such a detailed analysis was outside the scope of the current study and the size composition data were not used.

Table 6. Observed values from the HUD and their assigned HSP index values for Pacific ocean perch adults.

	Abs Min Depth	Pref Min Depth	Optimum	Pref Max Depth	Abs Max Depth
Value in HUD	25	100	275	450	825
HSP index value	0.0	0.19	1	0.236	0.0

The five points (depth, HSP index) are plotted in Figure 4 with four lines drawn between them (the line labeled Habitat). Data points are extracted from these four lines and fed to a GAM that smoothes the data (the line labeled "Smooth"). The line labeled Survey in Figure 4 is the profile that was produced from the GAM analysis of the survey data and is included in the plot to compare with the results obtained from the HUD data. The depth profile in (Smooth) is then extrapolated over latitude 32° to 49° and the result is shown in Figure 5.

The same procedure is performed for the latitude data and the two profiles are then multiplied together and scaled up so the maximum HSP index value yields 1.

$$HUD_{index} = Depth_{index} \cdot Latitude_{index}$$

Note: these are not probabilities, but rather index values that are scaled up to 1 to be comparable to the probability profiles produced from the NMFS survey data. The final index profile is shown in Figure 6.

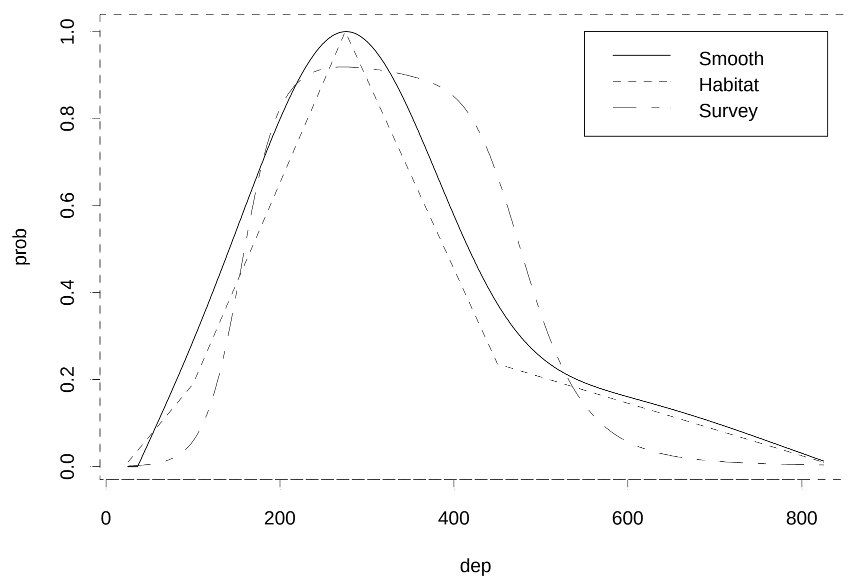

Figure 4. Comparison of probability profiles for depth based on the survey data and the HUD (smoothed and unsmoothed).

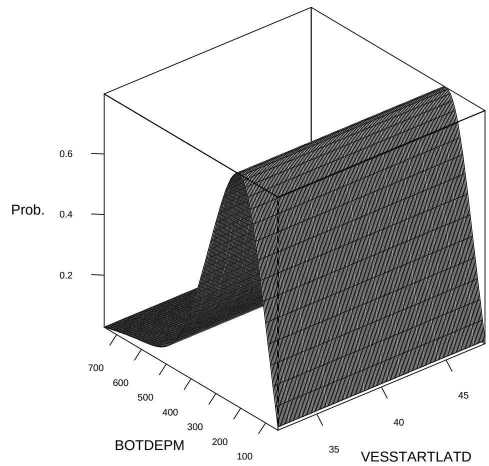

Figure 5. HUD depth profile extrapolated over the latitude interval 32-49 degrees.

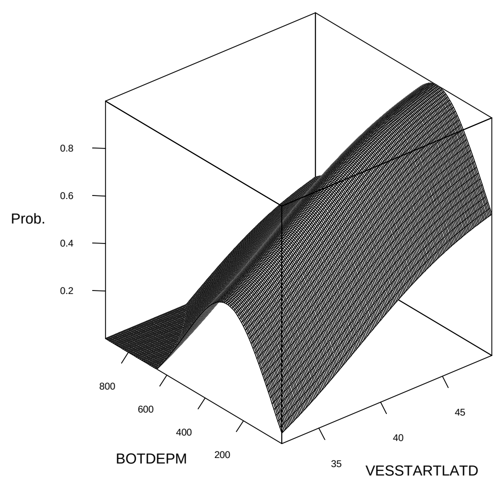

Figure 6. Index profile for adult Pacific ocean perch, based on the observations in the HUD.

Table 7 shows a summary of the outcome of the modeling of depth and latitude profiles for species and life stages in the Groundfish FMP. Of the species/life stage combinations that have latitude/depth probability profiles there are three categories. The Survey category indicates that the profile was derived solely on the basis of survey data. The Survey+ category is for species/life stages that needed expert opinion to complete their profiles but were otherwise completed using survey data. The HUD category signifies those species that could not be modeled using survey data, and had profiles developed on the basis of the information in the HUD. The distinction between these categories has important implications for the interpretation of the results and their use in identifying EFH. In particular, the depth/latitude habitat suitability profiles derived from survey data can be regarded as true probabilities, but those interpreted from the HUD data represent relative indices only. We note, however, that the calculation of the final Habitat Suitability Probabilities (HSP) includes information on substrate preferences interpreted from the HUD, and therefore it is debatable whether any of the HSPs produced can be regarded as true probabilities. This is discussed further in Section 3.5.3.

There are two categories of species/life stages that did not have profiles developed. The first ("insufficient data") contains species/life stages for which some data are available on their habitat preferences/requirements, but this was insufficient to develop a profile. The second category contains species/life stages for which we had no data at all in the HUD.

Table 7. Summary of sources of information on the species and life stages in the Groundfish FMP used for the EFH Model.

		Source of latitude and Depth Data in the EFH Model				Level of Substrate information in the HUD			
	Common Name	Adults	Juveniles	Larvae	Eggs	Adults	Juveniles	Larvae	Eggs
1	Arrowtooth flounder	Survey+	HUD	HUD	HUD	4	4	3	3
2	Aurora rockfish	Survey	HUD	Too Few Data	No Data	3	3	3	No Data
3	Bank rockfish	Survey	HUD	No Data	No Data	4	4	No Data	No Data
4	Big skate	HUD	HUD	No Data	HUD	4	3	No Data	4
5	Black rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
6	Black-and-yellow rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
7	Blackgill rockfish	Survey	HUD	HUD	No Data	4	3	3	No Data
8	Blue rockfish	HUD	HUD	HUD	No Data	4	4	3	No Data
9	Bocaccio	Survey+	HUD	HUD	No Data	4	4	4	No Data
10	Bronzespotted rockfish	HUD	HUD	No Data	No Data	4	4	No Data	No Data
11	Brown rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
12	Butter sole	HUD	Too Few Data	Too Few Data	Too Few Data	4	4	4	4
13	Cabezon	HUD	Too Few Data	Too Few Data	Too Few Data	4	4	3	4
14	Calico rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
15	California scorpionfish	HUD	Too Few Data	No Data	Too Few Data	4	4	No Data	3
16	California skate	HUD	HUD	No Data	HUD	4	3	No Data	4
17	Canary rockfish	Survey+	HUD	Too Few Data	No Data	4	4	3	No Data
18	Chilipepper	Survey+	HUD	Too Few Data	No Data	4	4	4	No Data
19	China rockfish	HUD	Too Few Data	Too Few Data	No Data	4	3	3	No Data
20	Copper rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	4	No Data
21	Cowcod	Survey	HUD	Too Few Data	No Data	4	4	3	No Data
22	Curlfin sole	Survey+	Too Few Data	Too Few Data	Too Few Data	4	4	3	3
23	Darkblotched rockfish	Survey	HUD	HUD	No Data	4	4	3	No Data
24	Dover sole	Survey+	HUD	Too Few Data	Too Few Data	4	4	3	3
25	Dusky rockfish	HUD	Too Few Data	No Data	No Data	4	4	No Data	No Data
26	English sole	Survey+	Too Few Data	Too Few Data	Too Few Data	4	4	3	3
27	Finescale codling	HUD	No Data	No Data	No Data	2	No Data	No Data	No Data
28	Flag rockfish	Survey	HUD	Too Few Data	No Data	4	4	3	No Data
29	Flathead sole	Survey+	Too Few Data	Too Few Data	Too Few Data	4	4	3	3
30	Gopher rockfish	HUD	HUD	HUD	No Data	4	4	3	No Data
31	Grass rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
32	Greenblotched rockfish	Survey	HUD	Too Few Data	No Data	4	4	3	No Data
33	Greenspotted rockfish	Survey	HUD	Too Few Data	No Data	4	4	3	No Data
34	Greenstriped rockfish	Survey	HUD	Too Few Data	No Data	4	4	3	No Data
35	Harlequin rockfish	HUD	Too Few Data	Too Few Data	No Data	4	3	3	No Data
36	Honeycomb rockfish	HUD	Too Few Data	No Data	No Data	4	4	No Data	No Data
37	Kelp greenling	HUD	HUD	HUD	HUD	4	4	3	4
38	Kelp rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	4	No Data
39	Leopard shark	HUD	HUD	No Data	No Data	4	2	No Data	No Data
40	Lingcod	Survey+	HUD	HUD	HUD	4	4	3	4

Table 7 Cont.

		Source of latitude and Depth Data in the EFH Model				Level of Substrate information in the HUD			
	Common Name	Adults	Juveniles	Larvae	Eggs	Adults	Juveniles	Larvae	Eggs
41	Longnose skate	HUD	HUD	No Data	HUD	3	3	No Data	2
42	Longspine thornyhead	HUD	HUD	Too Few Data	Too Few Data	4	4	3	4
43	Mexican rockfish	HUD	HUD	HUD	No Data	4	3	3	No Data
44	Olive rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
45	Pacific cod	Survey+	HUD	HUD	HUD	4	4	3	4
46	Pacific hake	HUD	HUD	HUD	HUD	3	3	4	3
47	Pacific ocean perch	Survey	HUD	HUD	No Data	4	3	3	No Data
48	Pacific rattail (grenadier)	HUD	Too Few Data	HUD	HUD	4	4	3	3
49	Pacific sanddab	Survey+	Too Few Data	Too Few Data	Too Few Data	4	4	3	3
50	Petrale sole	Survey+	HUD	Too Few Data	Too Few Data	4	4	3	3
51	Pink rockfish	HUD	Too Few Data	No Data	No Data	4	3	No Data	No Data
52	Quillback rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
53	Redbanded rockfish	Survey	Too Few Data	No Data	No Data	4	3	No Data	No Data
54	Redstripe rockfish	Survey	Too Few Data	Too Few Data	No Data	4	4	3	No Data
55	Rex sole	Survey+	Too Few Data	Too Few Data	Too Few Data	4	4	3	3
56	Rock sole	HUD	Too Few Data	Too Few Data	Too Few Data	4	4	3	4
57	Rosethorn rockfish	Survey	Too Few Data	Too Few Data	No Data	4	3	3	No Data
58	Rosy rockfish	HUD	HUD	No Data	No Data	4	4	No Data	No Data
59	Rougheye rockfish	Survey	HUD	No Data	No Data	4	4	No Data	No Data
60	Sablefish	HUD	HUD	HUD	HUD	4	4	4	3
61	Sand sole	HUD	HUD	Too Few Data	Too Few Data	4	4	3	3
62	Sharpchin rockfish	Survey	HUD	HUD	No Data	4	4	3	No Data
63	Shortbelly rockfish	Survey+	Too Few Data	Too Few Data	No Data	4	4	3	No Data
64	Shortraker rockfish	Survey	Too Few Data	Too Few Data	No Data	4	2	3	No Data
65	Shortspine thornyhead	HUD	HUD	Too Few Data	HUD	4	4	4	4
66	Silvergray rockfish	Survey	Too Few Data	Too Few Data	No Data	3	4	3	No Data
67	Soupfin shark	HUD	HUD	No Data	No Data	4	4	No Data	No Data
68	Speckled rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
69	Spiny dogfish	HUD	HUD	No Data	No Data	4	4	No Data	No Data
70	Splitnose rockfish	Survey	HUD	HUD	No Data	4	4	3	No Data
71	Spotted ratfish	HUD	HUD	No Data	HUD	4	4	No Data	4
72	Squarespot rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
73	Starry flounder	HUD	Too Few Data	Too Few Data	HUD	4	4	3	4
74	Starry rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
75	Stripetail rockfish	Survey+	HUD	Too Few Data	No Data	4	4	3	No Data
76	Tiger rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
77	Treefish	HUD	Too Few Data	Too Few Data	No Data	4	4	3	No Data
78	Vermilion rockfish	HUD	Too Few Data	Too Few Data	No Data	4	4	4	No Data
79	Widow rockfish	Survey	Too Few Data	Too Few Data	No Data	4	4	3	No Data
80	Yelloweye rockfish	HUD	HUD	Too Few Data	No Data	4	4	3	No Data
81	Yellowmouth rockfish	Survey	HUD	Too Few Data	No Data	3	3	3	No Data
82	Yellowtail rockfish	Survey+	HUD	Too Few Data	No Data	4	4	3	No Data

For the latitude/depth profiles, 20 came from the surveys (Surveys), 16 from the surveys with expert opinion to fill in the gaps (Survey+), 124 came from the HUD, 94 had too few data in the HUD, and 74 had no data at all. The values in the substrate columns indicate the maximum level of habitat classification in the HUD in each case (Level 4 being the highest, see Table 8): 162 were classified to Level 4, 88 to Level 3 and 4 to Level 2. No data on substrate associations were available for 74 species/life stage combinations. (Note that species are classified in the HUD as being associated with the water column, where appropriate.)

3.4.2.2 Benthic Substrate

Extracting Information from the HUD

The HUD (Section 2.3.4.2.) contains data on the types of substrates used by species in the FMP. This strength of the link between species/life stages and the each substrate with which it is known to associate is measured in terms of a four-point scale: unknown, weak, medium, and strong. In order to incorporate information about substrate preferences into the BBN model, the four point scale was translated into habitat suitability probabilities as follows: unknown = 0.33[6], weak = 0.33, medium = 0.66, and strong = 1. These probabilities differ from the probabilities derived from the surveys in that they are subjective and not based directly on actual observational data. They are, however, based on the best scientific evidence available in the literature and currently represent the best available data for including substrate in the BBN model. As part of the future analysis, the sensitivity of the output to the assumed probability levels should be investigated, along with the possibility of including a measure of uncertainty into the model. This could be achieved, for example, by expressing the probabilities as ranges or distributions rather than fixed points.

The substrate classification system in the HUD is on four levels, based on the Our Living Oceans (OLO) habitat classification and is shown in Table 8. However, substrate is not classified to the fourth level in all cases (see Table 7). For some species and life stages, the level of information only allows us to make a link to a substrate at a higher level of classification. Nevertheless, this represents the best information available and all such links between species and substrates were used in the EFH model.

Reconciling the Substrate Classifications in the HUD and the GIS

The substrate classification system in the HUD is similar to the system used in the GIS, which was devised by Gary Greene (Moss Landing Marine Lab) and is described in Appendix 3. However, there were some differences that required reconciling so that the output from the EFH Model could be plotted directly in the GIS. We therefore devised a system of correspondence between the two systems, as described below.

[6] Where the habitat association was recorded as "unknown" in the HUD we assumed that the habitat suitability should be at the same level as if it had been recorded as "weak". This is because there must have been some level of association recorded for the information to be entered into the database, even if the strength of the association is unknown. An alternative approach that was considered was to give these records a score of zero, but this would have eliminated them from the analysis, thereby giving these habitat types no chance of being identified as EFH for these species and life stages.

Table 8. Four-level classification of substrate types (geological and biogenic) in the habitat use database, based on the OLO classification system.

Level 1	Level 2	Level 3
Abyssal Plain	Basin	Abyssopelagic Zone
Coastal Intertidal	Benthos	Artificial Structure
Estuarine	Ice	Bathypelagic Zone
Island Shelf	Intertidal Benthos	Biogenic
Shelf	Seamount	Biogenic Reef
Slope/Rise	Submarine Canyon	Epipelagic Zone
Slope/Rise/Plain	Subtidal Benthos	Fast Ice
Unknown	Unknown	Hard Bottom
	Water Column	Mesopelagic Zone
		Mixed Bottom
		Pack Ice
		Tide Pool
		Unconsolidated
		Unknown
		Vegetated Bottom

Level 4		
Algal Beds/Macro	Gyre	Sea Anemones
Algal Beds/Micro	Macrophyte Canopy	Sea Lilies
Artificial Reef	Marine Moss	Sea Urchins
Basketstars	Mixed Mud/Sand	Sea Whips
Bedrock	Mollusk Reef	Seasonal Fast Ice
Boulder	Mud	Seasonal Pack Ice
Brittlestars	Mud/Boulders	Seawater Surface
Clay	Mud/Cobble	Silt
Cobble	Mud/gravel	Silt/Sand
Coral Reef/Barrier Reef	Mud/Rock	Soft Bottom/Boulder
Coral Reef/Fringe Reef	Oil/Gas Platform	Soft Bottom/Rock
Coral Reef/Patch Reef	Permanent Fast Ice	Sponges
Current System	Permanent Pack Ice	Tube Worms
Demosponges	Piers	Unknown
Drift Algae	Rooted Vascular	Upwelling Zone
Emergent Wetlands	Sand	Vase Sponges
Fronts	Sand/Boulders	Worm Reef
Gooseneck Barnacles	Sand/Cobble	
Gravel	Sand/Gravel	
Gravel/Cobble	Sand/Gravel/Cobble	
Gravel/Rock	Sand/Mud/Rock	
	Sand/Rock	

The habitat codes in the GIS data comprise four levels as shown below: Mega Habitat, Habitat Induration, Meso/Macro Habitat, and Modifier. These are copied here for ease of reference:

Mega habitat:

A	Continental Rise
B	Basin
F	Slope
R	Ridge
S	Shelf

Induration:

h	Hard
s	Soft

Meso/Macro habitat :

c	Canyon
e	Exposure
c/f	Canyon floor
g	Gully
g/f	Gully floor
i	Iceformed
l	Landslide
(blank)	Sedimentary

Modifier:

u	Unconsolidated
b/p	Bimodal
o	Outwash

The last level (Modifier) is largely redundant and does not add very much to the information, since each combination of the other three fields only has at most one value of the Modifier field. The HUD uses four levels (see above), but Level 4 represents more detail than is really needed for mapping the GIS habitats. Only some of the categories in Levels 1 to 3 relate directly to the GIS classification. In the following mapping scheme, the letters refer to the habitat description used in the GIS classification.

F (Slope) should be mapped to Slope/Rise, and S (Shelf) to Shelf. Also B (Basin) maps to Slope/Rise, Basin. Mapping A (Continental Rise) and R (Ridge) is less straightforward—should they both be Slope/Rise, or does A correspond to Abyssal Plain?

h (Hard) maps to Hard Bottom and s (Soft) to Unconsolidated, but Mixed Bottom in the HUD is not specified in the GIS data. In almost all cases where it occurs in the database there are also values for either Hard or Unconsolidated. In these cases it can perhaps be ignored, given that it cannot be mapped directly. However, it could be represented as a level of uncertainty in the BBN model, since there is a non-zero probability that the fish in question will be associated with both hard and soft bottoms. In cases where it occurs without a value for either hard or unconsolidated both s and h in the GIS data were given the value for Mixed Bottom.

Both c (Canyon) and c/f (Canyon Floor) map to Submarine Canyon in the HUD. The other Meso/Macro Habitat values have no obvious corresponding values in the habitat use database, but can be treated as

Benthos. The habitat use database does not have any Basin or Canyon data, so it is unclear whether to put this with Basin or Slope Canyon.

The correspondence used between the two databases is as follows:

Habitat Use Database	GIS Habitat Codes
Shelf, Benthos, Hard	She, Shi_b/p
Shelf, Benthos, Soft	Ss_u, Ssg, Ssg/f, Ssi_o
Shelf, Canyon, Hard	Shc
Shelf, Canyon, Soft	Ssc_u, Ssc/f_u
Slope, Benthos, Hard	Fhe, Fhg, Fhl, (Rhe, Ahe)
Slope, Benthos, Soft	Fs_u, Fsg, Fsg/f, Fsl, (Rs_u, As_u, Asg, Asl)
Slope, Canyon, Hard	Fhc, Fhc/f, (Ahc)
Slope, Canyon, Soft	Fsc_u, Fsc/f_u, (Asc/f, Asc_u)
Slope, Basin, Hard	Bhe
Slope, Basin, Soft	Bs_u, Bsg, Bsg/f_u, (Bsc/f, Bsc_u)

Codes in parentheses are considered to be hard to correspond between the two databases.

Some Level 2 and 3 habitats in the HUD are given as Unknown. The Level 2 unknowns all have a probability of 0, so they can safely be ignored. The Level 3 unknowns apply to only a few species, and in most cases the type of substrate can be inferred from other habitats or the NMFS Life Histories Appendix as follows:

Species	Habitat
Galeorhinus	Probably Soft
Antimora	No information
Coryphaenoides	Soft
Sebastolobus	Soft
Sebastes helvomaculatus	Hard
S. diploproa	Soft/ Mixed?
S. ruberrimus	Unclear – probably Hard/Mixed
S. reedi	Hard

As noted in Section 2.2.4, there are several species/life stages in the Groundfish FMP that have no association with a benthic substrate type, but instead occur in the water column. There are values for minimum and maximum latitude recorded in the HUD for these species/life stages to the extent that these are known. For some there are also minimum and maximum depths recorded. These depth ranges are intended to indicate geographic distribution rather than position in the water column (Bruce McCain, pers. comm.). It is therefore possible to model habitat suitability for these cases using the methodology described in Section 3.4.2.1. There is, however, no substrate component, and at present, no other way of further refining the probability profile, beyond what is provided by the depth and latitude ranges. This results in habitat suitability profiles that contain much less contrast and also cover wider areas than for the species and life stages that are associated with benthic substrates.

3.4.3 The Bayesian Network for the EFH Model (Version 1)

Figure 7 shows the EFH Model use to calculate HSP for a GIS polygon with observed values of substrate type, depth, and latitude.

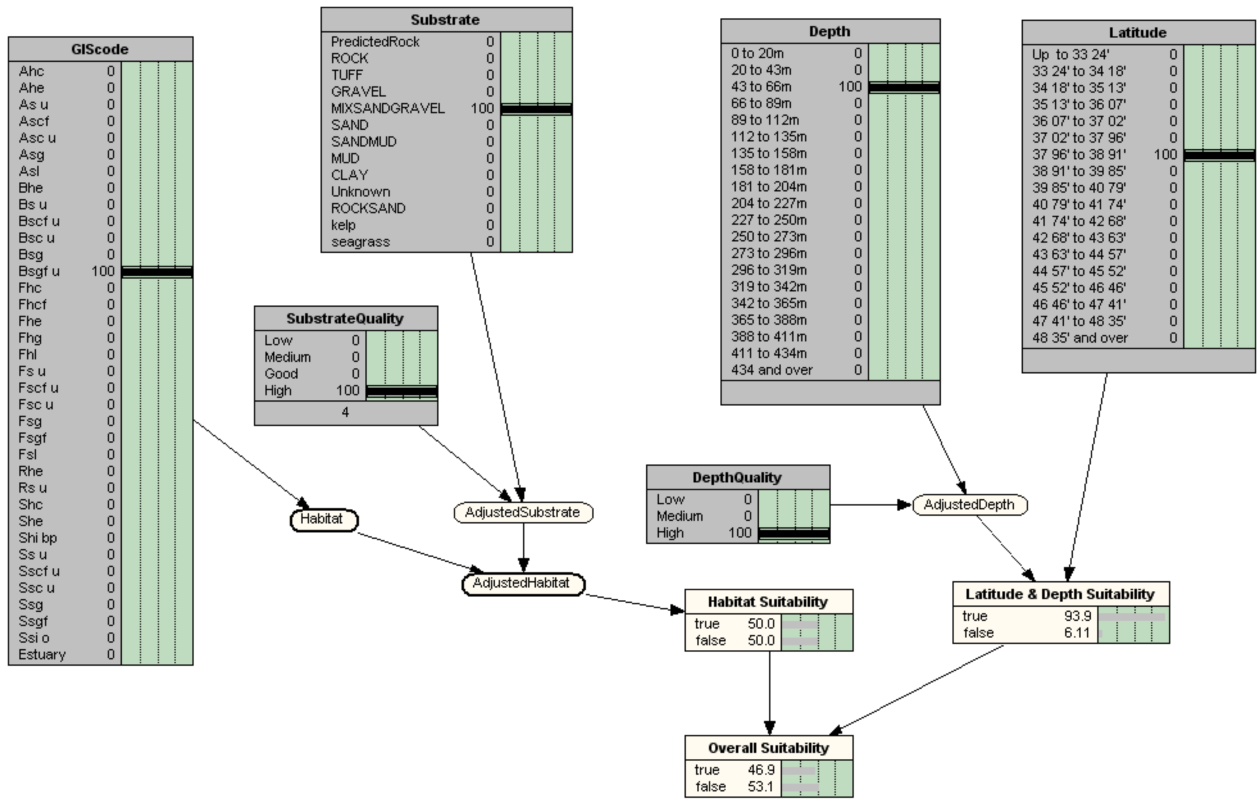

Figure 7. The EFH Model showing substrate, depth, latitude, and data quality nodes

For the given GIS polygon, the habitat code, substrate, depth, and latitude are entered into the appropriate nodes in the BBN. The model includes the facility for allowing measures of uncertainty in habitat characteristics, as described in Section 2.2.5, to be included explicitly. Uncertainty in the substrate classification is accommodated by means of the *SubstrateQuality* node which represents the quality of the substrate data (low/medium/good/high). This assigns a probability distribution (elicited from expert judgments) of possible true substrates, given an observed substrate. The resulting substrate type is in the *AdjustedSubstrate* node in the BBN. There is a similar facility that allows for uncertainty in depth observations. However, neither of these facilities is effectively activated in Version 1 of the model, because it has not been possible yet to fully develop the data quality metrics, nor test their effects on the model outputs. This is achieved by permanently setting the substrate and depth data quality indicators to “High”, which leaves the data in the *AdjustedSubstrate* and *AdjustedDepth* nodes the same as those in the *Substrate* and *Depth* nodes respectively.

The Substrate Suitability node calculates the Habitat Suitability Probability (HSP) corresponding to the Adjusted Substrate. The node uses suitability probabilities obtained from the HUD (see Section 3.4.2). Similarly, the Latitude & Depth Suitability node uses the combined HSP value estimated by GAM modeling.

Finally, the Overall Suitability node calculates the estimated joint HSP value of the polygon by multiplying the Substrate and Latitude/Depth HSPs, thus:

$$HSP(overall) = HSP(substrate) \times HSP(depth, latitude)$$

This specification of the model treats depth/latitude and substrate as independent factors in determining the overall habitat suitability probability. This assumes that there is no interaction between them. A later version of the model could investigate the validity of this assumption.

HSP values are calculated for a given species/life stage for all the habitat polygons in the GIS, which are uniquely identified by their substrate type, depth range (every 10 m), and latitude range (every 10 minutes).

A computer program written for the project reads the polygon data from a GIS based data file, passes them efficiently to the model, which calculates the HSP values, and writes these values back to the GIS data file. These HSP values are then plotted for the entire coast in the form of a contour plot. Ways of identifying EFH from these plots and data are discussed in the next section.

3.5 EFH Model Output

3.5.1 Database and Maps of Habitat Suitability

The primary output of the EFH Model is in the form of a database of HSP values by species and life stage for every benthic habitat polygon in the GIS. A total of 160 species/life stage combinations have been analyzed to date out of a possible total of 328. The remaining 168 species/life stages have not been completed due to insufficient data. All of the adult and most of the juvenile stages have been covered either by the survey data or by the information in the HUD. Of those remaining, 69 cases are eggs (84% of species), 66 are larvae (80% of species) and 33 are juveniles (40 % of species). Of these, 94 have some data available, but not enough to develop HSP profiles. There are no data at all for 68% (56 species) of egg stages. Seventeen species have no data available for their larval stages. It is therefore mainly eggs and larvae for which information is lacking on habitat associations.

The HSP data are presented in contour plots produces by the GIS (included in Appendix B to the FMP).

3.5.2 Validation of Model Results

The HSP profiles from the EFH Model incorporate relatively new data sets and modeling techniques that have been developed specifically for this project. The results obtained to date from the EFH Model have already raised some concerns, particularly over the effect of bias in the survey data arising from the non-random coverage of substrates. Essentially the trawl is limited in its capability to sample on very rocky substrates. Species that specifically associate with such substrates will therefore not be well sampled, and may be under-represented in the survey data that are used to model the effects of latitude and depth.

As time goes by, the model and its outputs will benefit from additional focused interaction with subject-matter experts for validation of the results. Validation, for purposes of this project, has been limited primarily to a qualitative review of the data sets and mapped output to identify results that are counter to the experience or expectations of the reviewers.

3.5.3 Using the EFH Model Output to Identify EFH

The final result of the EFH analysis is maps by life history stage for each groundfish species that show on a qualitative scale the importance of different habitat to that species. There are various ways in which these maps can be used to identify EFH in a more or less inclusive way. In the Groundfish FMP, groundfish EFH is identified in a precautionary way to include all areas of known occurrence of groundfish species. This area includes all of the areas identified by the EFH model output as having a suitability value greater than zero.

Model output—the species/life stage HSP maps—could be used to evaluate the effects future management decisions on groundfish EFH and in consultations on nonfishing impacts to EFH. These outputs allow some additional discrimination as to the relative value of different areas as groundfish habitat. In using the maps, however, it is important to remember that, while they look similar in terms of a product of the analysis, the type, accuracy, and precision of the information that has gone into each is highly variable. They should not, therefore, be treated all with the same level of confidence.

Table 7 is a very important table in that it provides a summary of the levels of information that have gone into the estimation of HSPs for each species and life stage. In the case of depth and latitude, the GAM models that used survey data estimated true probabilities of the survey encountering species across the area they covered. However, the profiles based on the HUD data are based on far fewer data that can be regarded to give a relative scale of likelihood at best. One important product of this difference is that the depth and latitude profiles derived from the HUD were scaled to have a maximum value of one, while profiles from the survey data can have a maximum value considerably less than one, particularly for rare species where the probability of occurrence in the survey catches is low everywhere.

In the case of the substrate component of the model, data inputs were derived entirely from the HUD and therefore cannot be regarded as true probabilities. The combination of these data with the depth and latitude data in the EFH Model means that the HSP profiles, whether or not the depth and latitude data were derived from the survey or the HUD, cannot be regarded as true probabilities. The data are on different scales, depending on where the input data came from.

It is important to remember when using the model outputs that a method that is considered to be appropriate for one species/life stage may not necessarily be appropriate for others. Having said that, it is possible to derive model output for groups of species and life stages, which could make the results easier to use than if each species/life stage is considered individually. Such groupings should take into account both the variable data inputs, and hence variable levels of uncertainty in the outputs. Other considerations used for groupings could be the status of the stocks (e.g., depleted, overfished, experiencing overfishing, etc.), species guilds, or species complexes used for management.

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6.0 LIST OF APPENDICES TO THE RISK ASSESSMENT

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