Exhibit C.6.b
Attachment 1
April 2004

Pacific Coast Groundfish EFH

Identification of Essential Fish Habitat for the Pacific Groundfish FMP

Prepared for

Pacific States Marine Fisheries Commission

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1 INTRODUCTION

1.1 The purpose of this document

NOAA Fisheries is developing an Environmental Impact Statement (EIS) that responds to a court directive and settlement agreement to complete new NEPA analyses for Amendment 11 to the Pacific Coast Groundfish FMP.A decision-making process for the EIS has been designed for policy to flow from assessment. A rigorous assessment of groundfish habitat on the west coast has been undertaken to set the stage for policy development. The EIS and the Council process will be the vehicles for developing policy in response to the assessment. This careful division of the scientific assessment from policy is pictured in the draft Decision-making Framework for the Pacific Coast Groundfish Essential Fish Habitat Environmental Impact Statement (Figure 1).

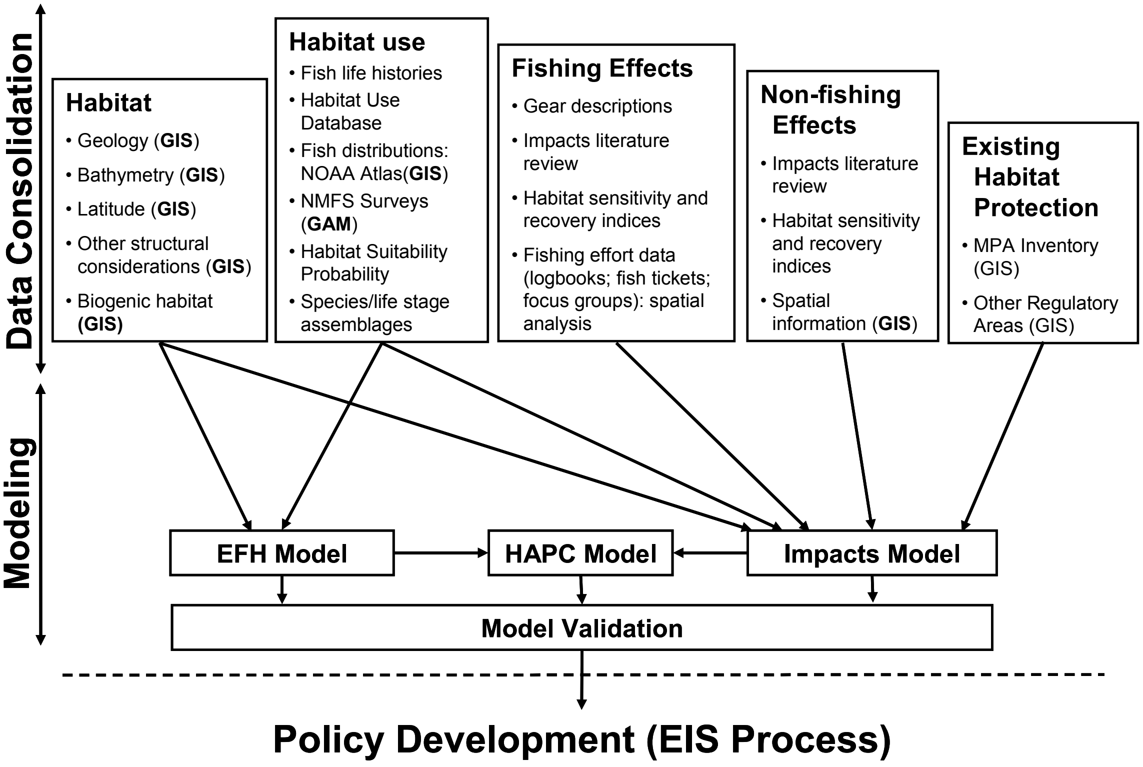

Figure 1 Draft framework for the assessment stage of the Pacific Coast Groundfish EFH EIS showing data inputs and separation of the assessment and policy components

Three models are depicted in Figure 1: EFH, HAPC and Impacts. Together these represent the analytical framework that is being developed to support preparation of the EIS and more specifically the development of Alternatives by the Council and NMFS. While these components are clearly integrated, it is possible, and perhaps desirable to address them initially one at a time, due to the complex and wide ranging scope of the issues they address. The first step in the process is the identification and description of EFH. This document therefore provides the details of the analysis of information on habitat and the use of habitat by groundfish that will lead to the development of alternatives for EFH for the Groundfish FMP.

The construction and implementation of the impacts model that will support the development of alternatives to prevent, mitigate, or minimize the adverse effects of fishing and fishing gear on EFH, to the extent practicable, will be presented separately as part of the full Analytical Framework.

The assessment has been proceeding along three major tracks: data consolidation, proof of concept, and full implementation. The results of the data consolidation phase for the EFH model are discussed in Chapter 2. Proof of concept ended in February 2003 with the endorsement of the preliminary assessment methodology. Full implementation of the EFH model is described in Chapters 3 and 4.

2 MAJOR DATA SOURCES

To consolidate the available data for describing and identifying EFH, NOAA Fisheries in cooperation with the Pacific States Marine Fisheries Commission (PSMFC) initiated a multi-faceted project that included:

1. Development of a GIS database that displays habitat types in comparison with known groundfish distribution/abundance and fishing effort;
2. Conduct of a literature review and development of a database on groundfish habitat associations;

Sections 2.1 and 2.2 describe the major attributes of the GIS and other databases that have been compiled for the EFH component of the overall project. These sections are organized in the same groups as shown in Figure 1 (the decisionmaking framework):

- West Coast fish habitat
- Use of habitat by groundfish

Preceding this, the following section provides some additional detail regarding the complexity of the data consolidation task with specifically respect to the development of the GIS.

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. Upon completion, this GIS is designed to seamlessly interact with the Bayesian Belief Network model (Section 3.3) and will be 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 a 822,000 square km 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, it is important to note the data incorporated does not always represent the best data, but the best data available to the project in the timeframe dictated.

- 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, requiring the team to utilize innovative tools and multiple programming languages to develop the best possible GIS on which to base the EFH, Impact, and HAPC 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 will allow 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 (Section 3.3.6) 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. Benthic habitat is characterized primarily on the basis of the physical substrate (Section 2.2.1.1). 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 (Section 2.2.1.3).

Many species in the Groundfish FMP have pelagic phases in their life cycles. Information on pelagic habitat such as temperature regimes, dissolved oxygen content, primary productivity and other components of water mass structures and movements is available, and could possibly be used to identify EFH for these species and life stages. However, as a priority, the project team has focused on the identification of EFH through species associations with benthic habitat and we have not attempted to use pelagic habitat characteristics in the same way. This is in part because the risk from impacts is expected to be greater for benthic habitats than for pelagic habitats and hence the former have received greater priority in terms of the identification of EFH. In addition, the transient and dynamic nature of pelagic habitats make it very difficult to delineate static geographic areas of the ocean and coast that are more or less important for groundfish than other areas. Hence, consideration of the pelagic habitat would naturally lead to the identification of most, if not all of the potential range of the pelagic phases of groundfish as EFH. As will be described later, the EFH model can accommodate this by considering information on depth and latitude ranges only of species and life stages that are not specifically associates with benthic habitat (see also Section 2.2.4).

2.2.1 Benthic Habitat

2.2.1.1 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 1). Data for California were developed by the Center for Habitat Studies at Moss Landing Marine Laboratories (Appendix 2). 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 2.

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:

Level 1: Megahabitat:
- Continental Rise/Apron;
- Basin Floor;
- Continental Slope;
- Ridge, Bank or Seamount;
- Continental Shelf.

Level 2: Seafloor Induration:
- Hard substrate;
- Soft substrate.

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. These are plotted for illustrative purposes in Figure 2.

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	

Habitat Code	Habitat Type	Mega Habitat	Habitat Induration	Meso/Macro Habitat	Modifier
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

In addition, for Oregon, the 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.

2.2.1.2 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 (Section 3.3.6). 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, however, 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.

We 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 (Figure 3). 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.

Figure 2 shows the various combinations of seafloor habitat and estuary habitat codes that 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.

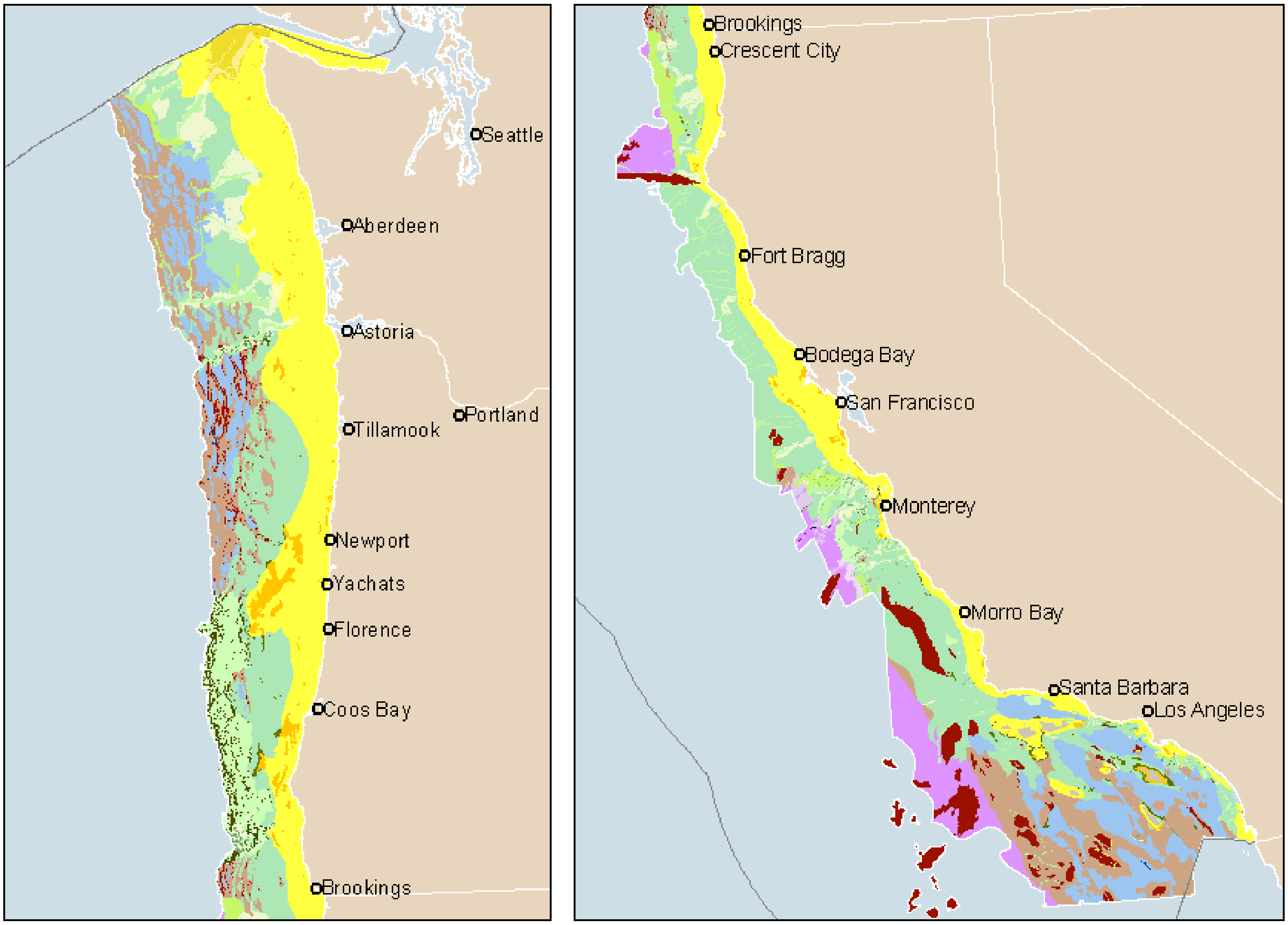

Figure 2. Thirty five (35) unique benthic types off the coasts of Washington, Oregon and California. Graphics created from data provided by MLML (CA) and OSU (OR, WA).

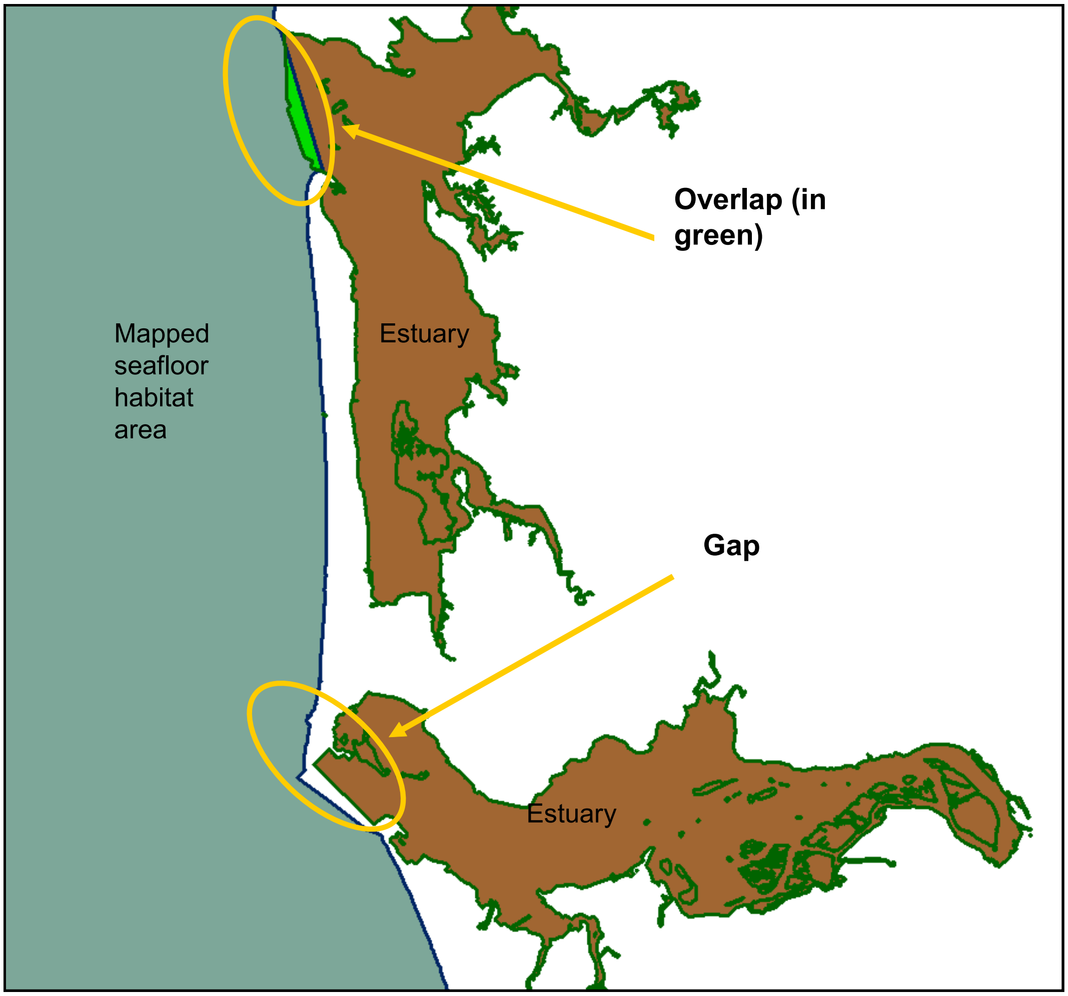

Figure 3. Examples of gaps and overlapping between data sets with respect to delineation of estuaries.

Table 2. Combinations of Seafloor Habitat and Estuary Habitat Codes.

Seafloor Habitat (hab_code)	Estuary Habitat (est_hab_code)	Ambiguous?	Input to EFH Model?
	Estuary	No	Yes
	Island	No	No
Island	Estuary	Yes	Yes
Island	Island	No	No
She, Ss_u (non-island seafloor habitat)	Estuary	No	Yes
She, Ss_u (non-island seafloor habitat)	Island	Yes	Yes
no data	Estuary	No	Yes
no data	Island	No	No
non-island seafloor habitat		No	Yes

A Primer on Geographic Information Systems

Almost 40 years ago a group of geographers developed a system for storing and organizing spatial information in a computer. This system, now known as GIS, allows a virtually unlimited amount of information to be tied to a single location in space. A GIS allows users to view layers of data at the coast wide, state, or estuary level with unprecedented clarity. Displaying information as varied as bathymetry, substrate, fishing effort, pollution sources, and oil and gas leases has lent a powerful tool to marine scientists. Information that was once only available as columns of numbers or charts is now being placed into geographic context, allowing scientists, members of the public, and decision makers to see at a glance the relationships between identified problems and the solutions proposed.

It is important to note a GIS is not simply a computer system for making maps, a GIS is also an analytical tool that allows users to query a collection of spatial and tabular data depicting the location, extent, and characteristics of geographic features. GIS allows users to answer questions that deal with issues of location, condition, trends, patterns, and strategic decision-making, such as Where is it?; What patterns exist?; What has changed since...?;; What if...? Because GIS uses geography, or space, as the common key between data sets, users can rapidly analyze multiple conditions over wide areas.

Due to its ability to synthesize large, disparate data sets, GIS is being used increasingly in coastal and marine research and management efforts worldwide. GIS and related technologies such as the global positioning system (GPS) and remote sensing provide a means to collect, aggregate, and analyze data generated by multiple sources. Today, GIS technology is rapidly replacing the traditional cartographic techniques that have typified most coastal mapping and resource inventory projects, affording users the ability to assess and display different scenarios prior to choosing a preferred management alternative.

2.2.1.3 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 several essential biological habitat components, specifically 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.

2.2.1.3.1 Canopy Kelp Beds

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* sp., 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 Game (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 of time (1989-1992, 1994-2000), and surveying the Straits of Juan de Fuca and the Pacific Coast every year. 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. Distribution of kelp beds is shown in Figure 4.

2.2.1.3.2 Seagrass

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 intial 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 were could not be included in the coastwide seagrass GIS layer. The spatial distribution of seagrass data incorporated into the GIS is shown in Figure 5. Table 3 lists the geographic coverage, time period, and sources of the seagrass data sets that were compiled.

2.2.1.3.3 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. An example within the US EEZ is the Oculina Bank on the Atlantic coast of Florida. On the West Coast, however, the significance of associations between structure forming invertebrates and groundfish species, in terms of being essential fish habitat, 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 4 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 (Figure 4). 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. Firstly, it should be noted that only presence data have been plotted in Figure 6; those trawl samples without structure forming invertebrates (i.e., absence data) have not been plotted. Secondly, the trawl samples are notoriously biased toward "trawlable", soft bottom, low relief habitats, and therefore complex rock structure, which is known to be important habitat for many structure forming invertebrates, is not well represented. The coral category, denoted on the map in blue, 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.

Figure 4. Distribution of kelp beds (*Nereocystis* sp. And *Macrocystis* sp.) delineated in green. Note: Kelp bed polygons drawn with thick lines to allow visualization at this map scale. Data sources: WDNR, ODFW, and CDFG

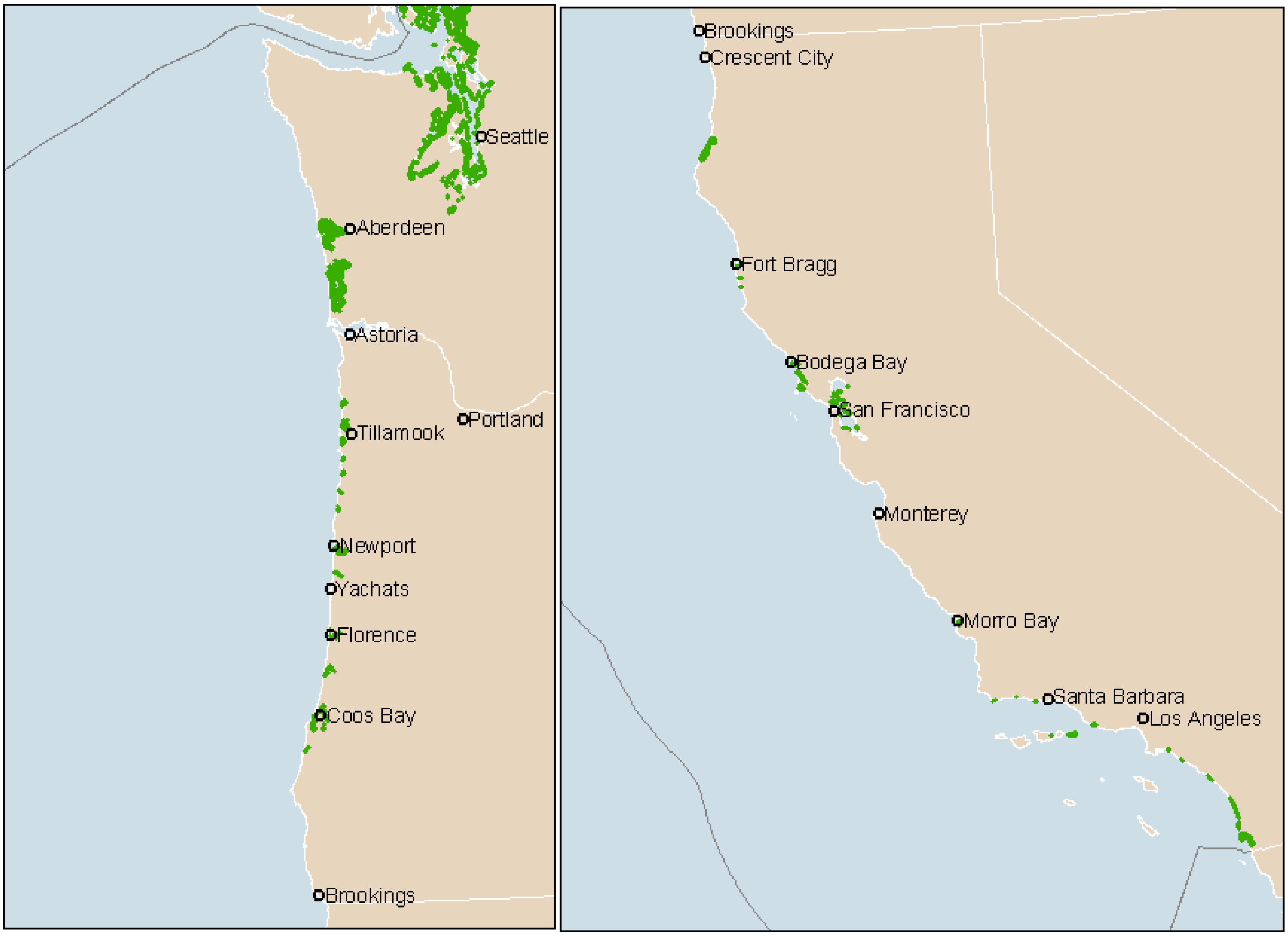

Figure 5 Distribution of seagrass along the west coast of the United States. Note: Seagrass polygons drawn with thick lines to allow visualization at this map scale. Seagrass data sources are listed in Table 3.

Table 3. 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, 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)

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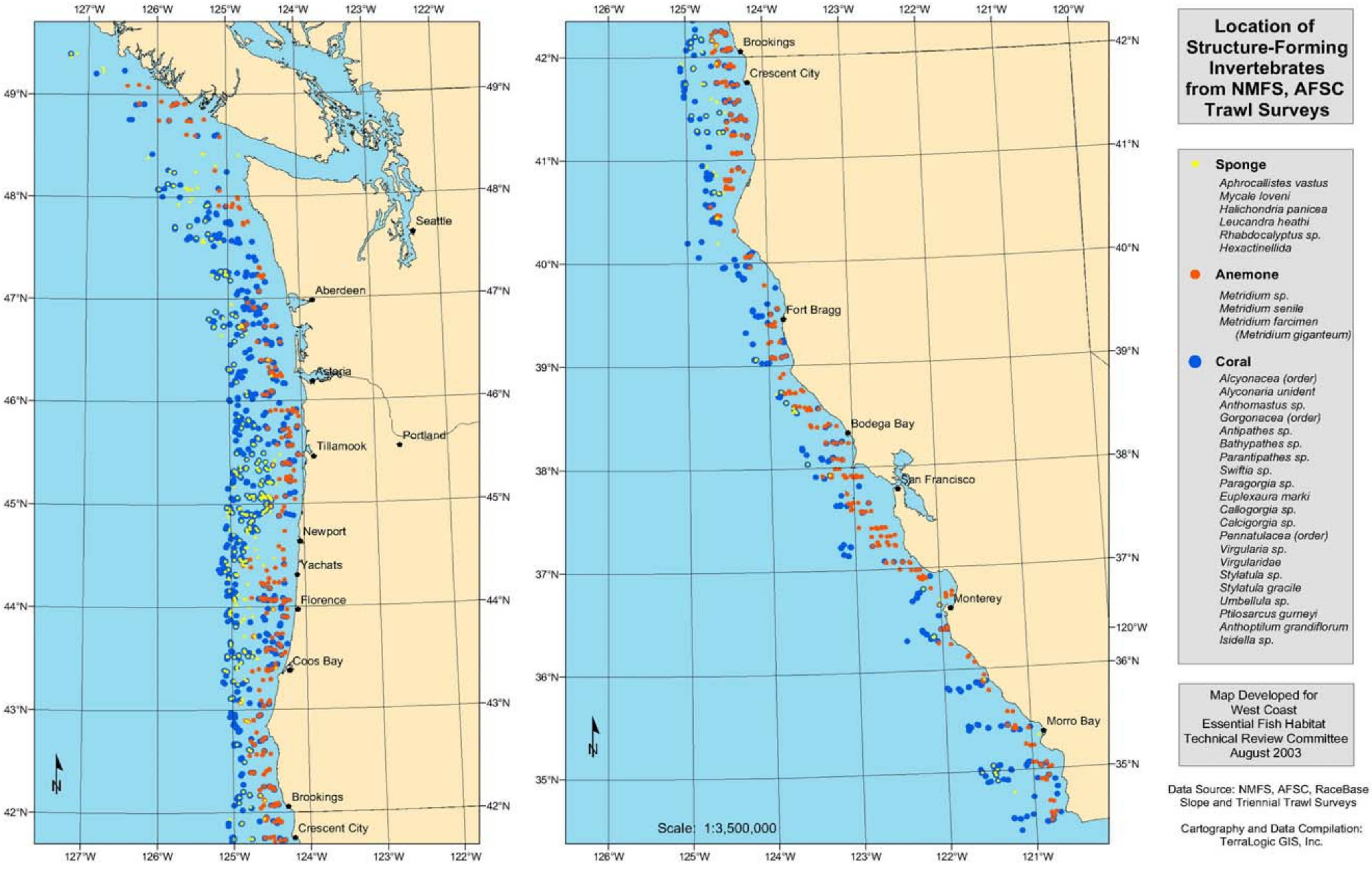

Figure 6. Locations of sponges, anemones and corals from NMFS AFSC trawl surveys.

2.2.2 Bathymetry

Water depth is one of the three habitat characteristics used in the EFH model to calculate habitat suitability values (Section 3.3). A single west coast bathymetric data layer was therefore targeted for development. 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° 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 1 (Goldfinger et. al. 2002). Bathymetry data for the remaining areas, (Washington and the southern-most 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 to200 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 the west coast, latitude is used as one of the three habitat characteristics in the EFH model to calculate habitat suitability values (Section 3.3). Initially, boxes delineating 1’ 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’ latitudinal zones would be a more appropriate level of detail. Therefore, a new GIS coverage depicting 10' 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. There may, for example be non-fishing impacts such as pollution that may 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 such as is required for EFH problematic. For these reasons, we have not attempted to map these features in the GIS in the same way as for the benthic substrate. Where possible, the habitat of 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 feature of the Bayesian approach to the modeling of habitat suitability probability (Section 3.2) is that the level of uncertainty in data inputs can be included explicitly. For example, 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 EFH model is structures to accommodate data of varying quality, providing information on that quality is available (Section **Error! Reference source not found.**). 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 1-40. Detailed documentation about the Washington/Oregon data quality layer is provided as Appendix 3. For modeling purposes, these data were grouped into four categories of data quality corresponding to the values 1-10, 11-20, 21-30, and 31-40. Figure 7 shows the four-level data quality layer for Oregon and Washington. No data quality layer is available for benthic habitat in California.

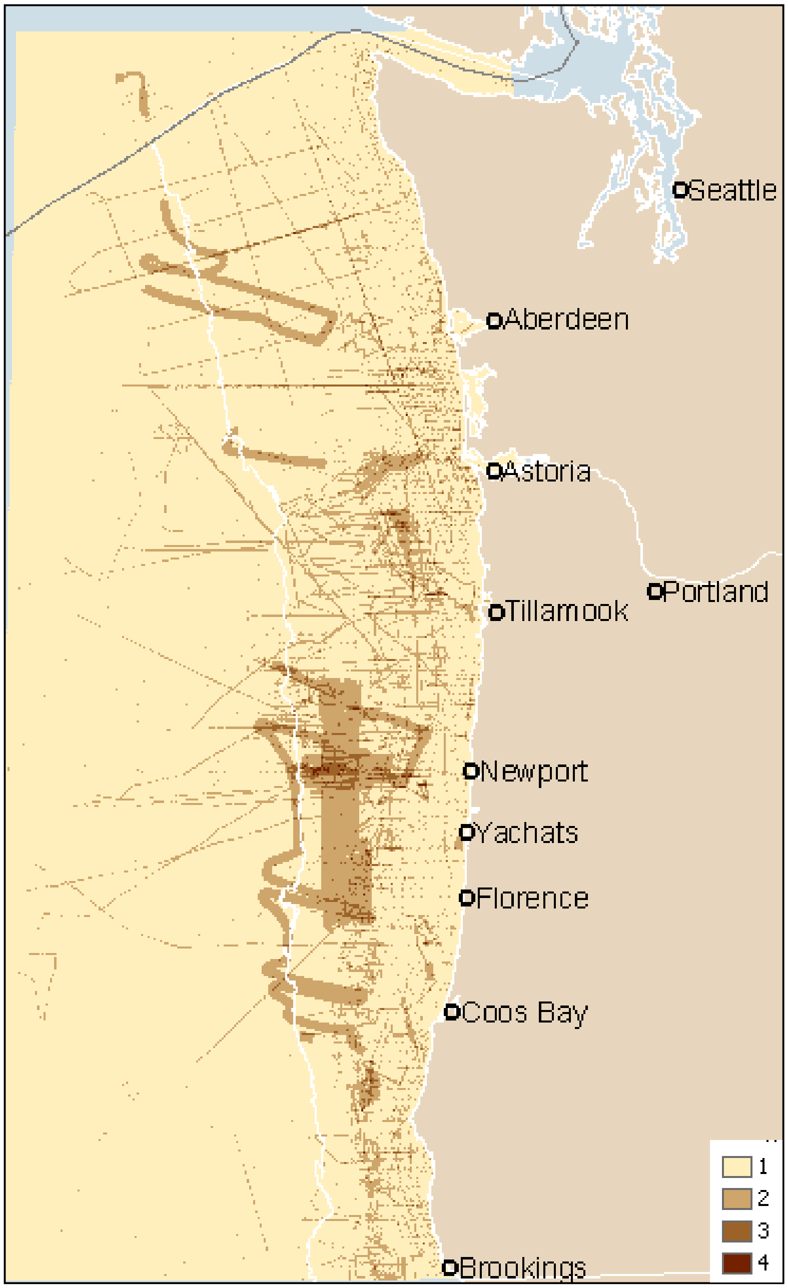

Figure 7 Four-level data quality layer for physical substrate off Oregon and Washington.

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 2nd best quality, the 3rd 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, we 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 (30 meter depth intervals – see Section XX) generally exceeded the scale of the error in even the worst data areas. At the March 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 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. In all, there are three survey series that have operated in the study area, which are described below. A summary comparison of the details of these surveys in 2001 is provided in Table 4. Survey coverage is illustrated in Figure 8.

The shelf survey (30-200 fathoms) by the Alaska Fisheries Science Center (AFSC) uses larger (120 to 130ft) 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 assessing a broader range of groundfish species. From 1987 to 1992, the depth range of the survey was 55 to 366m. In 1995, the lower depth was increased to 500m in order to cover the habitat of slope rockfish more completely. The final 2001 survey encompassed the coastal waters from Pt. Conception, California, to central Vancouver Island, British Columbia (34°30'-49°06'N). 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).

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

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 "deep water 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), to Morro Bay, California (35°N), 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 to 2000 and 2002) has been a segmented transect design that divides the US Pacific coast into 10deg, equidistant sections north to south & 10 east-west segments based on depth. The area covered in 1998-2000 was 34deg 15min to 48deg 15min latitude. In 2002, the area covered expanded at the southern margin to 32deg 30min (i.e. south of Point Conception) and contracted very slightly at the northern margin to 48deg 10min 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.

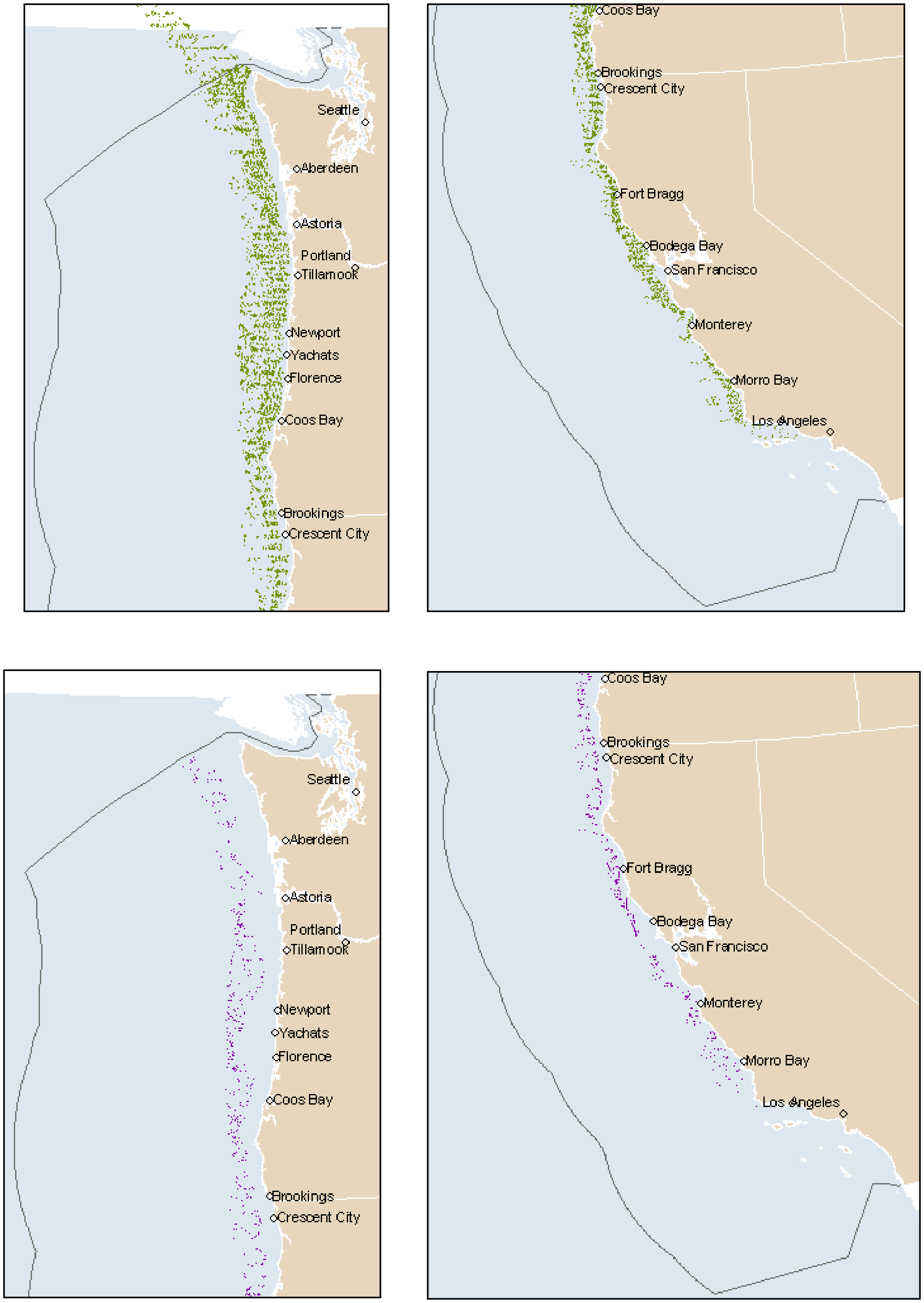
The survey data can also be analyzed to characterize the preferences of species and life stages for different components of the habitat. For example it is possible to explore the relationships between catch per unit effort (cpue) and habitat attributes such as latitude and depth (see Sections 2.3.4.3 and 0)

Table 4 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

Item (year=2001)	**NWFSC Slope Survey**	**AFSC Triennial Shelf Survey**	**AFSC Slope Survey**
Survey Type and depth	Slope (100-700 fathoms)	Shelf (30-200 fathoms)	Slope (100-700 fathoms)
LOA Vessel	68-92 ft.	125-128	225
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, ? 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



(a)

(b)

Figure 8. Survey station locations for the AFSC Slope and Shelf Surveys (a) and the NWFSC Slope Survey (b). Graphics created by TerraLogic GIS Inc.

2.3.2 Ichthyoplankton surveys

In this section we describe surveys that have been undertaken that could provide some information on the distribution of planktonic phases of groundfish species. In fact, data from these surveys have not been used in the EFH model. They do not provide a comprehensive coast wide coverage and, 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 2.2.4).

2.3.2.1 CalCOFI Ichthyoplankton Surveys

The California Cooperative Oceanic Fisheries Investigations 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 Exclusive Economic Zone (200 miles) were conducted periodically during the 1980s. They were intended to complement the egg and larval data obtained from the CalCOFI ichthyoplankton surveys and 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 1980's, 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 1990's 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 5.

Table 5. Groundfish distributions mapped in the NOAA Atlas (1990).

		Life History Stage							
COMMON NAME	SPECIES NAME	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 elongatus	x	x				x		x
Pacific cod	Gadus macrocephalus	x			x	x	x		
Pacific hake (prev. Pacific whiting)	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 (FMU)) and the habitats they use. This section describes the information available to describe these relationships.

2.3.4.1 The Updated Life Histories Descriptions Appendix

In 1998, A Life Histories Appendix to Amendment 11 to the Pacific Coast Groundfish FMP described the life histories and EFH designations for each of the 83 individual species that the FMP manages. The appendix was prepared by a team led by Cyreis Schmitt[2] (at the time, affiliated with the Northwest Fisheries Science Center). 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 in the format of ArcView were included.

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[2] The EFH Core Team for West Coast Groundfish: Ed Casillas, Lee Crockett, Yvonne deReynier, Jim Glock, Mark Helvey, Ben Meyer, Cyreis Schmitt, and Mary Yoklavich, and staff: Allison Bailey, Ben Chao, Brad Johnson, and Tami Pepperell

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 5 years. In response to this requirement for periodic review, the life history descriptions were recently updated by Bruce McCain with assistance from Stacey Miller and Robin Gintner of the NOAA Fisheries, Northwest Fisheries Science Center (NOAA Fisheries 2003). 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). Within the updated appendix, the current 82 FMP groundfish species are sequenced alphabetically according to the common names (Appendix 4). This document also includes nine summary tables and a list of references cited.

The Life Histories Appendix provides 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.

The updated Appendix has been presented to the PFMC in draft form so that NOAA Fisheries can consider appropriate comments prior to its inclusion in the EIS. Specifically, comments are being sought on the types of habitat preferred by various life history stages of the FMP species, and on species-habitat relationships not adequately addressed in this draft.

2.3.4.2 The habitat use database

The Life Histories Appendix (NOAA Fisheries 2003) also provides 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 usage 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 as necessary. 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 Updated Life History Descriptions Appendix compiled by NMFS (see Section 2.2.2.1). This Appendix contains information on each of the species in the groundfish FMP, and includes range, fishery, habitat, migrations and movements, reproduction, growth and development, and trophic interactions. Certain elements of this information need 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, HAPCs and fishing impacts (See Appendix 8 - Manual of the Habitat Use Database).

2.3.4.3 Habitat Suitability Modeling

Habitat suitability modeling (HSM) is a tool for predicting the quality or suitability of habitat for a given species based on known affinities with habitat characteristics, such as depth and substrate type. This information is combined with maps of those same habitat characteristics to produce maps of expected distributions of species and life stages. One such technique is termed habitat suitability index (HSI) modeling. A suitability index provides a probability that the habitat is suitable for the species, and hence a probability that the species will occur where that habitat occurs. If the value of the index is high in a particular location, then the chances that the species occurs there are higher than if the value of the index is low. HSI models use regression techniques to analyze data on several environmental parameters and calculate an index of species occurrence. This methodology has potential for use in designating EFH and HAPC, and an example application by scientists from the National Ocean Service (NOS) is described in Appendix 5. It is also described in more detail in various scientific publications (see for example Christensen *et al*. 1997, Clark *et al*. 1999, Coyne and Christensen 1997, Rubec *et al*. 1998, Rubec *et al*. 1999, Monaco and Christensen 1997 and Brown *et al*. 2000).

Habitat suitability indices are an important component of the EFH model described in Section 0. Use of this approach, and particularly the modeling of NMFS survey data, to obtain the indices are described in that section.

3 MODELING EFH

3.1 Introduction

The EFH Final Rule provides regulations and guidance on the implementation of the EFH provisions of the M-S Act. It includes information on the types of information that can be used for describing and identifying EFH. In this study, we have developed a modeling approach 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 2.3.1) for as many species 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 is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing management alternatives for identification of EFH.

The model has been designed to take advantage of the GIS data and literature review under development by NOAA Fisheries. 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. Presentations of the methodology have been made to the TRC and the SSC of the Pacific Fishery Management Council. Adjustments to the methodology have been made based on input of these committees.

3.2 Network models

Bayesian Belief Networks (BBN), a particular type of network model, were chosen as a suitable analytical tool for developing the EFH model. The essential features of BBN models and the reasons why this approach was used are described in the following sections.

3.2.1 Why Network Models?

Traditional statistical modeling defines and builds models for a response (outcome) in terms of sets of explanatory variables (attributes). Each explanatory variable in a model is seen as *directly* impacting on the response variable. With explanatory variables x_1, x_2, …, x_p, and response y, the situation can be represented by the diagram in
Figure 9.

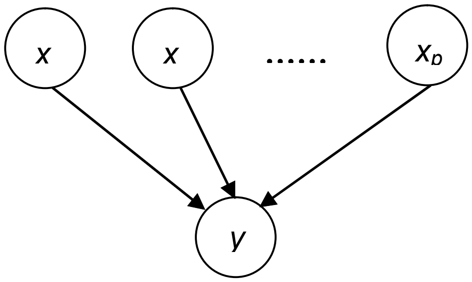

Figure 9 . Explanatory variables directly impacting on a response variable.

In reality, however, it can happen that the relationships between variables are not as simple as this model allows. The effect of one *x*-variable on the response *y* may be mediated through another *x*-variable, or through two or more *x*-variables. It could also happen that some of the *x*-variables affect some of the others. Indeed, with datasets containing many variables, it is easy to envisage quite complex patterns of association. The roles of "response" and "explanatory" become blurred, with variables taking on each role in turn. In a simple example, illustrated in Figure 10, variables *E* and *D* could be regarded as "responses", and *A* and *B* as "explanatory." But *C* seems to play both roles. It looks like a response with *A* and *B* acting as explanatory variables, and it is an "explanatory" variable for *E*. The variables are modeled as random variables and the links are probabilistic. A link from *A* to *C* would be interpreted as meaning that the value of *A* affects the value of *C* by means of influencing the probability distribution of *C*.

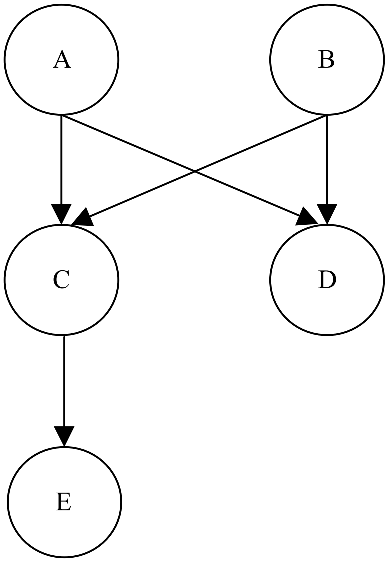

Figure 10. Indirect mediation of effects of explanatory variables.

Historically, these models evolved largely in the artificial intelligence (AI) community, and form the basis of *expert systems*. Generally they are not tools for statistical inference but rather they are mechanisms for encoding probabilistic causal relationships and making predictions from them. Because of their AI background, it is not surprising that the current terminology of network models is quite different from statistical terms, and is perhaps less familiar. Sometimes there is an exact correspondence between an AI term and a statistical one, the two terms being different names for the same concept.

3.2.2 Bayesian Networks

Early applications of Bayesian networks (BN) were in medical diagnosis and genetics, but recently there has been an explosion in their use, including for environmental impact assessment, tracing faults in computer systems and software, robotics, and many other areas (see Appendix 6 for sources of information on BNs). A growing area of interest is the management of natural resources under uncertainty. For example, a BN model was developed for assessing the impacts of land use changes on bull trout populations in the USA (Lee 2000). Another recent application of BNs is modeling uncertainties in fish stock assessment and the impact of seal culling on fish stocks (Hammond & O'Brien 2001). Marcot *et al*. (2001) have used BNs for evaluating population viability under different land management alternatives, while Wisdom *et al*. (2002) used BNs in conservation planning for the greater sage-grouse.

The network models that we are using consist of a number of *nodes* (random variables) connected by *directed* links. A node that has a directed link leading from it to another node is called a *parent* node; the latter is a *child* node. Cycles are not permitted: that is, it is not possible to start from any node and, following the directed links, end up back at the same node. Most of the currently available software for building and analyzing BNs requires that the nodes are discrete, taking only a finite set of possible values, and we assume this to be the case in what follows. Continuous variables can be accommodated by grouping their values into class intervals. An introductory account of BNs is given by Jensen (1996) while a more rigorous and complete treatment is Cowell *et al*. (1999).

To explain the basic ideas, consider the simple example from Figure 10. For simplicity, assume that all of the nodes are binary variables, taking values T or F (true or false). The probabilistic mechanism that governs the relationship between, say, *E* and its parent *C* is the *conditional probability distribution* of *E* given *C*. This can be expressed as a table:

	E	
C	*F*	*T*
F	p_{00}	p_{01}
T	p_{10}	p_{11}

The table of conditional probabilities for node *C*, which has parents *A* and *B,* would have the following form:

		C	
A	*B*	*F*	*T*
F	*F*	p_{000}	p_{001}

F	*T*	p_{010}	p_{011}
T	*F*	p_{100}	p_{101}
T	*T*	p_{110}	p_{111}

A node with no parents (*A* or *B* in the example) would have just a *prior* probability table:

A	
F	*T*
p_0	p_1

The complete specification of a BN consists of

(a) the set of nodes,
(b) the directed causal links between the nodes,
(c) the tables of conditional probabilities for each node.

3.2.3 Estimating the Conditional Probabilities

In practice, there are several possible ways of obtaining estimates for the conditional (and prior) probabilities. If sufficient data are available then cross-tabulating each node with its parents should produce the estimates. There are alternatives to deriving the probabilities from data, however. It is possible to use *subjective* probabilities or *degrees of belief*, usually encoded from expert opinions. In many of the early applications of BNs in medical diagnosis this was generally the approach that was used. There has been some recent research into developing systematic ways of *eliciting* prior beliefs from experts and building probability distributions from them (O'Hagan 1998).

3.2.4 Evidence and Updating

In the simple example of Figure 3, if the states of the nodes (i.e. the values of the variables) *A* and *B* were known, then it would be possible to use the rules of probability to calculate the probabilities of the various combinations of values of the other nodes in the network. This kind of reasoning in a BN can be called "prior to posterior," in the sense that the reasoning follows the directions of the causal links in the network. Suppose now that the state of node *E* were known. What could be said about the other nodes? The *updating algorithm* of Lauritzen and Spiegelhalter (1998) allows us to calculate the posterior probabilities of all other nodes in the network (and this works for *any* BN), given the known value at *E*, or indeed, given any combination of known nodes. In the jargon of expert systems, "knowing" the value of a node is called "entering evidence." This is "posterior to prior" reasoning and allows us to infer something about the states of nodes by reasoning *against* the direction of the causal links. The updating algorithm is a very powerful tool in BNs and enables us to make useful predictions and examine "what if" scenarios with ease. Various software packages are available which facilitate the construction of BNs and implement the updating algorithm. For this project, we are using the program Netica (Norsys 1998).

3.3 The EFH Model

3.3.1 Introduction

The M-S Act defined EFH to mean “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (M-S Act § 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 (50CFR 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 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, we also note 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. We note, however, that 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)).

3.3.2 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 of 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. Habitat restoration will be a vital tool to recover degraded habitats and improve habitat quality and quantity, enhancing benefits to the species and society.

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.

3.3.3 Identifying EFH for the FMP

According to the M-S Act, 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 M-S Act in reference to EFH refers to the FMU of an FMP. The EIS must therefore develop alternatives for EFH based on individual species/life stages aggregated to a single EFH designation for Pacific Coast Groundfish. In the EIS, a single map will be used to describe and identify EFH for the fishery. However, the analysis that produces that map will include the preparation of electronic 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 usage be made, if possible, through appropriate means. For example, such inferences could be made on the basis of information regarding habitat usage 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. As explained in Section 2.1.2, the CEQ Regulations mandate a process for dealing with incomplete or unavailable information

While identification of EFH is carried out at the fishery (FMP) level, the determination of whether an area should be EFH depends upon 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 multiple species habitat needs. The FMP for the groundfish fishery includes 82 species (Appendix 4). Descriptions of groundfish fishery EFH for each of the 82 species 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 habitat areas of particular concern (HAPC) within areas designated as EFH (600.815(a)(8)).

3.3.4 Use 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:

Level 4 – production rates by habitat are available
Level 3 – growth, reproduction, or survival rates within habitats are available
Level 2 – habitat-related densities of the species are available; and
Level 1 – distribution data are available for some or all portions of the geographic range of the species.

The table below provides additional detail on the meanings to be inferred from this list.

Layer	Possible units/information sources
Level 4: Production rates	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.

Layer	Possible units/information sources
Level 3: Growth, reproduction or survival rates	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).
Level 2: Density	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.
Level 1: Distribution	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.

In developing a process for identifying EFH we have built a model that expresses the probability that a particular location contains suitable habitat for species in the groundfish FMP (see Section 0), 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, b).

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, we are attempting to do 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 is 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 11 illustrates the expectation that on a relative scale, if information is available at level 4, it is likely to be possible 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 of 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 11 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 what 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)). CEQ regulations (1502.22) require agencies to make clear when information is lacking.

3.3.5 Types of information available for identifying EFH

There are two main categories of information available that can be used 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 Table 6. Only the shaded cells of Table 6 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.

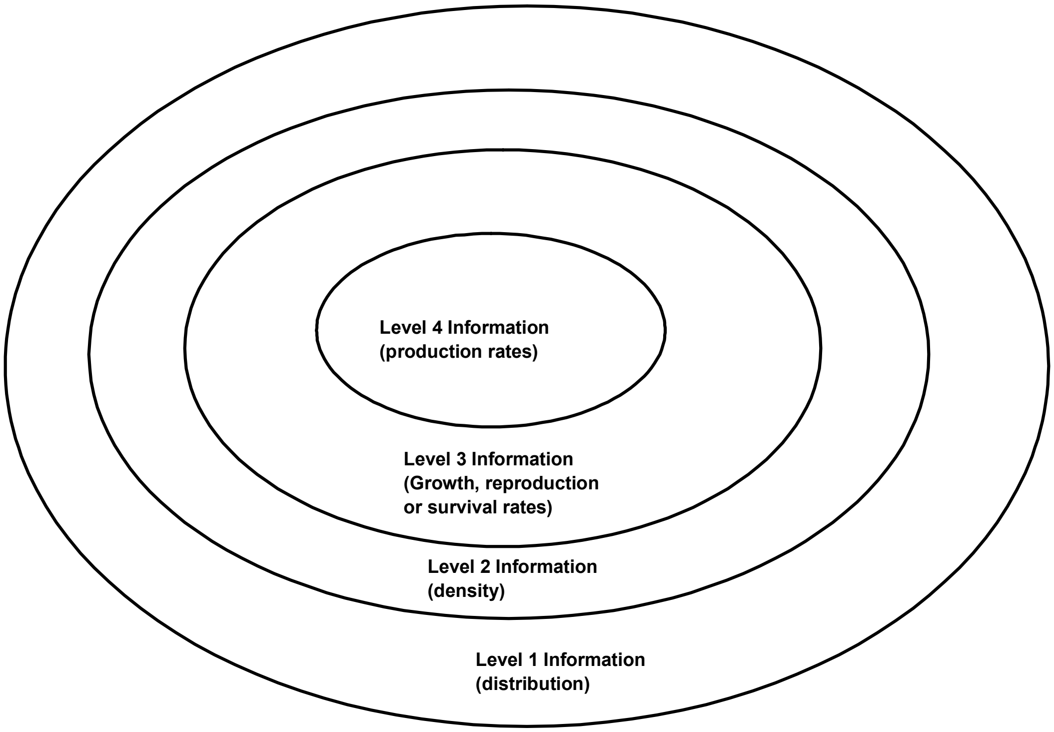

Figure 11. Diagrammatic representation of the effect of levels of information and the relative extent of the area of EFH likely to be identified for an individual species/life stage (not to scale).

Table 6. 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

3.3.6 BN model for identification of EFH

Robust methods need to be devised for identifying EFH in a climate of uncertainty. Various sources of data are available for doing this (Section 3.3.4, Table 6). The approach adopted in the BN model for identification of EFH falls under the heading of spatial modeling of habitat suitability probability (Levels 1 and 2 under species-habitat relationship modeling in Table 6).

The BN model takes information about the preferences of species/life stages for certain habitat conditions, in the form of Habitat Suitability Indices (HSIs), and uses this to plot habitat suitability probabilities (see Section 3.3.6.1) across the habitat parcels mapped in the GIS. Three habitat attributes or parameters are used in the west coast model to describe the habitat conditions: depth, latitude and habitat type, where habitat type comprises two characteristics: substrate and topography. Taken together, these three parameters are considered to provide a reasonable basis for predicting the habitat suitability probability for all species and life sages in the groundfish FMP.

3.3.6.1 Habitat suitability probability

The model therefore 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).

A habitat suitability probability (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. HSP is the output of the Bayesian network model for determining essential fish habitat (EFH). It represents the quantitative link between habitat characteristics (habitat type, depth and latitude) and the probability of occurrence of species in the FMP (3.3.6.1).

The overall HSP is calculated from separate probabilities derived from HSIs 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 (Clark *et al* 1999, Rubec *et al* 1999, Brown *et al* 2000, Rubec *et al* 1998, Christensen *et al* 1997). 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 fish and 1 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 (See Appendix 5 for details of the HSI methodology used by NOS). At the February meeting of the TRC, the possibility of using the NOS HIS data directly in the BN model was discussed. Although these data do provide a useful guide for the BN 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 representative of 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. A more detailed discussion of these issues is presented in Appendix 5.

In recent years, there has been increasing interest in generalized additive models (GAMs) (Hastie & Tibshirani, 1990) which have been particularly useful in modeling fish abundance and related parameters (Swartzman *et al* 1992, Augustin *et al* 1998, Borchers, Richardson *et al*, 1997, Borchers, Buckland *et al*, 1997). 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 BN 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 BN model for identifying EFH are shown, in a slightly simplified form, in Figure 12.

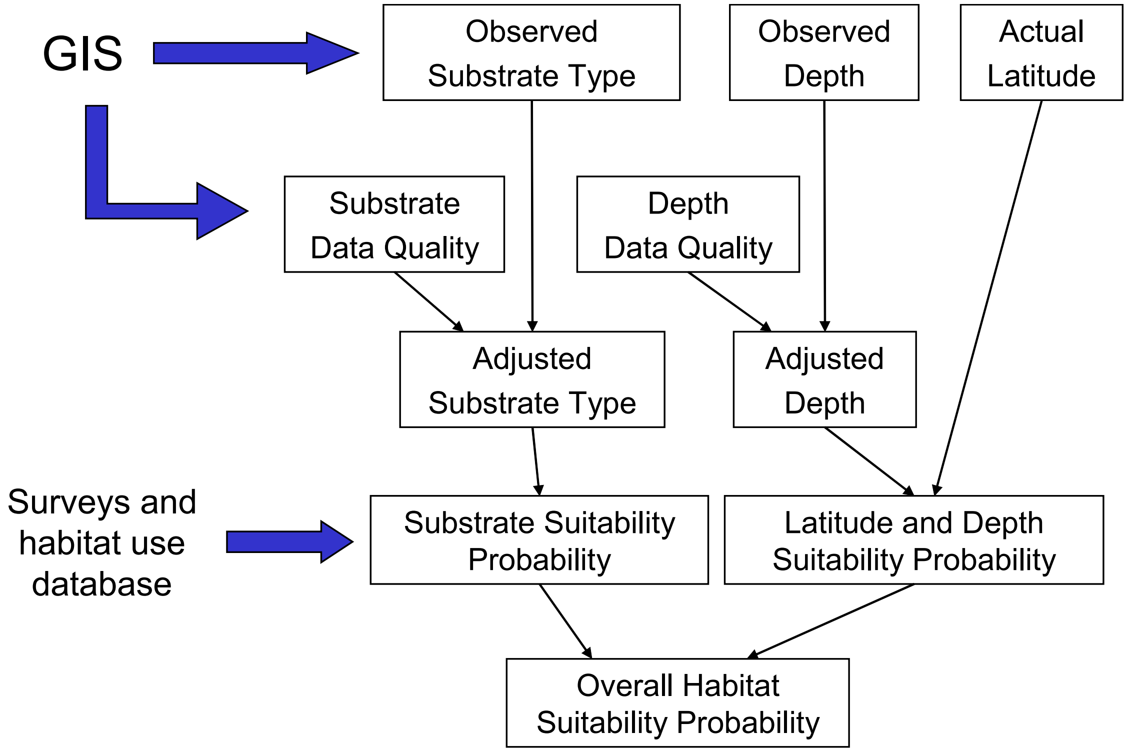

Figure 12. Simplified relationships in the BN model to identify EFH.

3.3.6.1.1 Modeling habitat suitability based on depth and latitude

(i) Using 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 BN model (Appendix 7). Initial runs involved using GAMs to model the effects of depth and latitude on relative abundance (cpue)[3], 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 3.3.4, 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 (See Appendix 7).

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[3] 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 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. [4]

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 6 degrees of freedom was found to smooth the data most adequately [5].

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 7 for details of the development of the modeling approach):

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

In addition to describing the exploratory data analyses, Appendix 7 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 heir profiles, because the surveys did not sample in the 0-30 meters depth range. 16 of these have been completed to date. The other 24 species could not be completed, because the experts could not provide the necessary information. The remaining 22 species in the FMP are not covered at all by the NMFS surveys. Profiles on the habitat ranges of the 46 species that could not be completed from the NMFS survey was derived from the habitat use database, described later in this section.

An example of the modeling output (HSP) for depth and latitude is provided in Figure 13. 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 Section 3.3.6.1.2.

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

[5] 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.

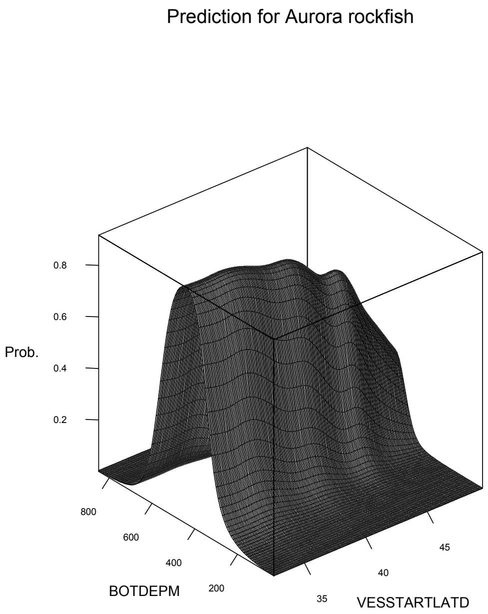


Figure 13. HSP for aurora rockfish.

(ii) Using the Habitat Use Database (HUD)

It was only possible to produce 36 complete habitat suitability probability profiles from the NMFS trawl survey data (including those completed with additional expert opinion). These are considered to be indicative of the HSP for only the adult life stages of the 36 species covered, because of the sampling gear used on the surveys. 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. Therefore, there is a theoretical total of 328 possible HSP profiles (82 x 4). Size 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.

The Habitat Use Database (HUD) contains absolute and preferred depth and latitude values for most of the species in the FMP and their life stages. Of the 328 possible combinations, No data are recorded in the HUD for a total of 74 species/life stage combinations, 56 of which are eggs and 17 of which 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. This is described in more detail in Appendix 7.

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 discuss the depth observations since the same principle will be applied to the latitude observations. Here we use Pacific Ocean perch (adults) 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 7 is calculated as

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

i.e. the 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.

Table 7: 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 then plotted in Figure 14 and 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 14 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 Figure 14 (Smooth) is then extrapolated over the latitude 32 to 49 and the result is shown in Figure 15.

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 16.

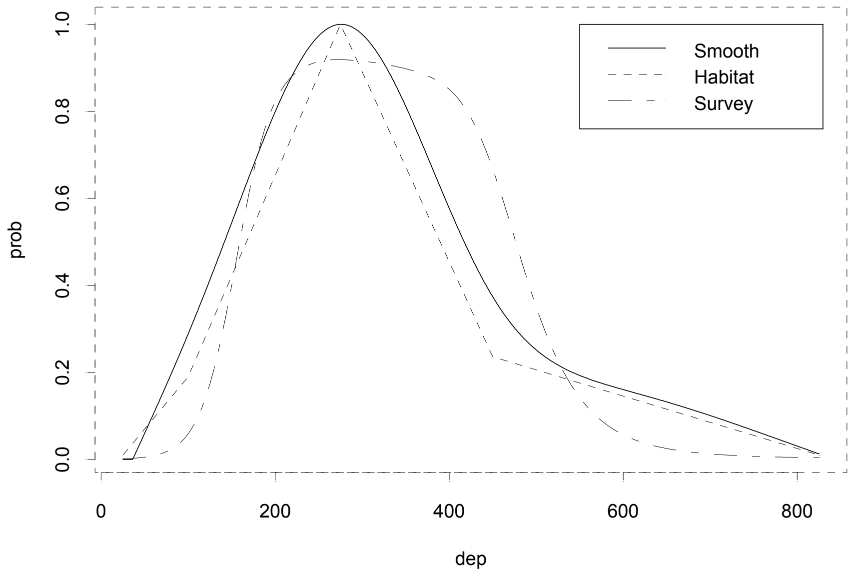


Figure 14: Comparison of probability profiles for depth based on the

survey data and the HUD
(smoothed and unsmoothed)

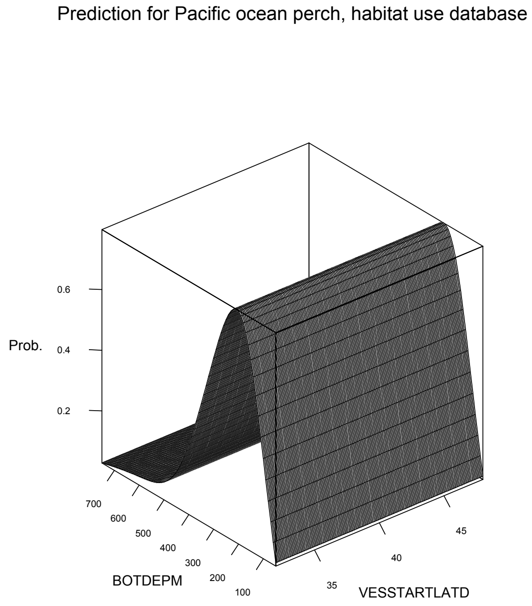


Figure 15: HUD depth profile extrapolated over the latitude interval 32-49 degrees.

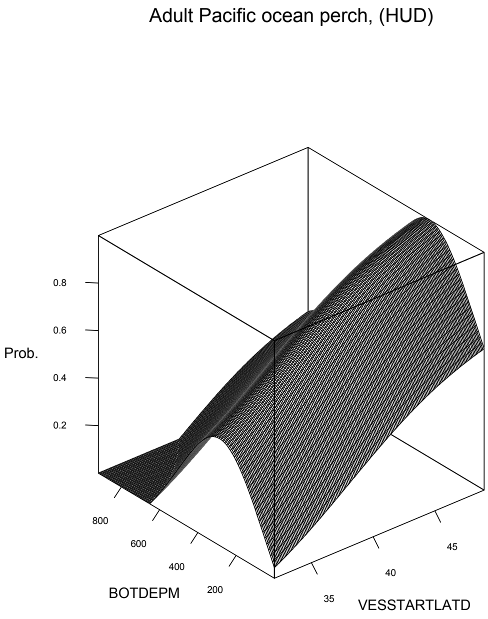
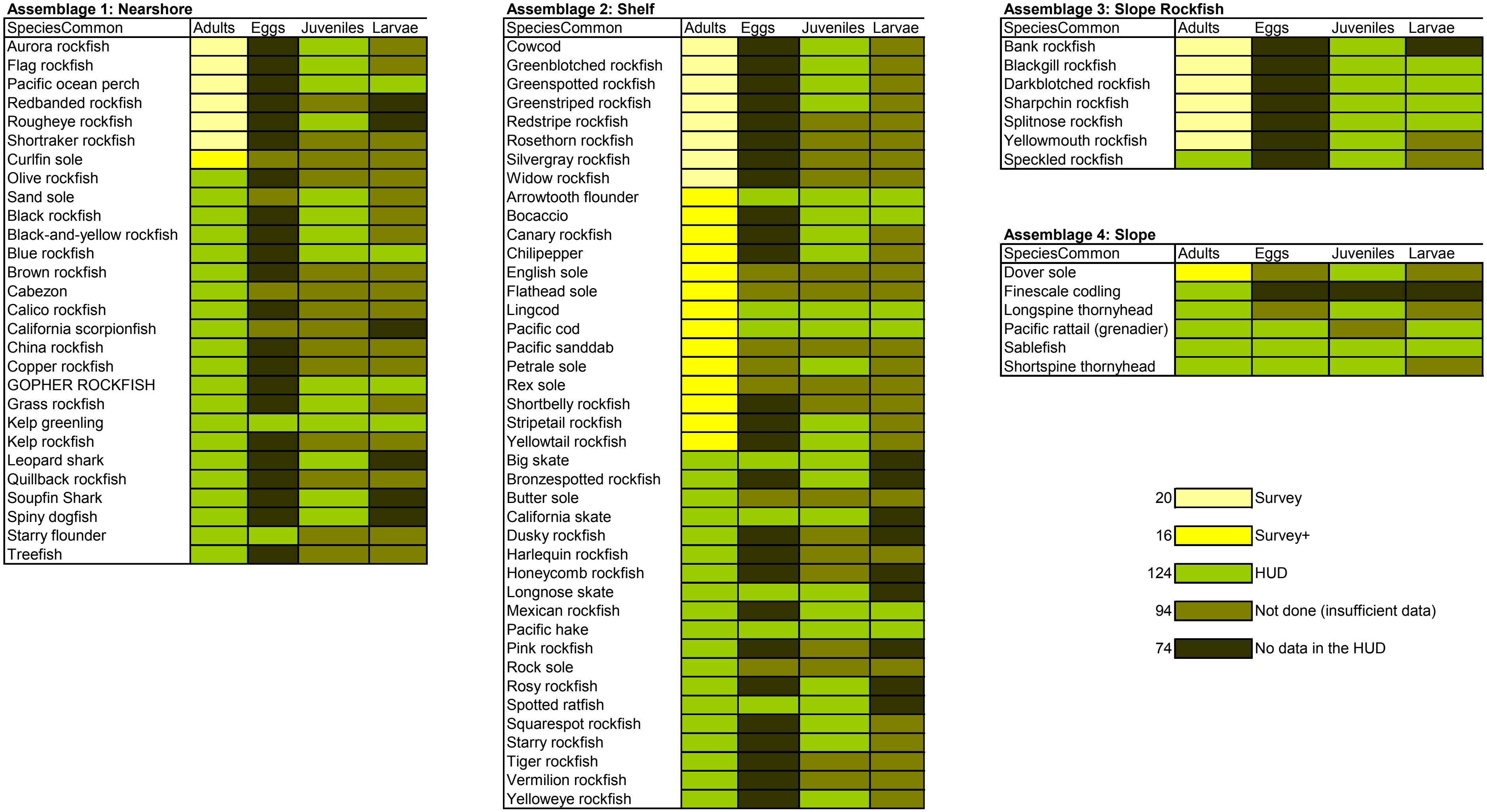


Figure 16: Index profile for adult pacific ocean perch, based on the observations in the HUD.

Figure 17 shows a summary of the outcome of the modeling of depth and latitude profiles for species and life stages in the Groundfish FMP.



Assemblage 1: Nearshore

SpeciesCommon	Adults	Eggs	Juveniles	Larvae
Aurora rockfish	⬜	⬛	🟩	🟫
Flag rockfish	⬜	⬛	🟩	🟫
Pacific ocean perch	⬜	⬛	🟩	🟩
Redbanded rockfish	⬜	⬛	🟫	⬛
Rougheye rockfish	⬜	⬛	🟩	⬛
Shortraker rockfish	⬜	⬛	🟫	🟫
Curlfin sole	🟨	🟫	🟫	🟫
Olive rockfish	🟩	⬛	🟫	🟫
Sand sole	🟩	🟫	🟩	🟫
Black rockfish	🟩	⬛	🟩	🟫
Black-and-yellow rockfish	🟩	⬛	🟩	🟫
Blue rockfish	🟩	⬛	🟩	🟩
Brown rockfish	🟩	⬛	🟫	🟫
Cabezon	🟩	🟫	🟫	🟫
Calico rockfish	🟩	⬛	🟫	🟫
California scorpionfish	🟩	🟫	🟫	⬛
China rockfish	🟩	⬛	🟫	🟫
Copper rockfish	🟩	⬛	🟫	🟫
GOPHER ROCKFISH	🟩	⬛	🟩	🟩
Grass rockfish	🟩	⬛	🟩	🟫
Kelp greenling	🟩	🟩	🟩	🟩
Kelp rockfish	🟩	⬛	🟫	🟫
Leopard shark	🟩	⬛	🟩	⬛
Quillback rockfish	🟩	⬛	🟫	🟫
Soupfin Shark	🟩	⬛	🟩	⬛
Spiny dogfish	🟩	⬛	🟩	⬛
Starry flounder	🟩	🟩	🟫	🟫
Treefish	🟩	⬛	🟫	🟫

Assemblage 2: Shelf

SpeciesCommon	Adults	Eggs	Juveniles	Larvae
Cowcod	⬜	⬛	🟩	🟫
Greenblotched rockfish	⬜	⬛	🟩	🟫
Greenspotted rockfish	⬜	⬛	🟩	🟫
Greenstriped rockfish	⬜	⬛	🟩	🟫
Redstripe rockfish	⬜	⬛	🟫	🟫
Rosethorn rockfish	⬜	⬛	🟫	🟫
Silvergray rockfish	⬜	⬛	🟫	🟫
Widow rockfish	⬜	⬛	🟫	🟫
Arrowtooth flounder	🟨	🟩	🟩	🟩
Bocaccio	🟨	⬛	🟩	🟩
Canary rockfish	🟨	⬛	🟩	🟫
Chilipepper	🟨	⬛	🟩	🟫
English sole	🟨	🟫	🟫	🟫
Flathead sole	🟨	🟫	🟫	🟫
Lingcod	🟨	🟩	🟩	🟩
Pacific cod	🟨	🟩	🟩	🟩
Pacific sanddab	🟨	🟫	🟫	🟫
Petrale sole	🟨	🟫	🟩	🟫
Rex sole	🟨	🟫	🟫	🟫
Shortbelly rockfish	🟨	⬛	🟫	🟫
Stripetail rockfish	🟨	⬛	🟩	🟫
Yellowtail rockfish	🟨	⬛	🟩	🟫
Big skate	🟩	🟩	🟩	⬛
Bronzespotted rockfish	🟩	⬛	🟩	⬛
Butter sole	🟩	🟫	🟫	🟫
California skate	🟩	🟩	🟩	⬛
Dusky rockfish	🟩	⬛	🟫	⬛
Harlequin rockfish	🟩	⬛	🟫	🟫
Honeycomb rockfish	🟩	⬛	🟫	⬛
Longnose skate	🟩	🟩	🟩	⬛
Mexican rockfish	🟩	⬛	🟩	🟩
Pacific hake	🟩	🟩	🟩	🟩
Pink rockfish	🟩	⬛	🟫	⬛
Rock sole	🟩	🟫	🟫	🟫
Rosy rockfish	🟩	⬛	🟩	⬛
Spotted ratfish	🟩	🟩	🟩	⬛
Squarespot rockfish	🟩	⬛	🟩	🟫
Starry rockfish	🟩	⬛	🟩	🟫
Tiger rockfish	🟩	⬛	🟫	🟫
Vermilion rockfish	🟩	⬛	🟫	🟫
Yelloweye rockfish	🟩	⬛	🟩	🟫

Assemblage 3: Slope Rockfish

SpeciesCommon	Adults	Eggs	Juveniles	Larvae
Bank rockfish	⬜	⬛	🟩	⬛
Blackgill rockfish	⬜	⬛	🟩	🟩
Darkblotched rockfish	⬜	⬛	🟩	🟩
Sharpchin rockfish	⬜	⬛	🟩	🟩
Splitnose rockfish	⬜	⬛	🟩	🟩
Yellowmouth rockfish	⬜	⬛	🟩	🟫
Speckled rockfish	🟩	⬛	🟩	🟫

Assemblage 4: Slope

SpeciesCommon	Adults	Eggs	Juveniles	Larvae
Dover sole	🟨	🟫	🟩	🟫
Finescale codling	🟩	⬛	⬛	⬛
Longspine thornyhead	🟩	🟫	🟩	🟫
Pacific rattail (grenadier)	🟩	🟩	🟫	🟩
Sablefish	🟩	🟩	🟩	🟩
Shortspine thornyhead	🟩	🟩	🟩	🟫

20	⬜	Survey
16	🟨	Survey+
124	🟩	HUD
94	🟫	Not done (insufficient data)
74	⬛	No data in the HUD

Figure 17 Summary of the species and life stages in the Groundfish FMP, separated into four putative assemblages showing the disposition of methods for modeling the depth/latitude profiles.

3.3.6.1.2 Modeling habitat suitability based on benthic substrate

The habitat use database (Section 2.3.4.2.) contains data on the association between species in the FMP and substrate type. This association is measured in terms of a four point scale: unknown, weak, medium and strong. Unknown refers to the situation where there is no information linking the species with the substrate type. For the purposes of this analysis, this is interpreted as meaning there is no association between the two. In order to incorporate information about substrate preferences into the BN 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 BN model. As part of the future analysis, the sensitivity of the output to the assumed probability levels will 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 habitat use database contains a substrate classification system that differs from the system used in the GIS. The latter was devised by Gary Greene (Moss Landing Marine Lab) and is described in Section Appendix 2. The former is based on the Our Living Oceans habitat classification and is shown in Table 8. In order to reconcile the different habitat definitions used in the habitat use database and the GIS we devised a system of correspondence between the two systems. This is described below.

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[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 recoded 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
Artifical 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 in Table 2: 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 3 fields only has at most one value of the Modifier field. The habitat use database uses four levels (see above), but level four 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 letters 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 habitat use database 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. It could, however, be represented as a level of uncertainty in the BN 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 habitat use database. 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 current correspondence 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 habitat use database 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, 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 3.3.6.1.1. 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.

3.3.6.2 Current BN model specification

Figure 18 shows the BN model use to calculate HSP for a GIS polygon with observed values of substrate type, depth and latitude.

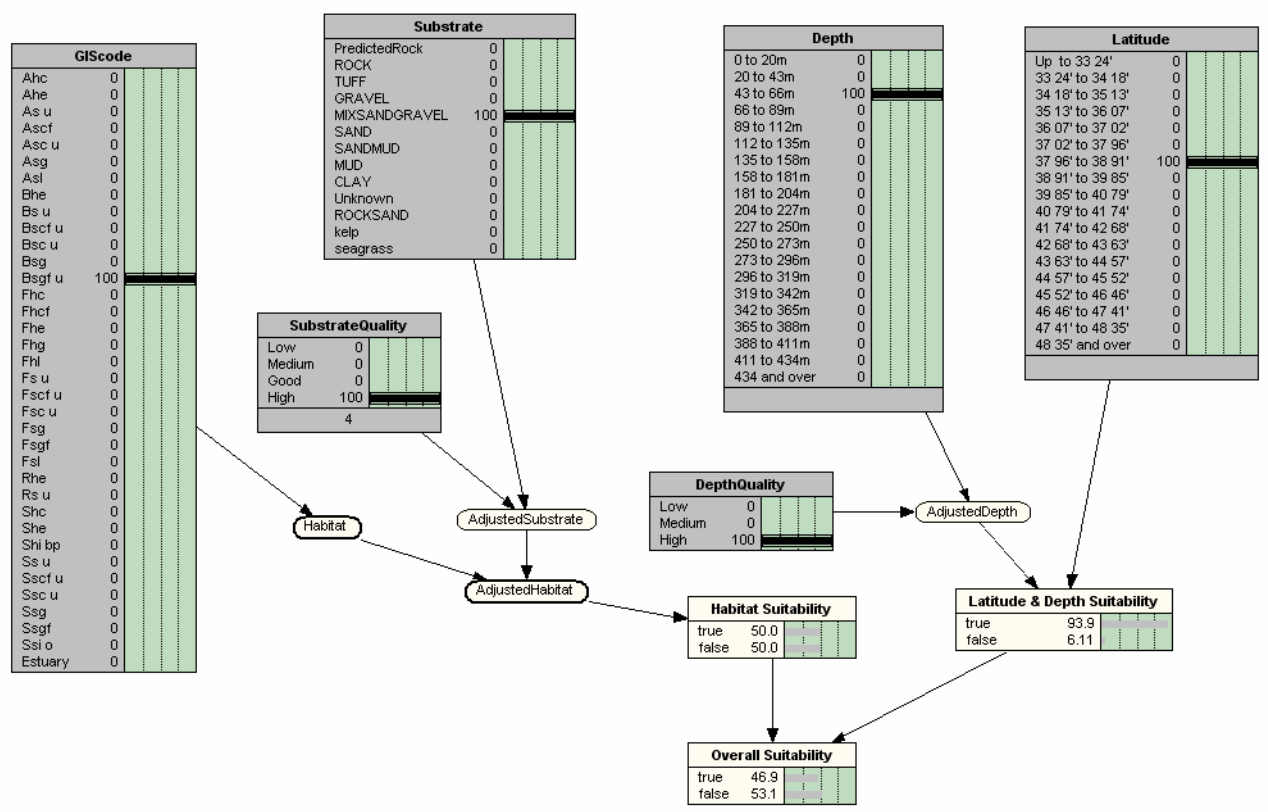


Figure 18. The EFH model showing substrate, depth, latitude and data quality nodes

For the given GIS polygon, the habitat code, substrate, depth and latitude are entered into the appropriate nodes in the BN. Uncertainty in the substrate classification is accommodated in the model 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 judgements) of possible true substrates, given an observed substrate. The resulting substrate type is in the *AdjustedSubstrate* node in the BN. A similar facility for allowing for uncertainty in depth observations has been included in the model, but this is not being used at present (the depth data quality indicator is permanently set to “High”, which leaves the depth in the *AdjustedDepth* node the same as the observed depth).

The Substrate Suitability node calculates the Habitat Suitability Probability (HSP) corresponding to the Adjusted Substrate. The node uses suitability probabilities obtained from the habitat use database (see Section 3.3.6.1). Similarly, the Latitude & Depth Suitability node uses the combined HSP value estimated by GAM modelling (see Section 3.3.6.1).

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

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

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, such that the HSP for a particular depth/latitude combination does not depend on substrate.

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 10m) and latitude range (every 10 minutes) (Figure 19). A computer program has been written to read the polygon data, pass them efficiently to the model, and to produce a file of the resulting HSP values. These HSP values are then plotted for the entire coast in the form of a contour plot (see example in Figure 20). EFH can then be identified on the basis of the areas mapped, for example by selecting an area where the HSP is above a pre-determined threshold level, the selection of which is a policy choice for resource managers (see Section 4).

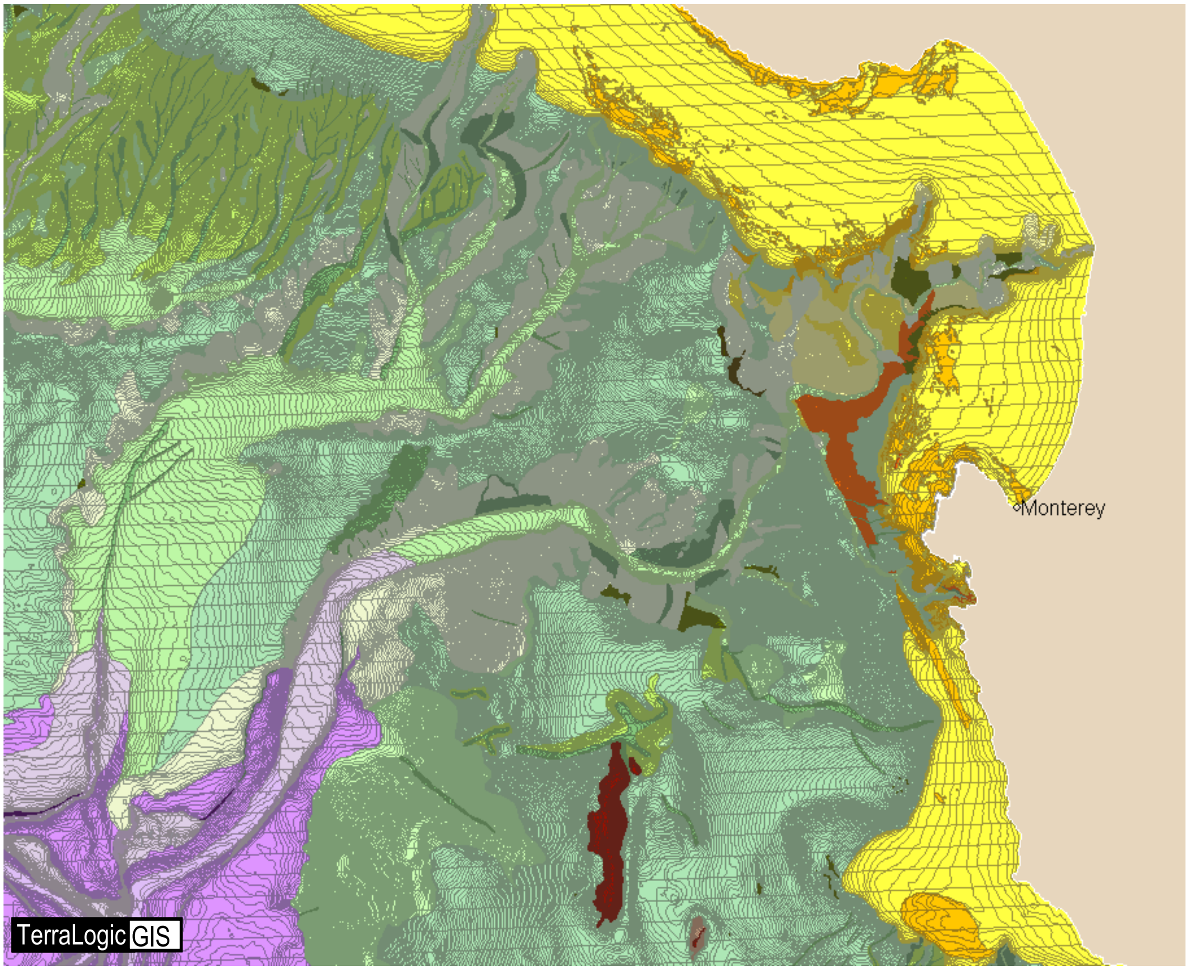
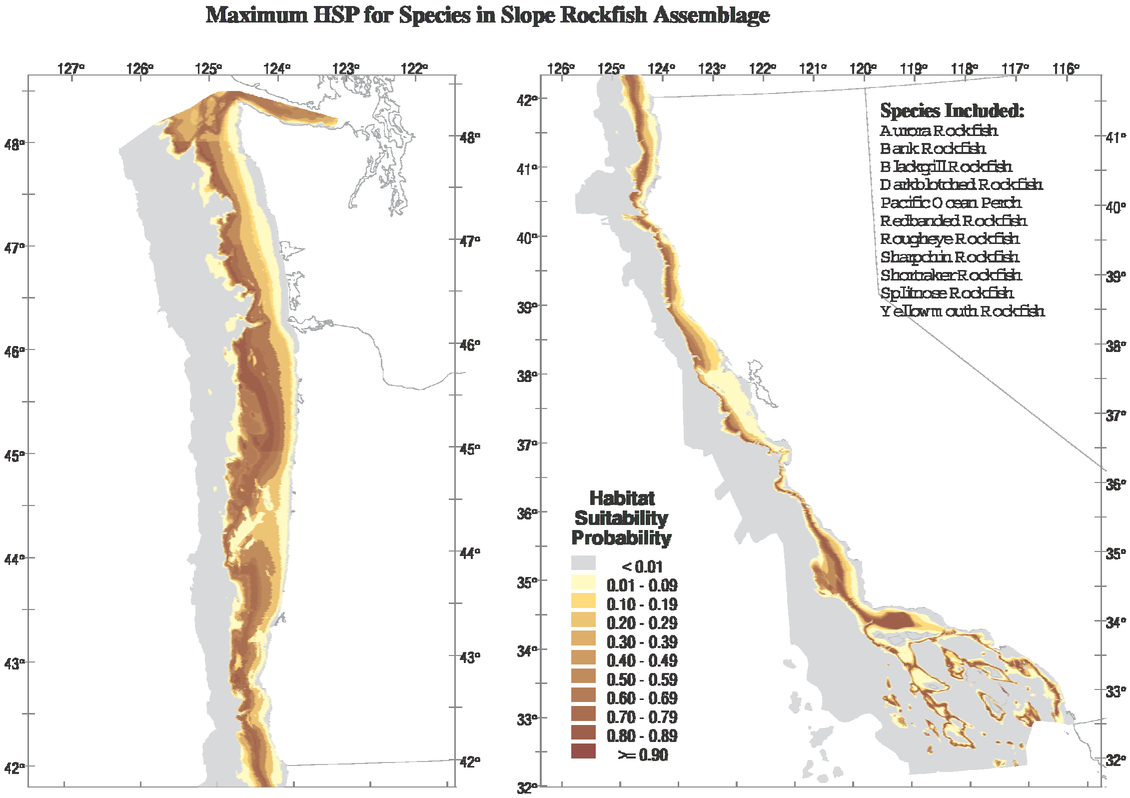


Figure 19. Portion of the Pacific Coast showing the division of the study area into polygons of unique habitat characteristics. the colors represent different substrate types.



Habitat Suitability Probability data output from MRAG/University of Reading EFH model. Cartography by Terralogic GIS, map date: October 31, 2003

Figure 20. Example plot of habitat suitability probability for the slope rockfish assemblage. Map based on preliminary HSP values derived from NMFS Survey data.

4 RESULTS

4.1 Maps of habitat suitability

Maps resulting from the BN model for EFH are produced separately from this document to preserve image quality, and will be made available on a CD ROM. Maps include the following species/lifestages:

kelp greenling adult
kelp greenling juvenile
kelp greenling larvae
kelp greenling eggs
greenspotted adult
greenspotted juvenile
arrowtooth juvenile
sablefish adult
Pacific Ocean perch larvae

4.2 Identification of EFH

The end 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. EFH can then be determined by selecting areas of habitat with scores higher than some predetermined value. A low value would produce a broad or inclusive identification of EFH, while a high value would reduce the area identified as EFH. The decision whether to adopt an inclusive or narrow definition of EFH should be considered from a policy standpoint. Adopting an inclusive definition may be appropriate given the incomplete and indirect nature of the information used to identify EFH. However, developing workable alternatives to reduce fishing impacts may be difficult if EFH is defined broadly. Adopting a relatively narrow EHF definition may make it easier to develop effective precautionary alternatives.

The GAM models estimate true probabilities of the survey encountering species across the area they cover. The suitability profiles based on HUD database are indices scaled to have a maximum value of one. The survey result can have a maximum value considerably less than one, particularly for rare species where the probability of occurrence is low everywhere. EFH for individual species should be placed on common scale before they are combined in an EFH definition for all groundfish species. It may also helpful to produce intermediary maps showing EFH maps for various subsets of groundfish, i.e., overfished species, species guilds, or species complexes used for management.

An alternative for EFH identification proposed by the SSC would identify the best 10% (or 20%, etc) of habitat over entire assessed region for each groundfish species, and then combine these areas for an overall definition of EFH. This would neatly avoid the problem of how to combine the results of the profiles based on the survey and HUD analyses.

4.3 Validation of model results

Full validation of the results of the EFH modeling exercise has not yet been undertaken.

Appendix 8 provides a preliminary comparison between the HSP values from the BN model and the habitat preferences described in the NMFS Life Histories Appendix (Section 2.3.4.1) and comments on the final combined probability profiles. These comparisons are for the species whose depth/latitude profiles were developed from the NMFS trawl survey data.

The results obtained to date 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.

Data from the NOAA Atlas (see Section 2.3.3) are available for some of the species and life stages modeled in this analysis. For those species where maps are available from both sources it is possible to create an overlay to make a comparison of the two distributions. This has not yet been undertaken.

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