Pacific Coast Groundfish EFH

Analytical Framework

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Prepared for

Pacific States Marine Fisheries Commission

By

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1 INTRODUCTION

NOTE: this is intended to be a "living" document. i.e. it is in draft form and incomplete at this stage. As the analytical framework develops and results are obtained, the report will be updated. It will not be finished until the assessment phase of the EIS project is complete.

1.1 <u>The purpose of this document</u>

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.

The decision making process for this project is designed for policy to flow from assessment. A rigorous assessment of groundfish habitat on the west coast is being developed to define the current condition of habitat and 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 TO BE INSERTED HERE.

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

The assessment process has officially been underway since March, 2002 when a team of NMFS and NOS scientists convened to sketch a strategy and identify data sources and responsible parties. The team identified the comparative risk assessment model described in Effects of Trawling and Dredging on Seafloor Habitat (NRC, 2002) as the conceptual starting point for Pacific coast groundfish. The Council reviewed the decisionmaking framework in April, 2002 and subsequently formed the Pacific Groundfish Habitat Techncial Review Committee (TRC) to guide the assessment process.

The assessment has been proceeding along three major tracks: data consolidation, proof of concept, and full implementation. The results of the data consolidation phase are discussed in

Chapter 2. Proof of concept ended in February 2003 with the endorsement of the preliminary assessment methodology. Full implementation is underway and described in Chapters 3 and 4.

1.2 <u>Habitat requirements for FMPs</u>

According to the statutory requirements (Federal Register 62, December 19, 1997, 66551), fishery management plans (FMPs) should contain:

(i) the habitat requirements for each life history stage for each species in the FMP;
(ii) a description and identification of EFH;
(iii) a description of fishing activities that may adversely affect EFH;
(iv) management options for mitigating adverse effects;
(v) identification of non-fishing effects;
(vi) a description of the cumulative and synergistic impacts of multiple effects;
(vii) a description of measures to promote and enhance EFH, particularly in habitat areas of particular concern;
(viii) a description of effects on EFH of loss of prey species;
(ix) identification of habitat areas of particular concern (HAPC);
(x) recommendations for future research; and
(xi) an allowance for subsequent review of EFH components.

There are several important tasks specified in the EFH guidelines, which are summarized under the following headings:

Information Development

- Produce a summary of all available biological information for each life history stage for each species
- Develop an inventory of available environmental and fisheries data to identify habitat-species data gaps
- Gather information on the current and historic stock size, geographic range of managed species, the habitat requirements and the distribution and characteristics of those habitats, by species life stage.

Designate and Evaluate

- Describe and identify EFH using information on distribution, density, growth, mortality, and production of each life stage and within all habitats occupied, or formerly occupied, by each species in the FMP.
- Assess whether, and to what extent a fishing activity is adversely impacting EFH
- Estimate the nature and extent of the adverse fishing impacts
- Assess the practicability of management measures. Examples of control options include fishing gear restrictions, seasonal/temporal area closures, and harvest restrictions.
- Identify and describe each non-fishing activity's likely impact on EFH

- For each non-fishing activity, describe the mechanisms, activities, and processes that cause adverse effects, and how these may affect habitat function.
- Describe and identify habitat areas of particular concern

Cumulative Effects

- Analyze how fishing and non-fishing activities influence habitat function on EFH, especially on habitat areas of particular concern, on an ecosystem or watershed scale.
- Describe and identify options to avoid, minimize, or compensate for the adverse effects of non-fishing or cumulative effects and promote conservation of EFH, and in particular habitat areas of particular concern
- Identify major prey species for species in the FMP, and describe the location of prey species habitat
- Describe and identify actions that cause a reduction of prey species population, including effects of loss habitat on prey species.

1.3 Structure of the document

Methodologies are described in this document under four main headings:

- Data sources
- Describing and identifying EFH;
- Identifying HAPCs;
- Addressing adverse effects of fishing on EFH; and
- Evaluating the consequences of the alternatives

The results arising from the application of these methods will be presented in later versions of this report and the DEIS in due course.

2 DATA SOURCES

To consolidate the available data and set the stage for a risk assessment that will underpin the EIS process, NOAA Fisheries in cooperation with the Pacific States Marine Fisheries Commission initiated a multi-faceted project as follows:

a) development of a GIS database that will display habitat types in comparison with known groundfish distribution/abundance and fishing effort;
b) conduct of a literature review and development of a database on groundfish habitat associations;
c) conduct of a literature review on fishing gear impacts to habitat; and
d) collection and analysis of information on fishing effort.

Add something on non-fishing impacts here?

2.1 GIS mapping of habitats

The first major requirement in mapping EFH, HAPCs and evaluating fishing impacts is the mapping of habitat itself. This was done using a geographic information system (GIS) created specifically for the EIS project. A GIS is the most effective and efficient way to analyze and present spatial information (see Text Box: A Primer on Geographic Information Systems).

Overall, the West Coast EFH GIS development has had two primary focuses: (1) generating and synthesizing new habitat information that was previously unavailable, and (2) compiling additional data sets that are as comprehensive as possible for the West Coast Exclusive Economic Zone (EEZ).

The integration of GIS datasets from disparate sources is an enormously complex and time consuming task. Merging together data from various sources presents many technical challenges, and requires numerous decisions about seemingly arcane, yet critical, details. For example, the large spatial extent of the West Coast EEZ combined with the need for highly detailed GIS data has caused the creation of GIS data sets that exceed the limitations of certain essential software algorithms. Therefore, alternative processing procedures have been developed to process and compile these data.

Often, procedures that are perceived to be “straightforward” and “seamless”, actually involve multiple intermediate steps and decisions about processing approach. For example, the benthic habitat data layers (described below), were provided in several geographic subsets. Ideally, they 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 small data gaps between subsets, (4) validating coding, (5) updating coding as new information is provided, and (6) projecting data to a common west coast projection. During these procedures, the goal was to remain as consistent as possible with the intent of the source data, while also creating comprehensive data coverage for the area of interest. In addition, wherever possible and practical, automated procedures were used, rather than more time-consuming manual editing procedures.

2.1.1 Physical habitat

2.1.1.1 Benthic Habitat Types

GIS data delineating the bottom-types and physiographic features associated with groundfish habitats were developed by experts in marine geology. 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. Benthic habitat data for California were developed by the Center for Habitat Studies at Moss Landing Marine Laboratories. 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 attached as Appendix X (to be developed).

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
- 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 (Table 1).

Table 1 Unique benthic habitat types have been delineated in the 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 criteria "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 the other rocky habitats in the classification, but retain an additional identifier indicating that it was predicted.

2.1.1.2 Bathymetry

Water depth is another key, physical characteristic which is used to delineate west coast groundfish habitat. Bathymetry data was compiled from various, disparate sources. All sources were individually contoured to 10-meter depth intervals, and compiled to create a GIS coverage delineating polygons of 10-meter depth ranges. The geographic extent of the final bathymetry data was set to the same extent as the benthic habitat data. In addition, the shoreline delineated by the benthic habitat data was used as the shoreline (i.e., 0-meter depth contour) for the bathymetry data, as well.

For California, Moss Landing Marine Lab provided 10-meter depth contours. 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 X (to be developed) (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 100-200 meters across, was filled by extending the ends of the contour lines to meet the shared boundary.

Because of the disparate nature of the bathymetry sources, the depth zones are discontinuous at the boundaries between data sources. No manual adjustment 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 visually assessment, this generalization process had minimal impact on the contour locations.

2.1.1.3 Latitude

Along the west coast, another primary determiner of groundfish habitat is latitude. Boxes delineating 1' latitudinal zones have been created and are overlayed with bathymetry and benthic habitat data to create a set of unique physical habitat polygons.

2.1.1.4 Data Quality

The benthic habitat maps 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 was available, or the data source was highly detailed, the interpretation will be of higher quality and accuracy.

A 'data quality' GIS layer indicates the degree of certainty that the mapped seafloor type represents the 'real' seafloor type. For Washington and Oregon benthic habitat maps, the Active Tectonics and Seafloor Mapping Lab at OSU has provided a data quality layer. The data quality layer was created by creating four separate 100-meter grids for each type of data (bathymetry, sidescan sonar, substrate samples, seismic reflection) and ranking the data sources on a scale of 1 to 10. The overall data quality layer is created by summing each of these individual data source quality layers. No data quality layer is currently available for benthic habitat in California.

2.1.2 Biogenic habitat

Biological organisms also play a critical role in determining groundfish habitat use and preference. For example, 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 will be compiled into a comprehensive data layer delineating kelp beds along the west coast. Kelp data compilation will be completed after June 30th, once final kelp data are available from Washington State.

A Primer on Geographic Information Systems

At its simplest level, a GIS is a sophisticated computer system capable of holding and displaying databases describing places and activities on the earth's surface to "paint a picture" of complex scenarios. Given that the majority of information pertaining to the marine environment has a spatial component, GIS and related geoprocessing technologies such as the global positioning system (GPS) and remote sensing provide a means to aggregate and analyze the data generated by disparate sources. GIS technology is rapidly replacing the traditional cartographic techniques that have typified most coastal mapping and resource inventory projects, and application to coastal and marine research and management efforts occurs worldwide.

A GIS is not simply a computer system for making maps, although it can create maps at different scales, different sizes, and with different colors and symbols. A GIS does not store a map in any conventional sense, nor does it store a particular image or view of a geographic area. Instead, a GIS stores the data from which the user can draw a desired view to suit a particular purpose. A GIS is also an analytical tool that allows the user to pose very complex questions to the computer, and receive answers in easy-to-interpret map form. The GIS database is a collection of spatial and tabular data depicting the location, extent, and characteristics of geographic features.

A 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...? It comprises layers of information occupying the same space so that users can rapidly analyze multiple conditions over wide areas. What a GIS cannot do, however, is generate scales of information that do not already exist in the input data. The scale of information that a GIS can analyze and display is fundamentally limited by the scale of the data that are used to create it.

2.2 Fish

2.2.1 NMFS Trawl Survey Data

Data from the National Marine Fisheries Service's west coast trawl surveys have been compiled and converted to GIS format. The surveys were conducted by the Alaska Fisheries Science Center and the Northwest Fisheries Science Center. These surveys census the groundfish occurring within the trawlable areas of continental shelf and slope out to approximately 1300 meters depth. 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.

These trawl survey data 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.

2.2.2 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 were 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 following 13 groundfish species and lifestages are available in GIS format:

Table 2 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

		Life History Stage							
COMMON NAME	**SPECIES NAME**	**adult**	**juvenile**	**mating**	**old juvenile**	**young juvenile**	**spawning**	**release of young**	**range**
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	

2.2.3 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 FMU) and the habitats they use. This section describes the information available on these relationships.

2.2.3.1 The Updated Life Histories Descriptions Appendix

In 1998 a document was appended to Amendment 11 to the Pacific Coast Groundfish FMP that describes 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[1] (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.

The 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. The draft of the updated appendix was prepared by Bruce McCain with assistance from Stacey Miller and Robin Gintner

[1] 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

of the NMFS, Northwest Fisheries Science Center. The draft was compiled by conducting literature searches using the *Cambridge Scientific Abstracts Internet Database Service*, and by reviewing recently completed summary documents, for example the California Department of Fish and Game's Nearshore Fishery Management, a draft nearshore fishes synopsis in a section of the Oregon Department of Fish and Wildlife's Nearshore Fisheries Management Plan, and the book *The rockfishes of the Northeast Pacific* by Love et al. published in 2002. Within the updated Appendix, the current 82 FMP groundfish species are sequenced alphabetically according to the common names (Appendix 1). This document also includes nine summary tables and a list of references cited.

The Appendix is therefore 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 NMFS 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.

2.2.3.2 The habitat use database

The Life Histories Appendix 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.

The Pacific Coast Grondfish 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 that 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.

The manual of the Habitat Use Database will be included as an appendix.

2.2.3.3 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. Since this methodology has potential for use in designating EFH and HAPC, we review it briefly here. It is 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).

Suitability index (SI) values are generated for important habitat characteristics. For example, one can calculate the likelihood of a species being present given a certain depth, latitude, and substrate type. In situations where trawl or other survey data are available, these can be used to generate SI values based on trends in species abundance with the habitat characteristic under consideration. For example, Figure 2 shows the change in the abundance of juvenile bocaccio with depth. The curved line is a mathematical model used to represent the data points shown on the graph. Table 3 shows how the data are used to calculate the HSI values.

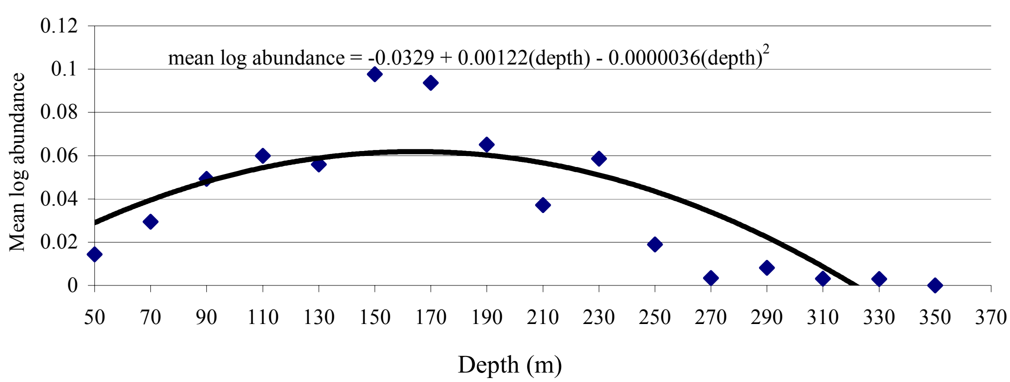

Figure 2 Polynomial regression curve fit with mean log abundance by categorical bathymetric class for juvenile bocaccio (graph provided by NOS).

Table 3 Example data matrix for calculating bathymetry SI values for juvenile bocaccio taken in NMFS trawl samples (Rubec et al., 1999).

Depth Class (m)	Effort (# of samples)	Mean log abundance	Predicted mean log abundance (x)	HSI (x/xmax)*10
50-69	219	.014	.019	3
70-89	361	.029	.035	5
90-109	447	.049	.048	7
110-129	489	.060	.058	8
130-149	398	.056	.065	9
150-169	252	.100	.069	10
170-189	200	.094	.070	10
190-209	213	.065	.069	10
210-229	182	.037	.064	9
230-249	98	.059	.057	8
250-269	92	.019	.047	7
270-289	89	.003	.034	5
290-309	74	.008	.018	3
310-329	98	.003	0	0
330-349	52	0	0	0

In data-poor situations, a literature review of the available information is carried out instead. Each reference provides a score indicating whether a species is present or absent within a given range for an environmental parameter. Presence/absence scores (1=present, 0=absent) are then summed for each range, and scaled by dividing by the maximum score. The resulting SI values range from 0 to 1, with 1 indicating highest suitability. For example, if authors of 5 out of 10 research studies said a certain fish was found between 50 and 100 meters, the SI score would be 0.5

Table 4 illustrates how SI scores are derived for each environmental parameter in the model, using depth as an example.

Table 4 Species occurrence table for presence of a species at different depths

	Depth category (m)				
Author	0-50	51-100	101-300	301-600	801-1000
Literature Reference 1	0	1	1	1	0
Literature Reference 2	0	1	1	0	0
Literature Reference 3	1	1	0	0	0
Literature Reference 4	1	1	0	0	0
Literature Reference 5	1	1	0	0	0
Literature Reference 6	0	1	1	0	0
Literature Reference 7	1	1	1	1	0
Total	4	7	4	2	0
SI Value	0.57	1.00	0.57	0.29	0.00

Species occurrence tables (also called matrices) are developed for each of the habitat characteristics in the model. Once SI values have been calculated for several habitat characteristics, by one or other of the methods described above, the values that relate to the conditions in each GIS map grid reference (i.e. based on maps of each of the habitat characteristics), are averaged and these averages are values are mapped. The resulting maps show the expected distribution of each species and life stage included in the analysis (Figure 3).

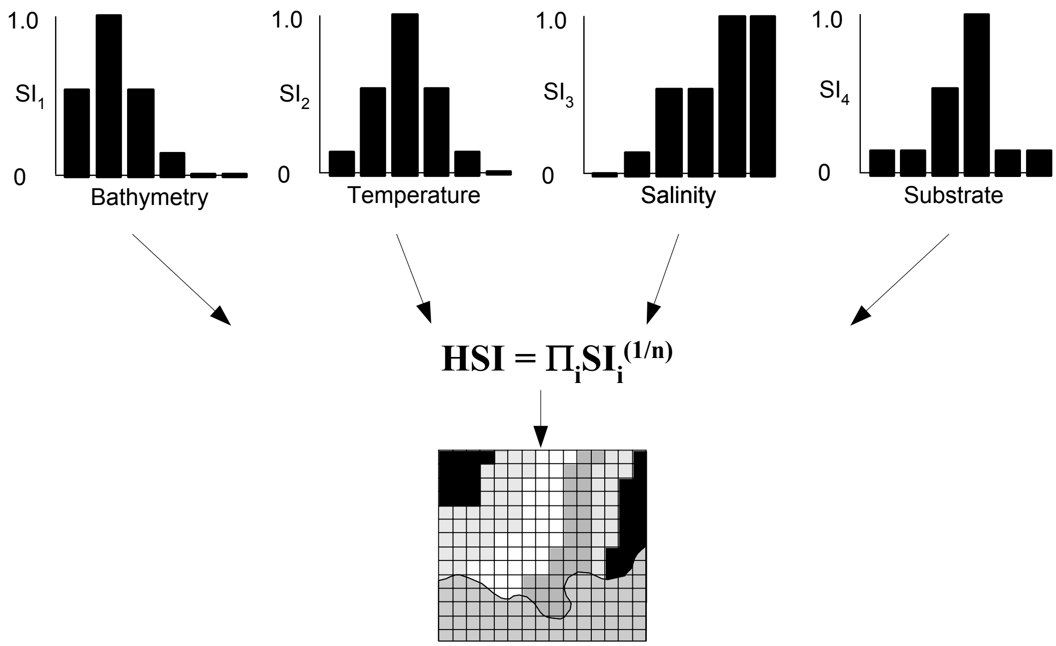

Figure 3 Mapping habitat suitability using SI scores

An important component of the HSI analysis is validation of the SI scores. For example, SI scores can be generated for an area that has survey or trawl data and then the predicted distribution of the species can be compared to the fish actually present, based on trawl and/or commercial fishery data. Alternatively, independent data from another source (e.g. recreational fisheries) can be used. For the model results to be considered valid, there should be a positive relationship between the independent abundance estimate and the SI score.

Initial testing of the HSI model for Pacific Coast Groundfish by independent trawl survey data and recreational catch data, indicates satisfactory model performance[2].

Currently, SI scores have been developed for 18 adult groundfish species from assessments of three central California marine sanctuaries. Depth and bottom substrate type were used as the habitat characteristics to examine habitat quality for benthic species. Mean sea surface temperature and depth were used to model pelagic species distribution. The substrate type consisted of two categories- hard and soft, although there are plans to further classify these to include, sand, mud, cobble, gravel, rock and boulders.

Additional work currently underway:

- using the HSI values to map species distribution across the entire west coast
- validation of the results

A report on the NOS HSI work will be provided as an appendix

2.3 Fisheries

2.3.1 Fishing gears

Summary of Fran's report

The Pacific States Marine Fisheries Commission has prepared a document that describes the fishing gears used on the west coast of the United States (excluding Alaska) and what components of those gears might affect structural habitat features. This gear description is one part of a 'fishing gear impact analysis' that requires an understanding of the gears used, how gear

[2] Spatial extrapolation of SI scores ideally requires that the following conditions are met:

- independence between the factors that are used to construct the SI scores; and
- sufficient variability in the studies so as to reflect conditions prevailing across the entire fisheries management area.

In addition, if the literature review approach is used, the literature studies should be carefully screened to ensure that differences in results between studies are genuinely related to habitat suitability, and are not confounded by differing methodologies, historical changes in habitat suitability (e.g. through pollution), changes in population size or density (e.g. through fishing pressure), or geographical location. Also, the references should contain no repetitions, for example through literature reviews or other citations of previous research findings

It seems unlikely that all these conditions have been fully met in the HSI approach. However, some model validation has been conducted, with favorable results.

affects habitat, the amount and distribution of fishing effort, and the sensitivity and resiliency of various habitat types.

The fishing gears report describes the types of fishing gear used on the west coast in potential groundfish essential fish habitat and the parts of the gear that might impact structural habitat features. It includes gear used by fishermen targeting groundfish as well as gear used to target other species.

Many different types of fishing gear are used to capture groundfish in commercial, tribal, and recreational fisheries. Groundfish are caught with trawl nets, gillnets, longline, troll, jig, rod and reel, vertical hook and line, pots (also called traps) and other gear (e.g. spears, throw nets). The groundfish commercial fishery is made up of "limited entry" and "open access" fisheries, with most of the commercial groundfish catch being taken under the limited entry program. There is also a tribal groundfish fishery and a recreational groundfish fishery. Table 5 summarizes the gear used by each of these sectors

Most fishing gear used to target non-groundfish species (such as salmon, shrimp, prawns, scallops, crabs, sea urchins, sea cucumbers, California and Pacific Halibut, herring, market squid, tunas, and other coastal pelagic and highly migratory species) is similar to those used to target groundfish. These gears include trawls, trolls, traps or pots, longlines, hook and line, jig, set net, trammel nets. Other gear that may be used includes seine nets, brush weirs, and mechanical collecting methods used to harvest kelp and sea urchins. These gear is described in section D, below.

Gear types in the PACFIN database are listed in Appendix 2

Table 5 Gear Types Used in the West Coast Groundfish Fisheries [6]

May need to update this with Fran's recent spreadsheets

	Trawl and Other Net	Longline, Pot, Hook and Line	Other
Limited Entry Fishery (commercial)	Bottom Trawl Mid-water trawl Whiting trawl Scottish Seine	Pot Longline	
Open Access Fishery Directed Fishery (commercial)	Set Gillnet Sculpin Trawl	Pot Longline Vertical hook/line Rod/Reel Troll/dinglebar Jig Drifted (fly gear) Stick	
Open Access Fishery Incidental Fishery (commercial)	Exempted trawl (pink shrimp, spot and ridgeback prawn, CA halibut, sea cucumber) setnet driftnet purse seine (round haul net)	Pot (Dungeness crab, CA sheephead, spot prawn) longline rod/reel troll	dive (spear) dive (with hook and line) poke pole
Tribal	as above	as above	as above
Recreational	dip net, throw net (within 3 miles)	Hook and Line methods Pots (within 3 miles) (from shore, private boat, commercial passenger vessel)	dive (spear)

A list of gear types used on the west coast is found in the "Notice of the Continuing Effect of the List of Fisheries" published in the Federal Register Vol 67, No. 12, Thursday January 17, 2002; http://www.nmfs.noaa.gov/prot_res/PR2/ Fisheries_Interactions/list_of_fisheries.html (could not access this URL). This list of commercial fisheries includes salmon net pen aquaculture and Washington and California kelp harvest. These activities are not included in this fishery gear description, but are described under the non-fishing effects section of the EFH environmental impact statement. The list does not include ghost shrimp pumping nor the poke pole fishery which are briefly described in the Commission's fishing gears document.

[6] Adapted from Goen and Hastie, 2002

2.3.2 West Coast Perspective on Fishing Gear Impacts

At its meeting on February 19-20, 2003, the Technical Review Committee reviewed the proposed risk assessment framework and recommended that Pacific States Marine Fisheries Commission contract for development of an index of fishing gear impacts by gear type that will serve as an input into the overall risk assessment. The Committee suggested that, while several literature review and indices exist that may be utilized for this project, there is no clear direction on how that information should be applied to the west coast. As justification for the recommendation, the committee cited the general lack of west coast specific studies and the need to determine specifically how to make inferences from studies that occurred in other parts of the world.

A project is currently underway that is utilizing currently available information to develop a draft index of adverse effects for fishing gears that are utilized on the west coast. For purposes of the analysis, adverse effects of fishing gear are defined consistent with NMFS EFH Final Rule and include "direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH" (50 CFR part 600.810). A written report that details and justifies interpretive decisions will accompany the draft index. The index is being developed alongside the risk assessment model and other information that is being applied to the EIS.

In due course, a draft report and effects index will be presented to the Council's committees in order to solicit recommendations. Based on the nature and extent of recommendations gained in committee, improved drafts may be prepared prior to briefing the full Council.

2.3.3 Fishing effort

In order to explore the effects of fishing on specific areas of fish habitat, we need an understanding of the extent and frequency, by gear and geographic location of fishing activity across the area covered by the FMP.

A summary of data sources for fishing effort is shown in Table 6 :

Table 6 Summary of sources of fishing effort data

(to be completed)

Data source	Scale/Units	Comments

Data source	Scale/Units	Comments

2.3.3.1 Commercial fishery

West coast commercial trawling effort has been recorded in logbooks and provided to state fisheries managers since 1987. These logbook entries include the starting point of the trawl, either by latitude/longitude or by logbook block number, the tow duration, the gear used, and the estimated weight of the catch for several species or species groups. The Pacific States Marine Fish Commission (PSMFC) created and maintains a comprehensive database (PACFIN) for commercial fishing data which includes west coast trawl logbook data. Commonly, the commercial trawling data are summarized geographically by the logbook blocks (usually 10-minute blocks).

As part of a larger project[3], Ecotrust, using data provided by PSMFC, has generated GIS data of annual summaries of west coast logbook data for 1987 to 2000. Annual trawl logbook effort is summarized by number of tows or total duration in hours by logbook block. In addition, annual summaries by the following PACFIN gear types are provided: groundfish trawl, midwater trawl, roller trawl, other trawl, pair trawl, flatfish trawl.

Effort data for the non-trawl commercial fishery (hook and line, longline, pot/trap) are also available per vessel (fake id), recorded by port-based fish tickets. Data available from PacFIN includes year and port where catch was landed, type of gear used, vessel length, species landed, prices and revenues, and International North Pacific Fisheries Commission (INPFC) area. Eight of these regions exist, each covering areas of thousands of miles.

Ecotrust has developed a predictive model to further resolve this information to levels consistent with the commercial trawl data (Ecotrust, 2003). Using this predictive model, catch in pounds and revenue in dollars are assigned to a specific 9 km block. The catch and revenue by 9 km block are also summarized by the following gear groups: hook and line, longline, pot and trap, trawl, and other gear. GIS data resulting from this model were provided for two years, 2000 and 1997.

2.3.3.2 Recreational fishery

The recreational fishery sector comprises the commercial passenger fishing vessel (CPFV) fleet (charters), private fishing vessels and other miscellaneous fishing activities. The Marine Recreational Fishery Statistics Surveys (MRFSS) is perhaps the most comprehensive, collecting information on all elements of the recreational fishery. This is a nationwide survey conducted since 1979, with the exception of 1990-2. Information is elicited through telephone surveys and

[3] Groundfish Fleet Restructuring Information and Analysis (GFR) Project (see www.ecotrust.org/gfr).

port interviews, and is collected on mode of fishing (e.g. charter, pier), catch information, distance from shore, and catch reference area. The questionnaire also makes provision for information on gear type use (see http://www.psmfc.org/recfin/). As expected, with a questionnaire of this nature, spatial resolution of the catch reference area is relatively poor. The California Department of Fish and Game collects species information on CPFV fishing and is apparently available at a 10nm by 10nm resolution from 1936 through 1997.

3 MODELING THE STATUS OF FISH HABITAT

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, designating HAPCs and mitigating fishing impacts on EFH. The guidelines advocate using information in a risk-averse fashion to ensure adequate protection of habitat for all species in the management units.

In this study, we develop a modeling approach for assessing the status of fish habitat and the risks to habitat function posed by fishing activities in the area covered by the Pacific Coast Groundfish FMP. The model is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing management alternatives for designation EFH, HAPCs, and management scenarios that are designed to mitigate specific risks to habitat and ecosystem function.

Bayesian Belief Networks were chosen as a suitable analytical tool (see Sections 3.2 and 3.3) . The models have been designed to take advantage of the GIS data and literature review under development by NOAA Fisheries. It is recognized that this assessment is occurring in a data-poor environment and therefore must be expressed in terms of probabilities rather than hard numbers. In these situations, the models have been structured to express limitations on each component of the assessment in conjunction with a best estimate in answer to fundamental questions of habitat function. Presentations of the methodology were made to the Technical Review Committee (TRC) of the Pacific Fishery Management Council. Proper adjustments to the methodology were made based on input of the TRC.

We implemented the methodology with the goal of, to the extent possible, answering the questions listed below for Pacific coast groundfish. Limitations on answering these questions were encountered, particularly in regards to the availability of data for model parameterization. Hence, further work will involve developing an initial suite of alternatives for EFH and HAPC designation and management measures in consultation with NOAA Fisheries as well as an analysis of the projected effects of alternatives on groundfish habitat.

- What areas could qualify as essential pursuant to section 303(a)(7) of the Magnuson Act?

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

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

3.2 Network models

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 following diagram:

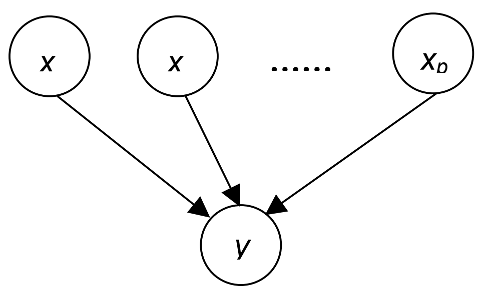

Figure 2 Explanatory variables directly impacting on a response variable

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 3, 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*.

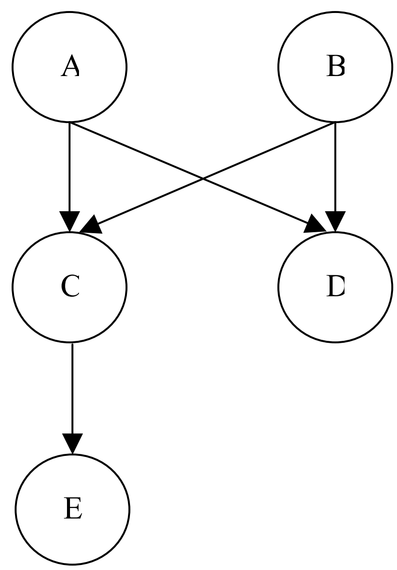

Figure 3 Indirect mediation of effects of explanatory variables

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 jargon, 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 BNs 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 5 for sources of information on BNs). A growing area of interest is the management of natural resources under uncertainty. For example, a BBN 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 which 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.

A model with these properties, after specifying the probabilities that govern the links, is called a *Bayesian Belief Network*, or just a Bayesian Network (BN). 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 of Figure 3. For simplicity, assume that all of the nodes are binary variables, taking values T or F (true or false). The probabilistic mechanism which 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 Essential Fish Habitat

3.3.1 Introduction

The M-S Act defined essential fish habitat 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 identification of sufficient EFH 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 are developing 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. In addition, 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 to be overfished, the EFH identification should be reviewed and amended, if appropriate (EFH Final Rule CFR 600.815(a)(1)(iv)(C)). A list of the Gulf of Mexico species that are considered to be overfished or experiencing overfishing is provided in Section 3.2.4. Fish stocks depleted by overfishing, or by other factors, tend to not use as much of the available habitat as a virgin stock or a stock at optimum biomass would use. The picture is complex, however, because other species may have expanded their range to fill some of these ecological niches.

3.3.2 Habitat characteristics of importance for fish

Habitat characteristics comprise a variety attributes and scales, including biological, physical (geological), and chemical parameters, location, and time. It is the interaction of environmental variables which 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, interannually, 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 designated for the fishery as a whole (16 U.S.C. §1853(a)(7)). The 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 maps 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 describing and identifying EFH is carried out at the fishery (FMP) level, the determination of whether an area should be identified as 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 83 species. Descriptions of groundfish fishery EFH for each of the 83 species and their life stages resulted in over 400 EFH identifications in the 1998 EFH Amendment. When these EFHs were taken together, the groundfish fishery EFH 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.

Some see this as a weakness in the EFH designation process, because if EFH is "everything" then the designation process apparently fails to focus conservation efforts on habitats that are truly "essential." However, this conclusion fails to 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. What the designation of EFH at the FMP level does is delineate the reference area for consultation purposes. A consultation process will be triggered when an agency plans to undertake an activity that potentially impacts habitat within 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 Types and levels of information

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 model for identifying EFH we wish to express the probability that a particular location contains suitable habitat for a given species life stage, based on our knowledge of the environmental conditions within that habitat and of the species/life stage's biological niche. 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 are notoriously difficult to obtain. Fish population density, or even presence/absence in data-poor situations (levels 2 and 1 described above) 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 & 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 & 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 designation should be acting to protect areas that would have high growth potential if protected, or whether we 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.

In accordance with this theoretical discussion, 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. 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 each species and life stage. If higher level information is available only for a portion of the species/life stage range then a decision needs to be made regarding how the information should be used – for example can the knowledge from the portion of the range covered be extrapolated to the rest of the range? In accordance with the requirement to use the highest level of detail available, the highest-level information should be used for the portion of the species/life stage range for which it is available, or to which the information could be validly extrapolated. Information at lower levels should be used only where higher-level information is unavailable and cannot be validly extrapolated.

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. 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. 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.

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 (Figure 2.1.1). As the information used to describe and identify EFH becomes less complex, so the area identified as EFH is likely to grow. For example, a determination based on areas where of production rates are highest is likely to result in a smaller area than a determination 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. This increase in the extent of EFH as the level of available information drops is in accordance with the risk-averse approach required by the EFH Final Rule. However, it is not always the case that the EFH identified based on the higher level of information will be entirely within the area identified based on the lower level. For example, a designation based on the areas of highest density (level 2) might not necessarily encompass the areas of highest productivity for some life stages (see discussion above).

Identifying a large area, based on distribution, would seem to be the most risk averse approach, but it is not sufficient to designate a large area of habitat as EFH 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 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.

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 of the levels of detail described in the EFH Final Rule may exist in both of these categories. Examples of such are provided Table 7.

Table 7 Types of information at the four levels of detail described in the EFH Final Rule

Replace contents of table with what is actually available (where it is). Indicate what is not available, but would be desirable

	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 probability of occurrence, or other forms of HSM

Level 1 – distribution data	Trawl survey data and the NOAA Atlas (Sections 2.2.1 and 2.2.2)	Simple habitat-species associations (Section 2.2.3)

Virtually no information at levels 3 and 4 exist for Pacific coast groundfish, and none that 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.

3.3.5 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), but there are minimal data for many of the species and life stages. The main sources of data for the EFH model are the habitat suitability indices resulting from the NOS project (Section 2.2.3.3) and the habitat use database (Section 2.2.3.2). Appendix 3 provides a discussion of the implications of using from these two main data sources. Although the use of habitat suitability indices in designating EFH does raise the concerns expressed in Section 2.2.3.3, these concerns can be alleviated to some extent by rigorous validation of HSI models under a range of conditions(see Section 3.3.6), for example, using trawl survey data (Section 2.2.1) and commercial fishery data, and by careful selection of the data sources used to build the HSI models. It would also be worth exploring whether particular life stages give a better indication of an area's growth potential than others; in this context, the presence of juvenile stages or of spawning-age adults may be particularly useful in the identification of EFH.

3.3.5.1 Current model specification

In our BN model for EFH designation, we use physical variables obtained from the GIS, combined with an HSI score or information from the habitat use database, to give a probability that a particular area is suitable habitat for a particular species or life stage. Figure 4 provides an indicative influence diagram for the EFH model. In this example, the *observed* characteristics were substrate = "sand", depth in range "depth3" and latitude in range "lat3". Data quality was "lo" for substrate and "med" for depth. The resulting probability that the parcel is suitable habitat for Species Sp1 (life-stage LS1) is 4.2%.

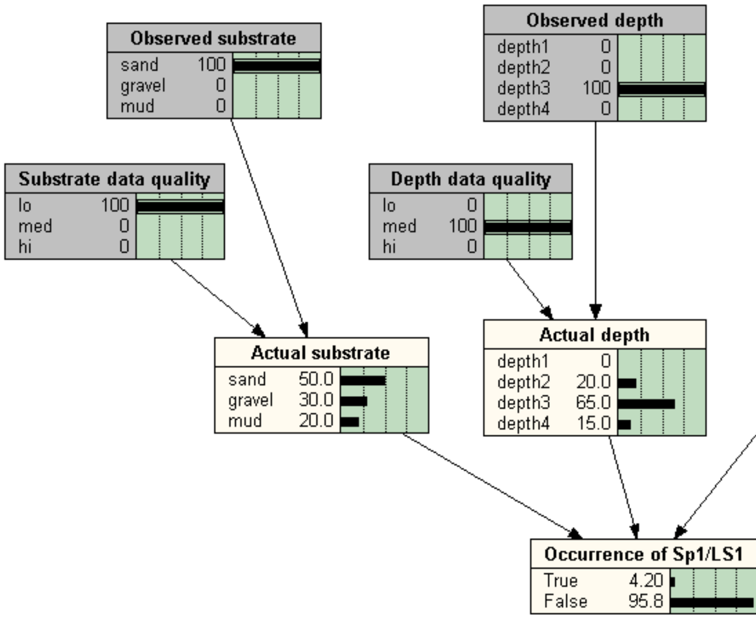

Figure 4 A simple EFH model with 4 depth ranges, 3 substrates and 5 latitude ranges substrate and depth data quality nodes (assuming these are available)

3.3.5.2 Treatment of uncertainty

There are a number of sources of uncertainty in determining the physical characteristics of a potential EFH parcel. These include:

- measurement errors (e.g. when a parcel has a probability of being assigned to one substrate type or depth when in fact it is another - caused by the methods used for assignation);
- transition zones (e.g. between 2 substrate types, or areas where depth changes sharply); and
- genuine mixtures within the parcel (e.g. gradual changes in depth or latitude).

The extent to which each is important will vary with the physical factor being measured (measurement error being more likely for substrate type than for latitude, for example). It will also vary with the degree of spatial resolution of the GIS and the size of EFH parcels.

As currently formulated, the model is focussed on the effect of measurement error, because it is demonstrating the procedure for assigning EFH by substrate type. It is assumed that there are several methods of determining substrate type within a potential EFH parcel. One method may give near-100% certainty that the substrate type recorded is actually present, the other method may only give 40% certainty. If there is uncertainty in the assignation of substrate type, it is necessary to adjust the expected substrate mix within the parcel to reflect the other possible substrates that may be present. This requires that some ground-truthing of the method has taken place, so that these probabilities can be assigned.

An alternative to this formulation for data quality is instead to give an EFH parcel a probability of having a certain physical characteristic (such as being mud) based on the characteristics of the surrounding parcels; hence a parcel in the middle of a mud area that is estimated also to be mud would have 100% probability of being mud, whereas a parcel near the edge of the area, which is thus likely to be in the transition zone between mud and sand, would be assigned a lower probability of being mud and a correspondingly higher probability of being sand. This would better reflect the issue of uncertainty in transition zones.

3.3.5.3 Identification of EFH

A probability is calculated that a parcel is of a particular substrate type (or depth range or latitude), based on the uncertainty in the data. These probabilities are combined to give an expectation of the substrate mix within the parcel. For each substrate type, a habitat suitability score is available. Hence the final probability of a parcel being suitable for a given species or life stage is the combination of the expected substrate mix and the suitability score for each substrate type. A similar procedure is envisaged for depth and latitude (with appropriate modifications to account for differing sources of uncertainty). The identification of EFH can then proceed by selecting a threshold probability value above which the parcel is deemed to be EFH, and below which it is not.

3.3.6 Validation of model results

To be completed

3.4 Habitat Areas of Particular Concern

3.4.1 Introduction

The EFH regulations encourage regional Fishery Management Councils to designate habitat areas of particular concern (HAPC) within areas identified as EFH to focus conservation priorities on specific habitat areas that play a particularly important role in the life cycles of federally managed fish species. EFH potentially encompasses a very broad range of habitat used by managed species. The designation of EFH is focussed on the habitat needs of individual species and life stages. EFH designation does not identify or attempt to add additional protection for areas of habitat within EFH that are most important to the survival and productivity of managed species, or particularly in need of protection for some other reason. EFH could be a very large component of the Pacific Coast ecosystem. However, identifying a few most important habitat areas as HAPC on the basis of their habitat attributes encourages a higher level of scrutiny for conservation, will afford those habitats extra protection, and give the fish species that occur there an extra buffer against adverse impacts. HAPCs may be designated for purposes other than mitigating adverse fishing impacts. This is reasonable since there may be some habitats that in an area that is stressed, but for which the threat from fishing activities is low.

3.4.2 Habitat considerations for designating HAPC

Whereas EFH must be described and identified for each species and life stage in the FMUs, HAPCs are identified on the basis of habitat level considerations. The Final Rule lists the following considerations that should guide the designation of HAPCs (50 CFR 600.815 (a) (8)):

- The importance of the ecological function provided by the habitat;
- The extent to which the habitat is sensitive to human-induced environmental degradation;
- Whether and to what extent development activities are or will be stressing the habitat; and
- The rarity of the habitat type.

Musick (1999) proposed using three principles to determine important habitat areas: utilization, availability, and vulnerability. DeAlteris (2002) advanced this concept by recommending priorities for habitat conservation inversely related to availability (comparable to the concept of rarity in the above list) and directly related to utilization (comparable to ecological importance) and vulnerability (comparable to sensitivity and stress). DeAlteris quantified these principles in evaluating effects of mobile fishing gears for the NE United States in making recommendations for prioritizations of fish habitat.

The designation of HAPCs is intended to identify to anyone considering actions that might be potentially threatening to habitat those areas of EFH considered to be of the highest importance in the life cycles of managed species and most in need of protection. An HAPC is expected to be a localized area of EFH that is especially ecologically important, sensitive, stressed, or rare when compared to the rest of EFH.

3.4.2.1 Ecological importance

In the context of this EIS, the ***ecological importance*** of a habitat stems from the function that it provides to the managed fish species. However, the Final Rule is not explicit regarding the metrics that should be used for measuring ecological importance Pacific coast fish utilize many types of habitat. A variety of approaches could be used to measure or represent ecological importance, including:

- habitats that support the ecological activities of a larger number of managed species life stages;
- habitats that support important ecological functions of managed species (bottlenecks); and
- habitats that support species that play an important role in the food web (e.g. forage species)

Insert description of the method for measuring ecological importance in the BN model – to be developed from the bullet list above

3.4.2.2 Sensitivity to human-induced environmental degradation

Human induced environmental degradation can result from both fishing activities and non-fishing activities such as coastal development and pollution. Certain habitat structures such as relief, hard/live bottom, kelp beds, seagrasses, and marshes are particularly sensitive to human-induced environmental degradation. They are sensitive to fishing gears and other activities such as dredging, mining, pipeline construction, coastal development, shipping, contaminants, and disposal.

Metrics for sensitivity should consider the inherent susceptibility of habitats to fishing and non-fishing impacts that are likely to result in impairment of the function of the habitat for fish species. This does not mean these impacts and the impairment have occurred, are occurring or will necessarily occur in the future. It is a measure of the potential for impairment given the types of activities that could affect the habitat, and the natural characteristics and situation of the habitats themselves.

An evaluation of fishing impacts is important both in the identification of potential sites of HAPC and to provide guidance on the types of impacts that need to be prevented, mitigated, or minimized under the requirements of the EFH Final Rule (600.815(a)(2)). In addition to providing a metric for identifying HAPCs, the evaluation of non-fishing impacts contributes to the evaluation of the likely benefits of possible modifications to fishing activity by providing information about cumulative impacts. Bearing in mind that only reasonably foreseeable changes to non-fishing activities can be considered in this EIS, an evaluation of non-fishing impacts is important in evaluating the practicability of the fishing impacts alternatives.

3.4.2.2.1 Sensitivity of habitats to fishing impacts

Different fishing gears affect habitats to different degrees. Mobile gears, such as bottom trawls and dredges, have a potential to affect habitat over a wide area, because the gear is in direct contact with and moves across the substrate and any biogenic structures. Non-mobile gears fish primarily in a fixed location, so their direct effects on habitat are generally confined to that location or "footprint." The damage from a single encounter in either case can range from negligible to severe. However, the adverse effects on EFH of fishing that are to be prevented, mitigated, or minimized relate to the functional relationship between habitat and fish.

Insert the sensitivity matrix from the west coast impacts analysis – to be completed

3.4.2.2.2 Sensitivity of habitats to non-fishing impacts

A number of non-fishing impacts to EFH occur throughout the Pacific coast region. These impacts include a variety of physical, water quality, and biological effects.

The analysis of non-fishing impacts should be conducted using a three-staged approach:

1. evaluate sensitivity of each habitat type to each potentially impacting non-fishing activity
2. develop quantitative and spatial measure of non-fishing impacts
3. estimate the habitat stress from non-fishing impact on the finest spatial scale possible.

(see below for stages 2 and 3)

e.g see approaches recently used in habitat and ecological stressor evaluations in the Tampa Bay area and elsewhere (Hession *et al*., 1996; Jackson *et al*., 2000; Kurz *et al*., 2001; Kurz *et al*., 2002).

3.4.2.3 Stress from development activities

Assessing the extent to which development activities are stressing or will stress areas of habitat requires knowledge of the spatial distribution of those activities in the past, present and possible future in relation to local habitats. To obtain a measure of the risk that an area is or will be stressed by development activities, data on the spatial intensity of these non-fishing activities must be combined with the sensitivity of habitats to impacts that they might cause.

The consideration of stress of habitat areas from development activities in identifying HAPCs offers two possible interpretations. First, identify stressed areas or areas likely to become stressed as HAPC. This approach is based on the concept of rehabilitation of areas for which recovery is possible. Secondly, identify areas free of stress as HAPC. This approach is based on the concept of protecting pristine areas through an increased conservation focus on the area. While many areas of the Gulf of Mexico have experienced irreversible stress from development (shoreline armor, dredge and fill), the continuum from pristine or nearly so to seriously degraded but capable of recovery covers a large amount of the Gulf of Mexico.

The interpretation used here is that the intention of the inclusion of the stress consideration for HAPC in the EFH Final Rule was to identify areas that are more stressed or in danger of becoming more stressed. The expectation is that areas that are pristine and are ecologically important for managed species will be identified through one or more of the other three considerations.

3.4.2.3.1 Distribution of development activities

To quantify the effects of non-fishing activities, GIS data that represented these activities need to be gathered from various sources throughout the Pacific coast region. Possible sources include the USGS, NOAA, USACOE, MMS, EPA, and local government agencies. Types of activities include the following:

- Dredge and fill (area in acres and numbers of fill points) – e.g. number of acres of dredge and fill within each statistical Point values can be created from the following data: aids to navigation, oil/gas structures, and marine facilities. These data are indicators of dredging since this would typically occur to facilitate passage of vessels in intercoastal waterways and access to marinas.
- Shoreline hardening (length in miles) – e.g. number of miles of shoreline modification values created from the following data: Environmental Sensitivity Index Shoreline.
- Impingement/entrainment/thermal impacts (point) – e.g. number of impingement and thermal points within each Statistical Zone.
- Structural Shading (points) – e.g. structural shading point values created form the following data: Marine Facilities (docks/piers) and Oil/Gas Structures (platforms).
- Boating Impacts (points and area in acres) – e.g. number of boating activity points ; number of acres of boating activity
- Altered Freshwater Inflow (points) – e.g. number of dams within a statistical zone.
- Point Source Pollution (points) – e.g. number of pollution points created from national pollution points maps (EPA).
- Non-Point Source Pollution (area in acres) – e.g. based on the total area of urban and agricultural land use (from USGS) within the contributing watersheds for a given statistical zone.
- Oil/Gas Operations (points, lines) – e.g. number of oil and gas operations and number of miles of oil and gas pipelines recorded within a statistical zone created from MMS database.
- Industrial Spills (points) – e.g. number of reported industrial spills from EPA databases.
- Toxic release (points) – e.g. number of toxic release points within each statistical zone created from EPA databases.
- Hypoxia (area in acres) – e.g. zones of low oxygen conditions.
- Harmful Algal Blooms (points) – e.g. from harmful algal bloom databases.

3.4.2.3.2 Risk of habitat stress from development activities

The third tier of the analysis is to develop the measure of stress. Risk of habitat stress depends on the sensitivity of the habitat to non-fishing (development) activities, and the intensity of those activities on a local scale. For each habitat type, habitat zone and non-fishing impact type:

$$\textbf{\textit{risk of habitat stress}} = \textbf{\textit{sensitivity to non-fishing impact}} \times \textbf{\textit{intensity of non-fishing activity}}$$

3.4.2.4 Habitat rarity

Musick (1999) recommended considering the availability of habitat in evaluating the need for habitat protection. Similarly, DeAlteris (2002) recommended an inverse relationship between availability (equivalent to a direct relationship with rarity) and habitat protection. If a habitat is ecologically important, and it is also rare, then the benefit of protecting it from adverse impacts will likely be greater than if it is more common. A unit loss of more rare habitat will likely cause a higher loss in production for the species using that habitat, than for more common habitat, where species have the opportunity to utilize other areas with similar habitat characteristics.

Calculation of habitat rarity requires subdivision of the total area into parcels of contiguous patches of a single habitat type, characterized, for example, by substrate/biogenic structure type, depth, and latitude. Ideally, the parcels should be of the same sort of local scale as that envisioned in the EFH Final Rule, so that the analysis can be used to identify viable candidate areas for HAPCs.

The ***rarity*** of a habitat parcel can be measured in terms of the mapped area of the habitat type relative to the total area of all mapped habitat types multiplied by the distance to the nearest neighboring parcel(s). Calculations of this type can be implemented relatively easily in a GIS that maps out all the habitats. The following is an example of a habitat rarity index calculation:

$$\text{Rarity Index Score for habitat type within Unit} = \frac{\text{Total Area of Unit}}{\text{Total area of habitat type within the Unit}} \times \text{Average of the nearest neighbor distance for the parcels of habitat type within the Unit}$$

Need to check on the effects of the nearest neighbor distance component of this formula

3.4.3 <u>BN model for identification of HAPCs</u>

3.4.3.1 Decision tree

The basic process of identifying HAPCs on the basis of the four considerations is illustrated in the decision tree in Figure 5. According to the current form of the decision tree, candidate areas must, in addition to meeting the "high" thresholds for one or more of the four considerations, meet a minimum threshold for ecological importance (in the current specification, the habitat use index must be above the lowest quartile). The rationale for this is that if an area is not above this threshold level of importance for the managed species from an ecological standpoint then it should not be identified as an HAPC. In practice, any area identified as a potential HAPC that does not meet this threshold would probably not be within any of the areas identified as EFH in any case. However, this will not be known until decisions have been made on the EFH alternatives.

The EFH Final Rule states that HAPCs are localized areas that are especially vulnerable or ecologically important. The decision tree refers to "EFH parcels" which are parcels or polygons identified in the GIS with particular levels for each of the indices linked to the four considerations.

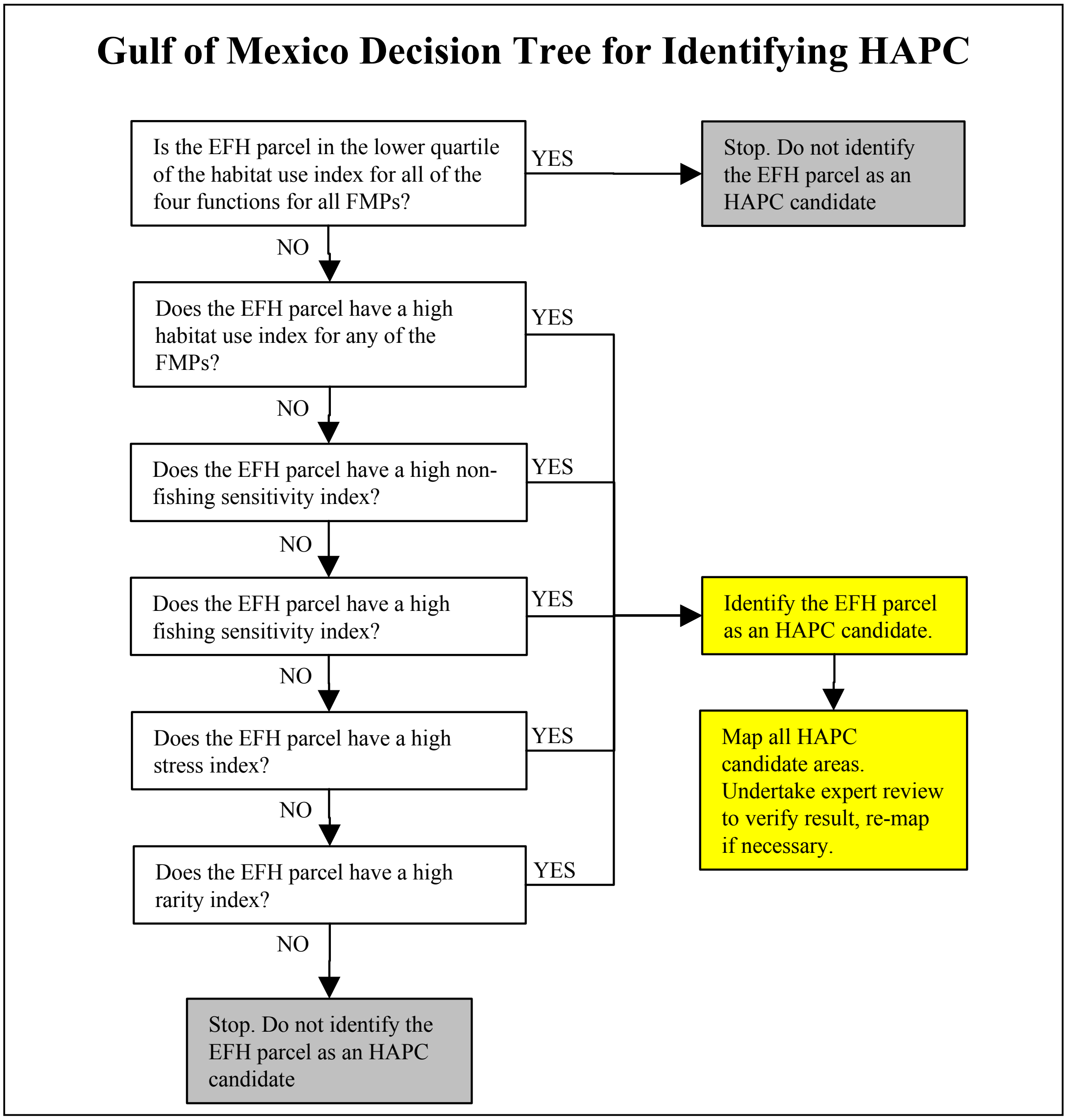

Figure 5 Decision tree for identifying HAPC candidate areas

3.4.3.2 Current model specification

At this stage we have developed only a preliminary network model to describe and identify habitat areas of particular concern (HAPC). The metrics for the considerations described in Section 3.4.2 could provide a basis from which to develop such a model, with nodes reflecting ecological importance, habitat sensitivity, habitat stress and habitat rarity. Figure 6 provides a simple diagrammatic representation of such a model.

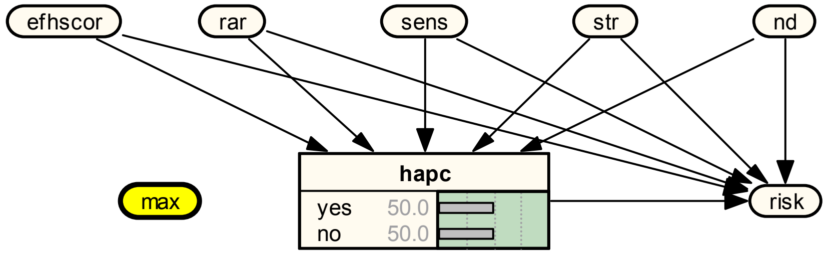

fig5.dne

Figure 6 Influence diagram for the BN model for identification of HAPC candidate areas

Each state within a node represents a score, quartile or similar measure for that characteristic. It is relatively easy to use the model to determine HAPC by measuring whether each characteristic exceeds a management threshold. Different thresholds may be defined for different characteristics. In terms of the regulations, if one of the nodes exceeds a threshold in a given habitat parcel then an area is defined as HAPC. In addition it is possible to then estimate a combined score for each of the nodes (as indicated by the node risk), based on a weighting of importance.

3.4.4 Validation of model results

To be completed

3.5 Fishing Impacts

3.5.1 Introduction

Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature. Each FMP must therefore be amended, as necessary, to prevent, mitigate, or minimize to the extent practicable adverse effects from fishing on EFH, including EFH designated under other Federal FMPs (600.815(a)(2)(ii)). In addition, Federal agencies must consult with NOAA Fisheries on Federal projects that may adversely impact EFH. These requirements recognize that both fishing and non-fishing actions may adversely affect fisheries productivity through a variety of impacts on EFH.

The EFH Final Rule (50 CFR 600.815(a)(2)(ii)) establishes a threshold for determining which fishing activities warrant analysis to prevent, mitigate, or minimize to the extent practicable the adverse effects of fishing on EFH:

> "Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature, based on the evaluation conducted pursuant to paragraph (a)(2)(i) of this section and/or the cumulative impacts analysis conducted pursuant to paragraph (a)(5) of this section."

As discussed in the preamble to the EFH Final Rule at 67 FR 2354, management action is warranted to regulate fishing activities that reduce the capacity of EFH to support managed species, not fishing activities that result in inconsequential changes to the habitat. The "minimal and temporary" standard in the regulations, therefore, is meant to help determine which fishing activities, individually and cumulatively, cause inconsequential effects to EFH.

In this context, temporary effects are those that are limited in duration and that allow the particular environment to recover without measurable impact. The following types of factors should be considered when determining if an impact is temporary:

- The duration of the impact;
- The frequency of the impact.

Minimal effects are those that may result in relatively small changes in the affected environment and insignificant changes in ecological functions. Whether an impact is minimal will depend on a number of factors:

- The intensity of the impact at the specific site being affected;
- The spatial extent of the impact relative to the availability of the habitat type affected;
- The sensitivity/vulnerability of the habitat to the impact;
- The habitat functions that may be altered by the impact (e.g., shelter from predators)
- The timing of the impact relative to when the species or life stages need the habitat.

3.5.2 Fishing impacts review

To be completed (see also Section 2.3.2)

3.5.3 BN model for fishing impacts

3.5.3.1 Current model specification

In this section, a simple model is developed to assess the impacts of alternative gear types on fish habitat. The model is parameterized to take advantage of a range of existing data sources. Figure 7 presents a simple influence diagram categorizing interactions between variables:

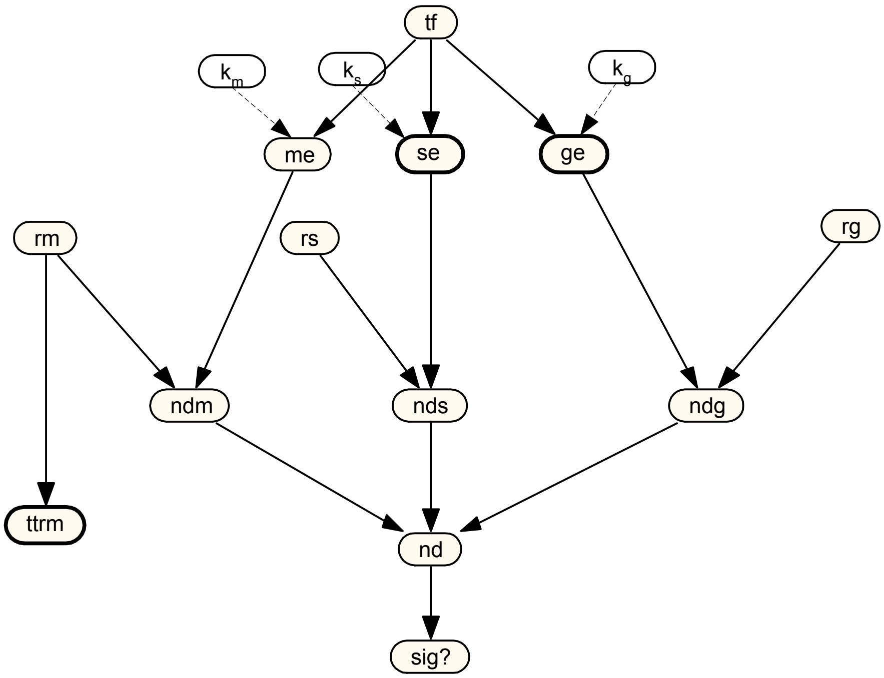

Figure 7 Influence diagram to estimate total impact of fishing gear

Total footprint (tf) is the proportion of a particular habitat parcel covered by a gear type. For trawls, the area is calculated as the product of width, total duration, and speed. Since the effort database currently contains information on total duration and set point location per vessel and per gear type, it is possible to determine the location of effort. However, since direction is not recorded, the proportions of any given area impacted can only be approximated. In the model, this is represented as a probability distribution.

Total footprint is multiplied by the proportion of each substrate type in habitat, to obtain an estimate of area trawled for each substrate. The implicit assumption is that trawl effort is uniform across substrates, in other words that fishing vessels do not favor fishing areas containing a particular habitat type. The proportion of each substrate trawled is then multiplied by a damage sensitivity score (k) for each substrate to derive a total damage for that substrate. In the influence diagram, three substrates are illustrated, mud (me), sand (se) and gravel (ge). Sensitivity of substrate to damage (k) is either represented as a constant, or, more likely, a probability distribution as reflected in the influence diagram (k_m, k_s and k_g). The relationship is indicated with a dotted line in the network diagram.

In a dynamic context, damage combines with habitat recovery in some functional relationship to obtain a net impact. In the network model, this is reflected in nodes for each substrate (ndm, nds and ndg). Appendix 4 describes one functional form that could be used to derive net damage. Summing across the nodes provides an estimate for net damage (nd). For management purposes it may be desirable to evaluate whether an impact is significant by identifying those impacts that exceed a certain threshold. The node ‘sig’ is included for that purpose.

3.5.3.2 Model extensions

We envisage the expansion of the network model by the addition of parent nodes for each gear type in the fishery. In the first instance, however, it will be necessary to develop a uniform measure for assessing footprint across alternative gear types. In the network model we then link the footprint of each gear type in the fishery with total footprint. We illustrate this for three gear types in Figure 8 by the addition nodes: f_{gt1}, f_{gt2} and f_{gt3}.

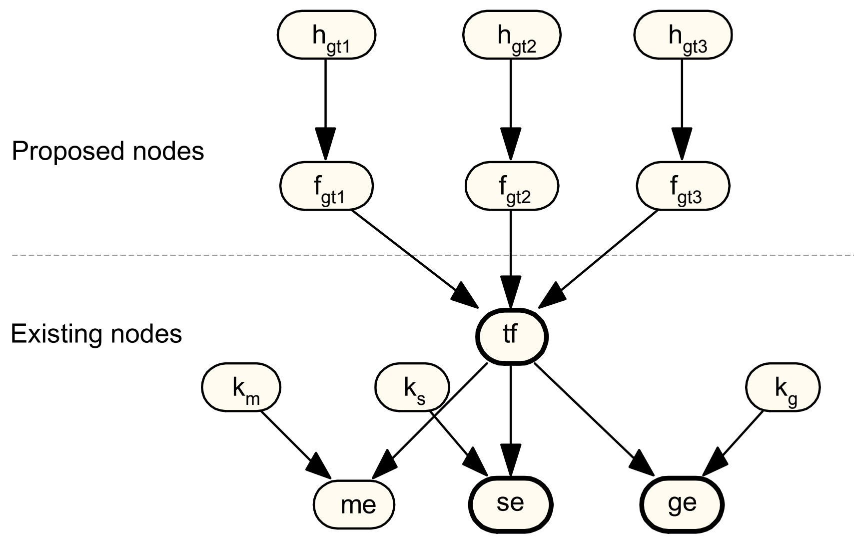

fig3.dne

Figure 8 Expanded influence diagram to estimate total impact of fishing gear

In the influence diagram this is done through the addition of a further layer of parent nodes (illustrated by h_{gt1}, h_{gt2} and h_{gt3}) to reflect harvest rates per gear type, by using some measure of catch per unit area. It is possible to use the model to simulate policy interventions such as fishing gear restrictions, seasonal/temporal area closures and harvesting quotas.

Management policies targeting specific fisheries sectors can also be modeled by reclassifying effort in the model. For example, Figure 9 illustrates the three management sectors: commercial limited entry (cle), commercial open access (coa) and recreational (rec), and two gear types, trawl (ft) and non-trawl (fnt):

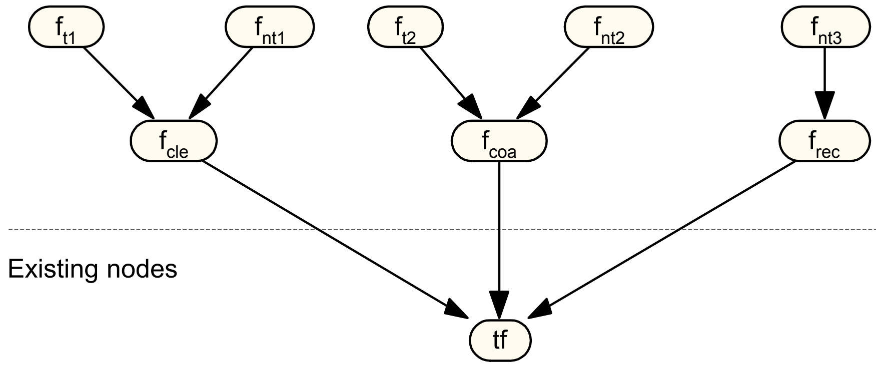

fig4.dne

Figure 9 Influence diagram showing the modeling of management options for adderssing fishing impacts

A variety of other specifications of effort are also possible, dependent on management objectives and the availability of data.

3.5.4 Validation of model results

To be completed

3.6 Further development of the BN models

[this section will be removed when the analysis is complete]

As described in this report, the team is developing three BN models for identification of EFH and HAPCs and for quantification of fishing impacts. These models have been populated with indicative data for demonstration purposes. The models show the power of the BN approach for addressing issues in the EFH EIS. The approach to fishing impacts is particularly promising. It is a step forward compared to other methods that have been proposed in that it includes a probability function for the footprint of each gear, which takes into account fisher behavior. Hence the area impacted is a function both of fishing effort and the degree to which vessels cover areas which have been previously fished during the same season. The model also incorporates the rate of recovery from fishing impacts, which varies with substrate type. The EFH model is able to accommodate a range of measures of the probability of an area being essential habitat, including Habitat Suitability Indices. It incorporates uncertainty both in terms of fish habitat associations, measurement error and a range of values for input variables within a single EFH parcel.

The models are still being developed. Several adjustments to the original models were suggested at the TRC meeting in February and have been implemented in the theoretical treatments presented here. The project is now in the phase of putting theory into practice by programming the models. This will be done using the Netica software and the C programming language. The programs are being designed to interface specifically with the main data sources and the GIS.

The programming phase of the project will address the following objectives:

(1) Address issues of scale and resolution in the use of data, particularly effort data in the impacts model and GIS data in the EFH model. Hence ensure that appropriate data are available to populate the models.

(2) Develop and program the algorithm for defining habitat units as intersections of latitude, depth contours and substrate boundaries, allowing for a probabilistic specification of depth and substrate to reflect uncertainties.

(3) Use the Pacific Coast Habitat Use Database (MRAG Americas), HSI data (NOS) and the RACE database (NMFS) to derive tables of conditional probabilities of presence of suitable habitat for each species/life-stages for each species (or species group) in each habitat unit.

(4) For the EFH model, using the Netica API (software that enables calls to BN procedures from a programming environment), program an algorithm to produce estimates of species/life stage presence probabilities for habitat units obtained from the existing GIS habitat data, and write the probabilities back to the GIS.

(5) Develop more realistic functional forms and statistical distributions for the impacts model. In particular for modeling: (i) fisher behavior, in terms of the degree of overlap of footprints from individual trawls (currently modeled using a Normal distribution); (ii) the impact of repeated trawls over the same location in one time period on net damage in that location (currently assumed that repeated trawls do not increase damage over a single trawl); (iii) the recovery rate (currently modeled as a logistic function).

(6) Investigate the use of Bayesian learning from cases to allow the adaptive improvement of the models over time as more data become available. This is particularly pertinent in the case of the impacts model. This is because substrates vary significantly in their rate of recovery from fishing impacts. Rate of recovery may also vary with gear type. Some indicative data exist on recovery rates and effort, but the availability of data currently and during future use of the model will be investigated; in particular, future data availability will have a strong influence on the best way to incorporate changes over time into the model. Although the importance of recovery over time may indicate the need for a dynamic model, the flexibility and relative simplicity of a learning by case approach is attractive. Also, given the uncertainties inherent in the system, learning by cases may be a more robust and realistic way to proceed, and one that is more suited to application in the real world.

(7) Based on the results of the impacts model and the EFH model, develop a BBN model for defining HAPC. This will involve: obtaining data to parameterize the non-fishing impacts node, programming the interaction with the GIS to get a habitat rarity score, and determining an appropriate weighting for combining inputs to get an HAPC score.

(8) Carry out scenario modeling using the completed EFH, HAPC and impacts models, so that the effects of mitigation strategies can be seen. In particular, this will involve trailing the use of learning by cases, ensuring that there are no paradoxical effects of reductions in fishing impact on HAPC designation, and evaluating the likely effects of fishing reduction on habitat in the light of the other factors causing concern about an EFH parcel (i.e. are they insignificant compared to non-fishing impacts). This modeling would take place within the GIS framework, hence the production of a working model that can be handed over to potential users will be a substantial programming task.

The main constraint on progress is now the availability of data. Once the GIS is completed and data on fishing impacts and fish habitat associations are available in the correct format, it will be possible to link the BN models with these databases. The models can then be used predictively.

Potential data bottlenecks include:

- entry of data into the habitat use database from the updated life histories appendix (needed for all three components of the analysis – EFH, HAPC and fishing impacts)
- completion of the GIS substrate and biogenic habitat layers, including the habitat quality information (needed for all three components of the analysis)
- preparation of a review of fishing impacts on habitat for the west coast, including development of indices of habitat sensitivity and recovery (needed for HAPC and fishing impacts)
- review and completion of the fishing effort data layers (needed for HAPC and fishing impacts)
- preparation of non-fishing impacts layers in the GIS (needed for cumulative impacts and practicability analyses)

4 RESULTS

This section is under development

4.1 Habitat maps

Maps of
benthic habitat
data quality
Bathymetry
Estuaries
Coastline
EEZ Existing management/protected areas

4.2 Network model results

4.2.1 EFH

Maps of probability of suitable habitat for species groups

8 species groups?
life stage groups?
Overall composite map

4.2.2 HAPC

Maps showing locations of habitat polygons identified as candidate sites for HAPCs
Separate maps for each of the 4 considerations (5 if you separate out fishing and non-fishnig sensitivity)
Compare with existing protected sites

4.2.3 Fishing Impacts

5 DISCUSSION

This section is under development

5.1 EFH

5.2 HAPC

5.3 Fishing Impacts

5.4 Potential structure of the alternatives

5.4.1 EFH alternatives

EFH must be described and identified the groundfish FMP as a whole.

5.4.1.1 Concepts for describing and identifying EFH

5.4.1.1.1 Concept 1: No action

This concept covers the requirement under NEPA for a "no action" alternative. It would result in no EFH being described and identified under the Pacific Coast Groundfish FMP. The No Action Alternatives would roll back the Council's designation of EFH under Amendment 11 to the Groundfish FMP. The purpose of including this alternative is primarily to provide a baseline against which the consequences of the other alternatives are compared.

5.4.1.1.2 Concept 2: Status quo

Under this concept, EFH is described and identified as in the Council's designation of EFH under Amendment 11 to the Groundfish FMP: the entire EEZ and marine and coastal waters inshore of the EEZ.

5.4.1.1.3 Concept 3: Threshold levels of probability of suitable habitat for managed species

Describe how threshold levels applied to the output of the Bayesian model would result in a range of alternatives for areas to be identified as EFH

5.4.2 HAPC alternatives

HAPC, by its definition in the EFH Final Rule, is a sub-set of EFH. HAPCs can therefore only be designated within the area described and identified as EFH under the FMP.

5.4.3 Fishing impacts alternatives

5.4.3.1 Possible Council actions

This section describes the types of actions that were considered when developing the range of fishing impacts alternatives to mitigate potential adverse impacts by a gear on a habitat. Many different actions are possible for each gear, and a subset of reasonable possibilities is presented below by gear type. The actions considered in developing the alternatives fell generally under five concepts: no action, gear modifications, time/area management, reduce fishing effort and full prohibition of the activity causing the impact. These concepts are described in more detail in the text table below.

Concept	Description
No action	No action alternatives are required by NEPA in part to provide a baseline for the consequences analysis, against which the consequences of all the other alternatives can be compared. Under this concept, no new measures for preventing, minimizing or mitigating adverse effects of fishing on EFH would be introduced. Adopt this concept as the fishing impacts alternative would require a determination that existing management measures adequately minimize, mitigate, or prevent potential adverse fishing impacts for all gears in all FMPs, to the degree practicable using best available scientific information (see Section 2.5.2 for a more complete rationale for the Alternative).
Gear modifications	Under this concept, alternatives are developed for modifications to the design and/or use of specific fishing gears that have a high potential of preventing, minimizing, or mitigating the adverse fishing impacts they cause. Fishing gears to which habitats are sensitive are identified and several alternatives for gear modifications to reduce adverse impacts are proposed.
Time/area closures	Alternatives create specific closed areas and closed seasons to prevent, minimize, or mitigate adverse fishing impacts in particular areas and at particular times of the year (as appropriate).
Reduce effort	The M-S act restricts access limitation to programs designed to achieve optimum yield.

Concept	Description
Gear prohibitions	This is the most restrictive approach to preventing, minimizing or mitigating adverse effects of fishing on EFH. Prohibition of gears on sensitive habitat could occur at two scales. First, prohibit the gear on only the habitats that the gear adversely impacts. This would require mapping of the habitats and drawing enforceable boundaries around the sensitive habitats. Second, prohibit gear throughout the EEZ. Such a prohibition would prevent a gear adversely affecting a habitat (to the extent it is enforced), but would also prevent use of the gear on habitats where it causes no adverse impact.

5.4.3.2 Previous Council actions

5.4.3.3 Possible further actions

5.5 Evaluating the consequences of the alternatives

Under development

Describe how the models can be used to evaluate the consequences of alternatives

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APPENDIX 1: LIST OF GROUNDFISH SPECIES IN LIFE HISTORIES APPENDIX

Count is 80 species. Two are missing

LEOPARD SHARK (Triakis semifasciata)
SOUPFIN SHARK (Galeorhinus zyopterus)
SPINY DOGFISH (Squalus acanthias)
BIG SKATE (Raja binoculata)
CALIFORNIA SKATE (Raja inornata)
RATFISH (Hydrolagus colliei)
FINESCALE CODLING (Antimora microlepis)
PACIFIC RATTAIL (Coryphaenoides acrolepis)
LINGCOD (Ophiodon elongatus)
CABEZON (Scorpaenichthys marmoratus)
KELP GREENLING (Hexagrammos decagrammus)
PACIFIC COD (Gadus macrocephalus)
PACIFIC WHITING (PACIFIC HAKE) (Merluccius productus)
SABLEFISH (Anoplopoma fimbria)
AURORA ROCKFISH (Sebastes aurora)
BANK ROCKFISH (Sebastes rufus)
BLACK ROCKFISH (Sebastes melanops)
BLACK-AND-YELLOW ROCKFISH (Sebastes chrysomelas)
BLACKGILL ROCKFISH (Sebastes melanostomus)
BLUE ROCKFISH (Sebastes mystinus)
BOCACCIO (Sebastes paucispinis)
BRONZESPOTTED ROCKFISH (Sebastes gilli)
BROWN ROCKFISH (Sebastes auriculatus)
CALICO ROCKFISH (Sebastes dalli)
CALIFORNIA SCORPIONFISH (Scorpaena guttata)
CANARY ROCKFISH (Sebastes pinniger)
CHILIPEPPER (Sebastes goodei)
CHINA ROCKFISH (Sebastes nebulosus)
COPPER ROCKFISH (Sebastes caurinus)
COWCOD (Sebastes levis)
DARKBLOTCHED ROCKFISH (Sebastes crameri)
DUSKY ROCKFISH (Sebastes ciliatus)
FLAG ROCKFISH (Sebastes rubrivinctus)
GOPHER ROCKFISH (Sebastes carnatus)
GRASS ROCKFISH (Sebastes rastrelliger)
GREENBLOTCHED ROCKFISH (Sebastes rosenblatti)
GREENSPOTTED ROCKFISH (Sebastes chlorostictus)
GREENSTRIPED ROCKFISH (Sebastes elongatus)
HARLEQUIN ROCKFISH (Sebastes variegatus)
HONEYCOMB ROCKFISH (Sebastes umbrosus)

KELP ROCKFISH (Sebastes atrovirens)
LONGSPINE THORNYHEAD (Sebastolobus altivelis)
MEXICAN ROCKFISH (Sebastes macdonaldi)
OLIVE ROCKFISH (Sebastes serranoides)
PACIFIC OCEAN PERCH (Sebastes alutus)
PINK ROCKFISH (Sebastes eos)
QUILLBACK ROCKFISH (Sebastes maliger)
REDBANDED ROCKFISH (Sebastes babcocki)
REDSTRIPE ROCKFISH (Sebastes proriger)
ROSETHORN ROCKFISH (Sebastes helvomaculatus)
ROSY ROCKFISH (Sebastes rosaceus)
ROUGHEYE ROCKFISH (Sebastes aleutianus)
SHARPCHIN ROCKFISH (Sebastes zacentrus)
SHORTBELLY ROCKFISH (Sebastes jordani)
SHORTRAKER ROCKFISH (Sebastes borealis)
SHORTSPINE THORNYHEAD (Sebastolobus alascanus)
SILVERGRAY ROCKFISH (Sebastes brevispinis)
SPECKLED ROCKFISH (Sebastes ovalis)
SPLITNOSE ROCKFISH (Sebastes diploproa)
SQUARESPOT ROCKFISH (Sebastes hopkinsi)
STARRY ROCKFISH (Sebastes constellatus)
STRIPETAIL ROCKFISH (Sebastes saxicola)
TIGER ROCKFISH (Sebastes nigrocinctus)
TREEFISH (Sebastes serriceps)
VERMILION ROCKFISH (Sebastes miniatus)
WIDOW ROCKFISH (Sebastes entomelas)
YELLOWEYE ROCKFISH (Sebastes ruberrimus)
YELLOWMOUTH ROCKFISH (Sebastes reedi)
YELLOWTAIL ROCKFISH (Sebastes flavidus)
BUTTER SOLE (Isopsetta isolepis)
CURLFIN SOLE (Pleuronichthys decurrens)
DOVER SOLE (Microstomus pacificus)
ENGLISH SOLE (Pleuronectes vetulus)
FLATHEAD SOLE (Hippoglossoides elassodon)
PACIFIC SANDDAB (Citharichthys sordidus)
PETRALE SOLE (Eopsetta jordani)
REX SOLE (Errex zachirus)
ROCK SOLE (Lepidopsetta bilineata)
SAND SOLE (Psettichthys melanostictus)
STARRY FLOUNDER (Platichthys stellatus)

APPENDIX 2: GEAR TYPES IN THE PACFIN DATABASE

The following table provides a list of the gear types contained in PacFIN database, and shows how these have currently been classified in the effort database for the GFR project

Need to update with Fran's recent table(s)

Gear Name	GRID	GFR Code	Summarized Gear Group
Bottom Trawl			
ALL TRAWLS EXCEPT SHRIMP TRAWLS	TWL	VG1	TRAWL
BEAM TRAWL	BMT	VG1	TRAWL
BOTTOM TRAWL	BTT	VG1	TRAWL
FLATFISH TRAWL	FFT	VG1	TRAWL
GROUNDFISH TRAWL (OTTER)	GFT	VG1	TRAWL
GROUNDFISH TRAWL FOOTROPE > 8 in.	GFL	VG1	TRAWL
GROUNDFISH TRAWLFOOTROPE < 8 in.	GFS	VG1	TRAWL
ROLLER TRAWL	RLT	VG1	TRAWL
Midwater Trawl			
BOTTOM TRAWL SMALL FREEZER TRAWLER	SFZ	VG2	TRAWL
BOTTOM TRAWL SURIMI TRAWLER	SRM	VG2	TRAWL
MIDWATER TRAWL - CATCHER/PROCESSOR	MDT	VG2	TRAWL
PAIR TRAWL	PRT	VG2	TRAWL
Long Line			
LONG LINE OR SETLINE	LGL	VG3	LONG LINE
Hook and Line			
ALL HOOK AND LINE GEAR EXCEPT TROLL	HKL	VG4	HOOK AND LINE
BOTTOMFISH TROLL	BTR	VG4	HOOK AND LINE
DROP LINE	DRL	VG4	HOOK AND LINE
HAND LINE	HDL	VG4	HOOK AND LINE
JIG	JIG	VG4	HOOK AND LINE
POLE (COMMERCIAL)	POL	VG4	HOOK AND LINE
SETLINE	STL	VG4	HOOK AND LINE
VERTICAL HOOK AND LINE GEAR	VHL	VG4	HOOK AND LINE
Pot and Trap			
FISH POT	FPT	VG5	POT AND TRAP

Gillnet			
DIP NET	DPN	VG6	OTHER
DRIFT GILL NET	DGN	VG6	OTHER
GILL NET	GLN	VG6	OTHER
OTHER NET GEAR	ONT	VG6	OTHER
SET NET	STN	VG6	OTHER
Other			
ALL DREDGE GEAR	DRG	VG7	OTHER
ALL GEARS	ALL	VG7	OTHER
ALL NET GEAR EXCEPT TRAWL	NET	VG7	OTHER
ALL OTHER MISCELLANEOUS GEAR	MSC	VG7	OTHER
ALL POT AND TRAP GEAR	POT	VG7	OTHER
BOTTOM TRAWL CATCHER BOAT FOREIGN	CBF	VG7	OTHER
BOTTOM TRAWL CATCHER BOAT JV	CBJ	VG7	OTHER
BOTTOM TRAWL LARGE FREEZER TRAWLER	LFZ	VG7	OTHER
DIVING GEAR	DVG	VG7	OTHER
HOOK AND LINE (RECREATIONAL)	HLR	VG7	OTHER
OTHER DREDGE GEAR	ODG	VG7	OTHER
OTHER KNOWN GEAR	OTH	VG7	OTHER
RIVER TRAWL	RVT	VG7	OTHER
SCALLOP DREDGE	SCD	VG7	OTHER
SEINE	SEN	VG7	OTHER
SUNKEN GILLNET	SGN	VG7	OTHER
TRAMMEL	TML	VG7	OTHER
UNKNOWN GEAR (BDS)	XXX	VG7	OTHER
UNKNOWN OR UNSPECIFIED GEAR	USP	VG7	OTHER
Other Trawl			
DANISH/SCOTTISH SEINE (TRAWL)	DNT	VG8	TRAWL
OTHER TRAWL GEAR	OTW	VG8	TRAWL
Shrimp Trawl			
ALL SHRIMP TRAWLS	TWS	VG9	TRAWL
PRAWN TRAWL	PWT	VG9	TRAWL
SHRIMP TRAWL DOUBLE RIGGED	DST	VG9	TRAWL
SHRIMP TRAWL SINGLE OR DOUBLE RIG	SHT	VG9	TRAWL
SHRIMP TRAWL-SINGLE RIGGED	SST	VG9	TRAWL
Troll			

ALL TROLL GEAR	TLS	VG10	OTHER
HAND TROLL	HTR	VG10	OTHER
POWER GURDY TROLL	PTR	VG10	OTHER
TROLL	TRL	VG10	OTHER
Crab Pot			
CRAB AND LOBSTER POT	CLP	VG11	POT AND TRAP
CRAB POT	CPT	VG11	POT AND TRAP
LOBSTER POT	LPT	VG11	POT AND TRAP
Other Pot			
OTHER POT GEAR	OPT	VG12	POT AND TRAP
PRAWN TRAP	PRW	VG12	POT AND TRAP
SNAIL TRAP	SPT	VG12	POT AND TRAP
Other Hook and Line			
OTHER HOOK AND LINE GEAR	OHL	VG13	HOOK AND LINE

APPENDIX 3: COMPARING THE HSI AND HABITAT USE DATABASE INFORMATION TO ESTIMATE CONDITIONAL PROBABILITIES FOR EFH

This appendix develops a methodology to compare suitability scores derived from information contained in the habitat use database with estimates derived using the habitat suitability (HSI) methodology. This has potential application in populating the conditional probabilities table of habitat suitability node used in the EFH model.

From the species-lifestage appendix the following physical information is available:

	Eggs	Larvae	Juveniles	Adults
Preferred depth (m)	0-50	0-50	200-700	200-500
Depth range (m)	0-50	0-600	100-700	9-1450
Hard	?	?	No	No
Soft	?	?	Yes	Yes

In converting this information into suitability scores we need an understanding of the relationship between preferred depth, depth range and probability of suitability. Ideally this should be derived from literature or expert review. In this case our choice reflects a precautionary approach, in that we assume habitat is suitable unless additional information is available to further delineate at higher resolution. We assume for illustrative purposes that the preferred depth provides a suitability of 1.00, and the depth range provides a suitability score of 0.75. Depth ranges outside the species-lifestage's indicated range receives a score of zero. Information on substrate association is less informative, so in cases of uncertainty we assign equal scores to both habitats.

Combining each depth range score with the score for each substrate type provides an indication of the suitability of that species lifestage to a range of environmental parameters (see Excel spreadsheet DoverSoleExample.xls for data used). Figure A1 provides a comparison between the habitat suitability tables and the data from lifestage appendix (substrate=soft, Dover sole, adult lifestage). The lifestage appendix provides a much flatter (and less informative) distribution of suitability across depth range than the HSI approach.

*Example using Dover sole (**Microstomus pacificus**)*

A. HSI method (adult lifestage only)

Depth	H.S.I	Suitability	Substrate	H.S.I	Suitability
0-50	2	0.20	hard	1.00	0.10
51-100	5	0.50	soft	10.00	1.00
101-200	6	0.60			
201-300	10	1.00			
301-400	10	1.00			
401-600	10	1.00			

601-800	8	0.80			
801-1000	6	0.60			
1000-2000	5	0.50			
>2000		0.00			

Suitability score for a given substrate and depth

Adults		Hard=	Soft=
		0.10	1.00
Depth	SI value	Suitability	Suitability
0-50	0.20	0.14	0.45
51-100	0.50	0.22	0.71
101-200	0.60	0.24	0.77
201-300	1.00	0.32	1.00
301-400	1.00	0.32	1.00
401-600	1.00	0.32	1.00
601-800	0.80	0.28	0.89
801-1000	0.60	0.24	0.77
1000-2000	0.50	0.22	0.71
>2000	0.00	0.00	0.00

B. Lifestage appendix method (Access database)

Depth ranges for different lifestages where species is known to occur

	Eggs	Larvae	Juveniles	Adults
Highest abundance	0-50	0-50	200-700	200-500
Range	0-50	0-600	100-700	9-1450

In the absence of data we need to make an assumption about the relationship between species occurrence and suitability. We assume in this example that, in areas of highest abundance the suitability score is 1.00. In other areas where the species is known to occur, the suitability score is 0.75. Outside the known range the suitability is 0.

Suitability score for different depth ranges

	Eggs	Larvae	Juveniles	Adults
	Suitability	Suitability	Suitability	Suitability
0-50	1	1	0	0.75
51-100	0	0.75	0	0.75
101-200	0	0.75	0.75	0.75
201-300	0	0.75	1	1
301-400	0	0.75	1	1

401-600	0	0.75	1	1
601-800	0	0	1	0.75
801-1000	0	0	0	0.75
1000-2000	0	0	0	0.75
>2000	0	0	0	0

For substrate, a species lifestage is given a probability of 1.00 if it is known to occur on that substrate, and 0 if it is known not to occur. In data poor areas we assume the highest suitability score so that the largest area possible is designated. We expect that, with improved data availability these scores may be refined. In areas where species are known to occur in both substrates, these may be accorded equal scores.

Suitability score for different substrates

	Eggs	Larvae	Juveniles	Adults
	Prob	Prob	Prob	Prob
Hard	1	1	0.01	0.01
Soft	1	1	1	1

Suitability score for a given substrate and depth

		Eggs	Larvae	Juveniles	Adults
		Prob	Prob	Prob	Prob
Hard	0-50	1.00	1.00	0.00	0.09
Hard	51-100	0.00	0.87	0.00	0.09
Hard	101-200	0.00	0.87	0.09	0.09
Hard	201-300	0.00	0.87	0.10	0.10
Hard	301-400	0.00	0.87	0.10	0.10
Hard	401-600	0.00	0.87	0.10	0.10
Hard	601-800	0.00	0.00	0.10	0.09
Hard	801-1000	0.00	0.00	0.00	0.09
Hard	1000-2000	0.00	0.00	0.00	0.09
Hard	>2000	0.00	0.00	0.00	0.00
Soft	0-50	1.00	1.00	0.00	0.87
Soft	51-100	0.00	0.87	0.00	0.87
Soft	101-200	0.00	0.87	0.87	0.87
Soft	201-300	0.00	0.87	1.00	1.00
Soft	301-400	0.00	0.87	1.00	1.00
Soft	401-600	0.00	0.87	1.00	1.00
Soft	601-800	0.00	0.00	1.00	0.87
Soft	801-1000	0.00	0.00	0.00	0.87
Soft	1000-2000	0.00	0.00	0.00	0.87
Soft	>2000	0.00	0.00	0.00	0.00

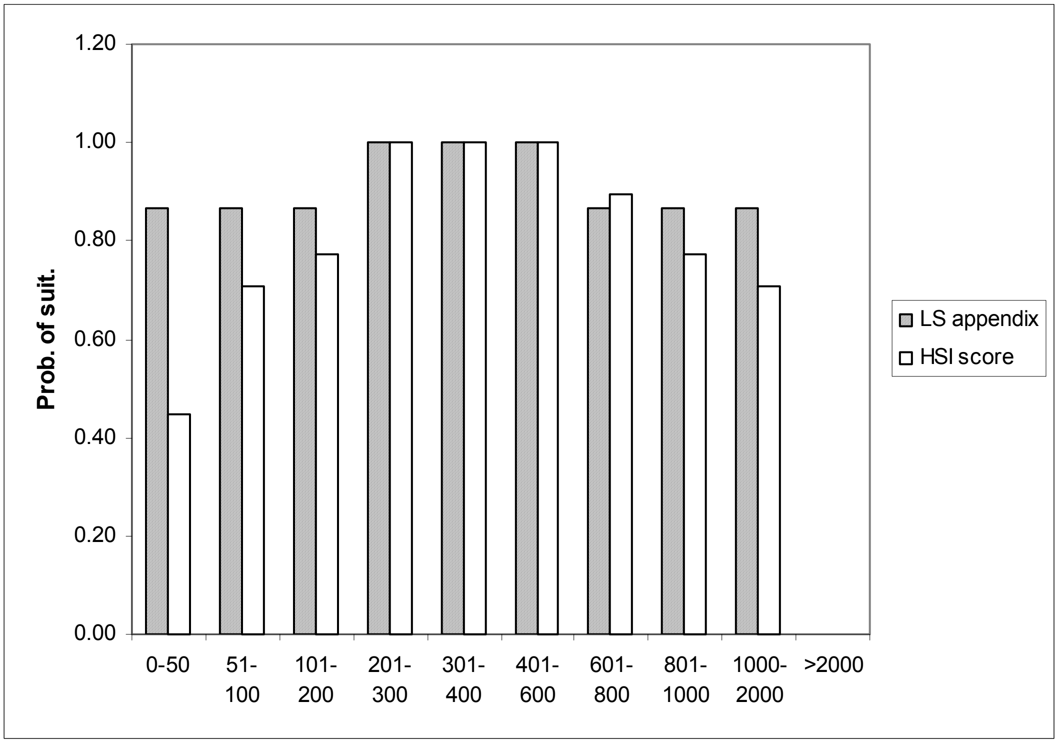

Figure A1. Comparing the probability distribution for the LS appendix with the HSI scoring (Illustrated with Dover Sole, adult lifestage. Results displayed for soft substrate).

APPENDIX 4: DISCRETE TIME DAMAGE MODEL FOR FISHING IMPACTS

A simple discrete time model may be developed by looking at the relationship between habitat, recovery and damage. While this model assume homogeneity across substrates, it is relatively easy to generalize this model to consider impacts on a substrate level. Let h_t be the percentage of a total habitat in an undamaged (pristine) state. The rate at which habitat recovers in time t+1 may then be written in the form:

$$h_{t+1} = h_t + r(h_t) - q(h_t, d_t) \qquad (1)$$

where $r(h_t)$ is a function representing habitat recovery, and $q(h_t, d_t)$ is a damage function, which is a function of the available habitat.

Various specifications of the damage function are possible. A simple time dependent relationship between habitat and damage may be represented as:

$$q(h_t, d_t) = d_t h_t,\ 0 \leq d_t \leq 1 \qquad (2)$$

where $d_t = (k * s * w * l_t * n_t)/ (1000 * A)$ is the damage per unit of habitat, s is the average speed of a vessel of a given gear (km/hr), w is the width of that gear type (m), l is the duration of an average trawl and n is the number of trawls in a given area of size A km^2. Finally, k is a weighting factor that reflects the sensitivity of a given habitat to damage from a certain gear-type.

We specify the growth function as a logistic equation:

$$r(h_t) = (e^r.h_t)/(1+ch_t) - h_t, \qquad (3)$$

where $c = (e^r-1)/100$ and r is the maximum recovery rate of the habitat per annum.

Constant damage rate
If we assume that the damage rate remains constant over time, in other words that $q(h_t) = dh_t$, it is possible to derive the conditions where habitat will stabilize. This occurs in the discrete time formulation when $h_{t+1} = h_t$. By solving equation 1 for the aforementioned conditions, the following equilibrium state is achieved:

$$h_t^* = (e^r-d-1)/(c(d+1)) \text{ for all } e^r>d+1, 0 \text{ otherwise} \qquad (4)$$

The net area damaged in equilibrium (nd) is then $100 - h_t^*$.

Variable damage rate
It will often be useful to relax the assumption of a constant damage function over time. For example, we may want to make use of historical data, or predict habitat change under variable conditions. The model that is used is a combination of equations (1), (2) and (3). It is useful in this case to plot the time path of the model, to consider the dynamic behavior of the model.

We demonstrate the model by showing habitat recovery (h) for a range of recovery (r) and damage (d) rates, and for different levels of variability (Figure A2). Variability is introduced by allowing damage to vary stochastically by drawing dt from a normal distribution with mean d and standard deviation δ. As damage rates are increased, overall habitat recovery is reduced. Increasing recovery rates for a given damage rate increases the percentage of habitat that is undamaged. Increasing variability in the damage rate causes greater inter-annual variability in the proportion of habitat that has recovered, for high recovery rates. Over the long term habitat recovery fluctuates around its equilibrium value.

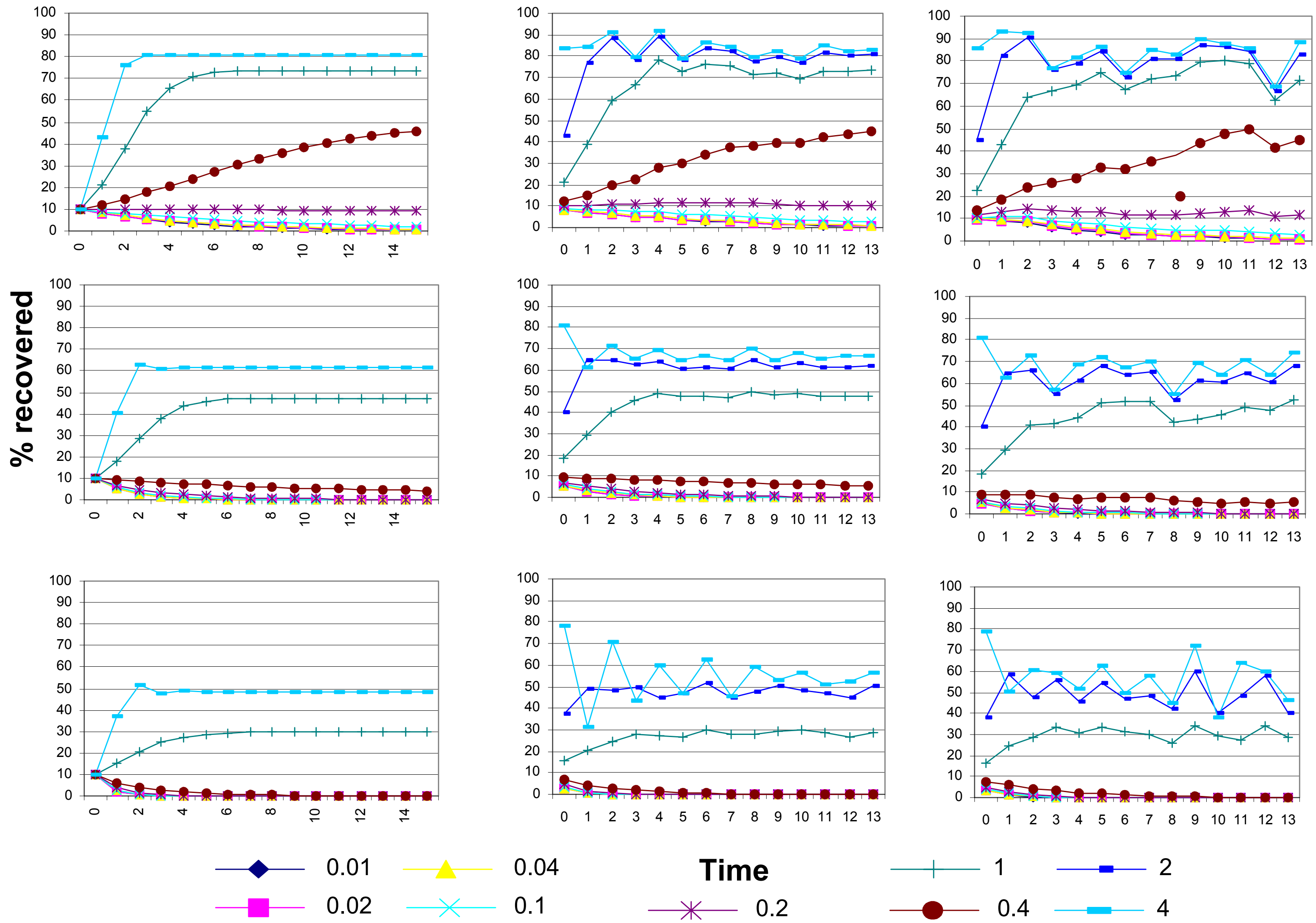

Figure A2. Dynamics of model for varying damage rates. Damage in each time period is sampled from a normal distribution, with mean 0.2 (row 1), 0.5 (row 2) and 0.8 (row 3), and standard deviation 0 (column 1) 0.05 (column 2) and 0.1 (column 3). Recovery rates vary from 0.01 to 4 (maximum 2 in the case of sd = 0) within each figure. The initial value for the percentage of habitat undamaged (h0) is 10%.

APPENDIX 5: USEFUL WEBSITES ON BAYESIAN BELIEF NETWORKS

General theory of network and other graphical models, with links to other sites
http://www.ai.mit.edu/~murphyk/Bayes/bnintro.html

Software products for creating network models
http://bayes.stat.washington.edu/almond/belief.html

Website for Bayes Net project
http://www.cs.orst.edu/~dambrosi/bayesian/frame.html

Genie product
http://www2.sis.pitt.edu/~genie

Netica product
www.norsys.com

Hugin product
www.hugin.com

Microsoft belief network Product
http://www.research.microsoft.com/dtg/msbn

Online tutorial for Bayesian inference and modelling
http://b-course.cs.helsinki.fi/