Appendix A

Prepared for Pacific Council EIS Oversight Committee August 2004 Meeting Briefing Book

Pacific Coast Groundfish FMP

Risk Assessment for the Pacific Groundfish FMP

Executive Summary

Prepared for

Pacific States Marine Fisheries Commission

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Executive Summary

Introduction

NOAA Fisheries is developing an Environmental Impact Statement (EIS) that responds to a court directive and settlement agreement to complete new NEPA analyses for Amendment 11 to the Pacific Coast Groundfish FMP.A decision-making process for the EIS has been designed for policy to flow from assessment. A rigorous assessment of groundfish habitat on the west coast has been undertaken to address the following fundamental questions, the answers to which will set the stage for policy development:

- 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 has included spatial and temporal analysis of the distribution of habitat types, distribution of fish species, habitat use by fish, sensitivities of habitat to perturbations, and the dynamics of fishing effort.

The EIS and the Council process are the vehicles for developing policy in response to the assessment. This careful division of the scientific assessment from policy is pictured in the decision-making framework for the Pacific Coast Groundfish Essential Fish Habitat Environmental Impact Statement (Figure 1).

The assessment has proceeded along three major tracks: data consolidation and infrastructure development, proof of concept, and assessment modeling and review (See Appendix 1). 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. Chapters 3, and 4 describe the assessment modeling. The results and review are presented in Chapter 5, along with information on how the assessment outputs can be used in the development of EFH identification and fishing impacts alternatives.

Figure 1 summarizes the five main types of data available for the risk assessment (green boxes) and shows how these feed into the analytical parts of the decision-making framework, collectively represent the Comprehensive Risk Assessment. Comprehensive Risk Assessment is the term we have applied to the integrated use of the best scientific information available in the development of guidance for the policy development process.

First and foremost, many of the data types in Figure 1 can be analyzed and presented in GIS maps and overlays to indicate where the most important and vulnerable habitats are distributed in relation to the activities that may be impacting them (fishing and non-fishing). This is represented by the arrows that feed directly from the green data boxes into the Comprehensive Risk Assessment box.

Thorough and responsible analysis of these data, however, involves substantially more than creating maps and visual overlays in the GIS. To represent better the processes that make a particular piece of habitat more or less “essential” for managed species, and the risks posed to that habitat by fishing and non-fishing activities, we have created a sophisticated modeling framework, represented by the red boxes in Figure 1. Two models are shown: the EFH Model and the Impacts Model. While these components are clearly integrated, it has proved to be both pragmatic and practical, to address them one at a time, in the modeling process due to the complex and wide ranging scope of the issues they address.

The first step in the process is the identification and description of EFH. Chapter 3 provides the details of the analysis of information on habitat and the use of habitat by groundfish that will lead to the development of alternatives for EFH for the Groundfish FMP.

The second step is an assessment of the risk to EFH from both fishing and non-fishing activities, that will assist the Council in the development of alternatives to prevent, mitigate, or minimize, to the extent practicable, the adverse effects of fishing and fishing gear on EFH. As stressed above, the Impacts Model forms only part of this process. In a previous version of the decision-making framework, it was envisioned that all of the data elements from the data consolidation phase might feed into the Impacts Model. However, in practice this has proved to be not possible at this stage, for reasons that are made evident in this document.

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

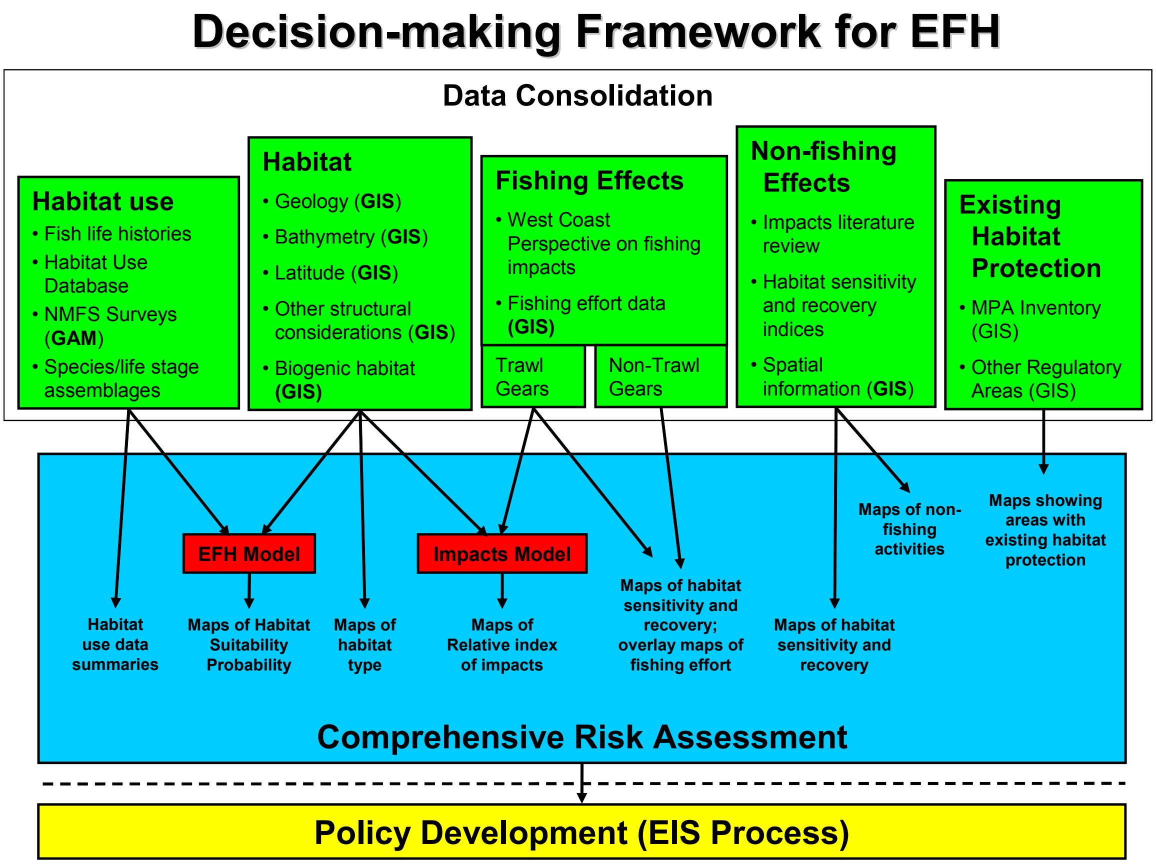


Figure 1. Decision-making framework for the assessment stage of the Pacific Coast Groundfish EFH EIS showing data inputs and separation of the assessment and policy components

Data Consolidation

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

1. Development of a GIS database that will display habitat types in comparison with known groundfish distribution/abundance and fishing effort;
2. Conduct of a literature review and development of a database on groundfish habitat associations;
3. Conduct of a literature review on fishing gear impacts to habitat;
4. Conduct of a literature review on non-fishing impacts to habitat; and
5. Collection and analysis of information on fishing effort.

As shown in Figure 1 (the decision-making framework), the various GIS and other databases that have been compiled for this project were organized into five major categories:

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

Within all of these categories, GIS has been a pivotal tool in compiling, analyzing and presenting data. The first two categories form the backbone of the EFH Model, while the first and third are the principal inputs into the Impacts Model. In this section we provide a description of the data collection and processing procedures in the first four categories. Information on existing habitat protection is presented in Section 6.

Fish habitat

The EFH model uses information on habitat preferences of species and life stages in the Groundfish FMP for three habitat characteristics; benthic habitat (including biogenic habitat), depth and latitude, to support the development of alternatives for identifying EFH.

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

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

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

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

Use of habitat by groundfish

NMFS trawl surveys provided source data for estimating the suitability of habitat for groundfish within the area covered by the FMP. The data from these trawl surveys were compiled and converted to GIS format. They can be used in geographic overlays with other information, such as fishing effort or habitat, to validate model outputs or assess the relationship between various layers.

The 1998 Life Histories Appendix to Amendment 11 updated in 2003 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. The informatiom is contains was transferred to a Pacific Coast Groundfish Habitat Use Relational Database developed as part of this project 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.

Effects of fishing gears on habitat

More than thirty fishing gear types are used on the west coast (excluding Alaska). The PSMFC prepared a document that describes these fishing gears and which components of those gears might affect structural habitat features. It includes gear used by fishermen targeting groundfish as well as gear used to target other species.
There exist several literature reviews of the effects of fishing gears on habitat, but these rarely contain information specific to the west coast and there is no clear direction on how information from other areas should be applied there. There is a general lack of west coast specific studies; only two studies directly on west coast gears were found to be useful. A new review was therefore undertaken as part of this risk assessment.

Fishing Effort

Spatial delineation of fishing effort data is necessary for the assessment of risk of impacts to EFH. Several data sets were available for potential inclusion into the assessment, each with its strengths and limitations:

- Trawl Logbook data from PACFIN
- Ecotrust's fishing effort model output
- Fisherman Focus Group data

All three sources of commercial fishing effort data have their strengths and weaknesses. The logbook data are extensive, both spatially and temporally, and are acknowledged to be the most comprehensive source of information on trawl effort currently available (SSC Groundfish Sub-committee review of Impacts Model, February 2004[1]). However, these data only includes information on trawl gear.

[1] Exhibit C.6.c, Attachment 1, Briefing Book for April 2004 Council meeting.

The assessment compared focus group data with both trawl logbook data and the Ecotrust model, looking for spatial coincidence and consistency in estimates of the area impacted by fishing. Focus group polygons showed relatively good agreement with trawl logbook data, but not with Ecotrust results for fixed gear types.

The SSC Groundfish Subcommittee recommended:

- against using the Ecotrust model output in the impacts model.
- using the focus group approach for collecting coastwide fixed gear information.

However, because the focus group information was limited to a small portion of the coast, it was not included in the current version of the Impacts Model

The recreational fishery sector comprises the commercial passenger fishing vessel (CPFV) fleet (charters), private fishing vessels, and other miscellaneous fishing activities. A summary is provided of available information on recreational fishing effort.

Effects of Non-Fishing activities on Groundfish Habitat

In 2003, NOAA Fisheries prepared a detailed description of non-fishing impacts to essential fish habitat and recommended conservation measures. Non-fishing activities have the potential to adversely affect the quantity or quality of EFH designated areas in riverine, estuarine, and marine systems. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharge, water diversions, thermal additions, actions that contribute to non-point source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. For each activity, known and potential adverse impacts to EFH are described in the review document.

Over 70 individuals at NMFS, USEPA, USACOE, MMS, USGS, Washington DNR, Washington DOE, Oregon DEQ, California Fish and Game as well as several private and non-profit organizations were contacted to collect data on the actual intensity of non-fishing activities witht eh potential to impact EFH. The list of collected west coast non-fishing impact data includes dredge disposal sites, shoreline hardening, marinas, land use land cover, oil and gas lease locations, Pacific cable information. etc. (**Error! Reference source not found.**)

In addition to the collection of available data, this process has yielded the added benefit of identifying numerous data gaps relevant to non-fishing impacts. While the generation of these various data sets is well beyond the scope and scale of this effort, it is hoped that this work will lead to additional initiatives that will start to tackle these gaps.

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

Identifying EFH

Designation of EFH for a fishery is achieved through an accounting of the habitat requirements for all life stages of all species in the FMU. While identification of EFH is carried out at the fishery (FMP) level, the determination of whether an area should be EFH depends upon habitat requirements at the level of individual species and life stages. Potentially, only one species/life stage in the FMU may be required to describe and identify an area as EFH for the FMP. Many areas of habitat, however, are likely to be designated for more than one species and life stage. The composite habitat requirements for all the species in the Pacific coast groundfish FMP are likely to result in large areas of habitat being described and identified as EFH, due to the overlay multiple species habitat needs.

The 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.

In this study, we developed a modeling approach (called the EFH Model) for assessing the likely importance of habitats for each species and life stage in the FMP (called Habitat Suitability Probability – HSP). This was done by evaluating the probability that particular habitats are suitable for particular species and life stages, based on available data sources; the NMFS groundfish surveys for as many species and life stages as possible, and information on habitat associations from the habitat use database for other species and life stages. The model is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing management alternatives for identification of EFH.

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

There are various ways in which these maps can be used to identify EFH in a more or less inclusive way. The decision whether to adopt an inclusive or narrow definition of EFH should be considered from a policy standpoint. Adopting an inclusive definition may be appropriate given the incomplete and indirect nature of the information used to identify EFH. However, developing workable alternatives to reduce fishing impacts may be difficult if EFH is defined broadly. Adopting a relatively narrow EHF definition may make it easier to develop effective precautionary alternatives.

One of the most obvious ways of using the maps would be to select the area of habitat for each species and life stage within which the HSP value is higher than some predetermined threshold value. A low value would produce a broad or inclusive identification of EFH, while a high value would reduce the area identified as EFH. In using the maps, however, it is important to remember that, while they look similar in terms of a product of the analysis, the type, accuracy and precision of the information that has gone into each is highly variable. They should not, therefore, be treated all with the same level of confidence.

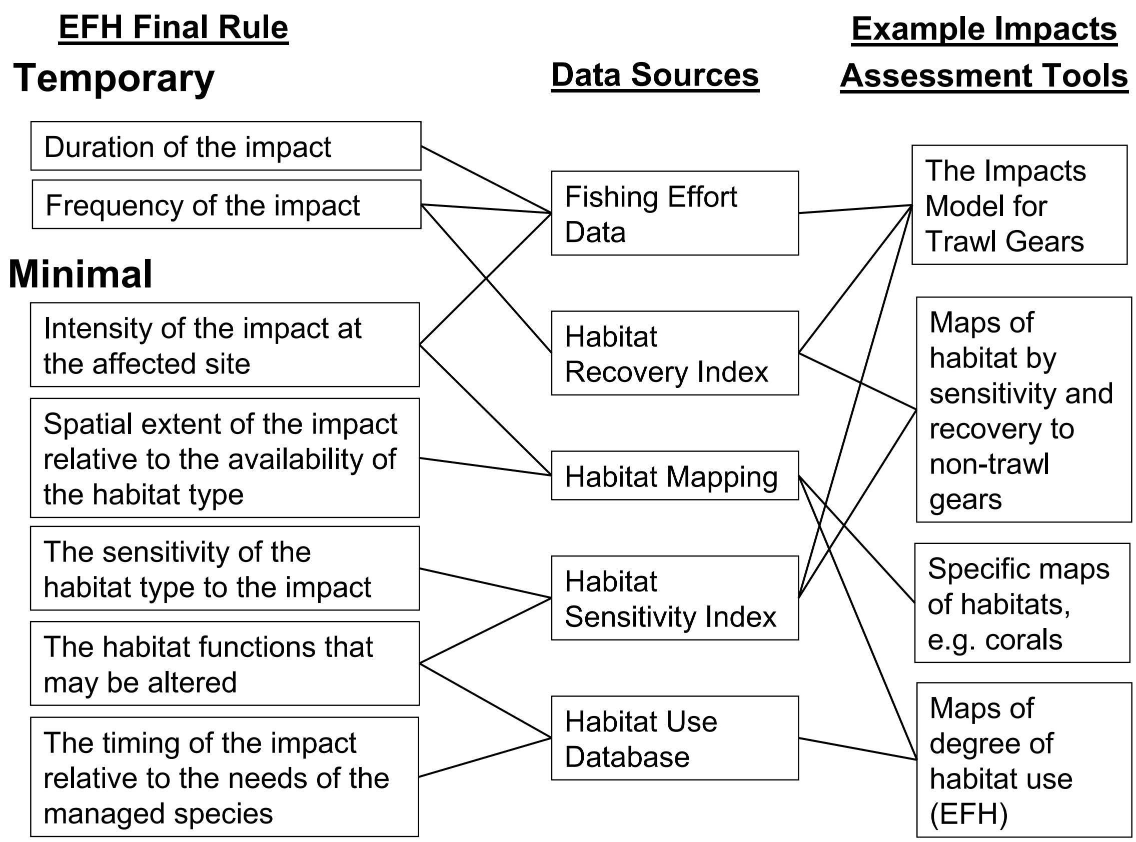
An alternative approach to identifying EFH proposed by the SSC would identify the best 10% (or 20%, 30% …etc) of habitat over entire assessed region for each groundfish species/lifestage, based on the HSP maps, and then combine these areas for all species and life stages for an overall definition of EFH.

Assessment of Impacts

The EFH Final Rule establishes a threshold for determining which fishing activities warrant analysis to address 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.



The measurement of impacts to EFH caused by fishing gears is clearly a complex process requiring substantial amounts of information. The diagram above indicates some of the relationships between the factors listed in the EFH Final Rule, the types of data we have available and the types of impacts assessment tools that could be derived from these.

There remain two major limitations in our understanding of the process by which fishing and non-fishing activities can impact EFH; the first is the relationship between fishing effort and habitat modification (i.e. how much modification of the habitat occurs for a given unit of fishing effort), and the second is the relationship between habitat modification and ecosystem productivity, more specifically the productivity of fish (i.e. how does a given amount of habitat modification impact the growth and/or reproductive success of fish). Presently there are very little data to fill either of these gaps. It was therefore necessary to find innovative ways of expressing the risk of impacts using the best information available.

Habitat sensitivity and recovery

In an effort to provide a quantitative measure of the degree of habitat modification resulting from a unit of fishing effort, two notional indices were developed: the Sensitivity Index and the Recovery Index. The Sensitivity index provides a relative measure of the sensitivity of habitats to the action of fishing gears. The Recovery Index provides a measure of the time taken for a habitat to recover to a pre-impacted state.….. se indices provide a useful first step in the quantification of fishing gear effects on habitat, they have some obvious limitations at this stage.

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While these indices provide a useful first step in the quantification of fishing gear effects on habitat, they have some obvious limitations at this stage. The sensitivity index provides a relative measure of the likely changes to habitat caused by interactions with various fishing gears. However, it is not explicit that the changes described in the index result from a single contact with the gear, nor what happens with subsequent contacts. The relationship between fishing effort and habitat change (impact) is likely to be complex and almost certainly non-linear. The process of recovery is similarly difficult to quantify. At this stage, however, we have no empirical data from which to develop such relationships. A first attempt is made, however, in the development of the Impacts Model.

A preliminary habitat sensitivity index was also developed for non-fishing activities.

The Impacts Model for trawl gears

We developed a second Bayesian Network model for examining fishing impacts by trawl gears (the Impacts Model). This model provides a framework for the quantitative consideration of habitat status and the effects over time of different management regimes based on the available data. These data are, in essence, the sensitivity and recovery matrices and the fishing effort data.

The model is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing alternatives for management scenarios that are designed to mitigate specific risks to habitat and ecosystem function. While the presentation and overlay of information in the GIS can provide a first order indication of areas of habitat that may be under threat and in need of protection, a quantitative approach is needed to bring together information from a variety of sources to better understand the processes involved.

The methodology was implemented with the goal of answering the questions listed in the introduction for Pacific coast groundfish, to the extent possible. Limitations on answering these questions were encountered, particularly in regards to the availability of data for model parameterization. With improved data, the utility of the impacts model for the management process could be substantially enhanced.

The Impacts Model provides a quantitative assessment of the biological impacts to EFH caused by bottom trawls. The model is dynamic and treats fishing impacts both spatially and temporally.

It is intended to be used to investigate relative changes over time and space in the relative level of impacts to EFH resulting from different management regimes or different intensities of gear use. These management regimes may either be in the past, in which case the model is used to investigate existing levels of impact and hence the current relative status of EFH, or they are alternative strategies for future management, in which case the model is used to investigate potential changes in impacts level resulting from management interventions.

The with the modeling approach is that we currently have no empirical basis for associating a quantum of fishing effort with a measurable impact on habitat. Hence, while the model provides an interesting comparison of the potential impacts from one area to another, we have no idea whether any, or all, of these levels of impacts are high enough to warrant mitigating action, or so low and benign that they represent no threat to species in the FMP.

With current information, we can only hope to model relative impacts, but it may be possible to provide some kind of calibration of the scale such that the output is at least informative in some sense. To enable this possibility, the scaling or tuning constant k was introduced into the Impacts Model to allow some flexibility in calibrating effort with impact. Due to the non-linear relationship between effort and impact, the choice of k has an important effect on the model outputs.

At this time there are no data available to provide an empirical calibration of the model, however, we do provide a methodology that calculates a value for k that provides the greatest contrast in the impacts scale. Essentially this takes the maximum range of effort and sets k to the value that provides the commensurate maximum range of net cumulative impact.

This still does not tell us whether the highest, of some other level of impact is significant, but, if impacts that are detrimental to managed species are resulting from trawl gear fishing effort, it does show where they are most likely to be occurring. It also shows us, if mitigating action is going to be taken, where it is likely to have the greatest benefit.[2]

Developing alternatives to mitigate impacts

Many different actions are possible to mitigate gear impacts, but they fall generally under possible five concepts: no action, gear modifications, time/area management, reduced fishing effort and full prohibition of a fishing gear. These are all types of input controls on the fishery. The Council could consider a range of approaches to implement such controls. Perhaps the most traditional would be straightforward regulation through the FMP. However, such action might prove unpopular and therefore difficult to implement and regulate. A more effective implementation might be achieved through the use of more cooperative action. For example, participants in the fishery could be encouraged to develop their own approaches to mitigation (e.g. through gear modification) that would be tested against performance criteria set by the Council.

[2] We note, however, that such benefit will depend greatly on many factors that are not included in the model, such as the behaviour of fishermen in response to regulation.

The Council might also wish to consider the role to be played by habitat restoration, perhaps in conjunction with one or more of these input controls. For example, if an area of degraded habitat is to be closed to fishing, then subsequent natural improvements to habitat quality and quantity could be accelerated through specific actions such as the installation of artificial reef structures. Such action might be particularly relevant in cases where recovery of habitat function for managed species is expected to progress slowly.

Existing habitat protection

The groundfish EFH project has served as a catalyst to compile information on existing spatial habitat protection measures not previously available on a coast wide scale. This is a twofold effort: the first involved compiling boundaries of marine managed areas and the second is developing a GIS coverage depicting existing federal regulations including identifying areas that are closed to some or all fishing gears for some or all of the time.

Data gaps analysis

Throughout the report, we have identified gaps in the information available for the comprehensive risk assessment. This is the first time a comprehensive, coast-wide assessment of EFH has been undertaken on the west coast. It has required the compilation of new datasets, the use of existing datasets for purposes other than those for which they were originally intended, and the innovation of novel assessment techniques. It is not surprising, therefore that this process has revealed many, and sometimes substantial gaps in our knowledge that it has not been possible to fill. Indeed, the identification and assessment of these gaps is perhaps one of the most important products of the research effort to date, and is one that should feed directly into the development of management alternatives.

The assessment itself has been designed, to the greatest extent possible, in a way that will allow updating as new information becomes available. We note, however, that some of the more fundamental types of missing information, should they become available, may warrant significant re-structuring of the approach, particularly in the case of the Impacts Model.

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1 INTRODUCTION

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The first step in the process is the identification and description of EFH. Chapter 3 provides the details of the analysis of information on habitat and the use of habitat by groundfish that will lead to the development of alternatives for EFH for the Groundfish FMP.

The second step is an assessment of the risk to EFH from both fishing and non-fishing activities, that will assist the Council in the development of alternatives to prevent, mitigate, or minimize, to the extent practicable, the adverse effects of fishing and fishing gear on EFH. As stressed above, the Impacts Model forms only part of this process. In a previous version of the decision-making framework, it was envisioned that all of the data elements from the data consolidation phase might feed into the Impacts Model. However, in practice this has proved to be not possible at this stage, for reasons that are made evident in this document.

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

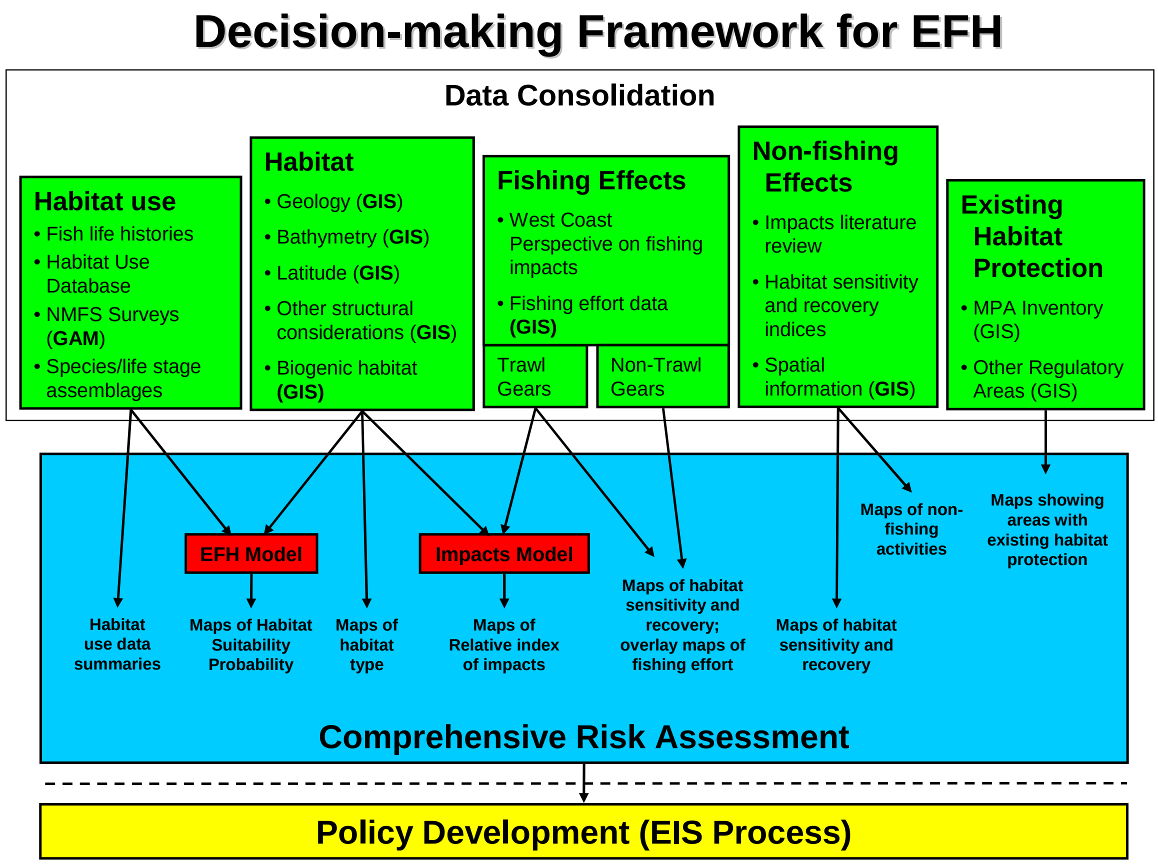

Figure 1. Decision-making framework for the assessment stage of the Pacific Coast Groundfish EFH EIS showing data inputs and separation of the assessment and policy components

2 DATA CONSOLIDATION

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

1. Development of a GIS database that displays habitat types in comparison with known groundfish distribution/abundance and fishing effort;
2. Conduct of a literature review and development of a database on groundfish habitat associations;
3. Conduct of a literature review on fishing gear impacts to habitat;
4. Conduct of a literature review on non-fishing impacts to habitat; and
5. Collection and analysis of information on fishing effort.

As shown in Figure 1 (the decision-making framework), the various GIS and other databases that have been compiled for this project were organized into five major categories:

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

Within all of these categories, GIS has been a pivotal tool in compiling, analyzing and presenting data. The first two categories form the backbone of the EFH Model, while the first and third are the principal inputs into the Impacts Model. In this section we provide a description of the data collection and processing procedures in the first four categories. Information on existing habitat protection is presented in Section 6.

2.1 GIS deployment in the EFH process

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

2.1.1 Challenges Encountered While Compiling EFH GIS

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

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

- Uniting Disparate Data Sets
  Reconciling data from disparate sources into a unified, coherent database presents a multitude of technical challenges, requiring decisions about seemingly arcane, yet critical, details. Almost all EFH data was available only as geographic subsets to the study area. Ideally, these data would be “stitched” together at their edges using straightforward GIS commands. In practice, however, combining these geographic subsets into one comprehensive GIS layer required additional processing including:

  1. modifying attribute definitions to make them identical,
  2. eliminating overlapping areas by determining which subset has priority,
  3. filling in data gaps between subsets,
  4. understanding and reconciling different source scales and spatial extents,
  5. validating coding,
  6. updating coding as new information is provided, and
  7. projecting data to a common west coast projection.

  During these procedures, the goal has been to remain as consistent as possible with the intent of the source data while also creating comprehensive data coverage for the area of interest. To facilitate this process, automated procedures were used in lieu of more time-consuming manual editing procedures.

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

2.1.2 GIS, Modeling, and Management

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

2.2 West Coast Fish Habitat

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

2.2.1 Benthic habitat

2.2.1.1 Summary

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

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

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

Estuaries are known to be important areas for some groundfish species, such as kelp greenling, starry flounder and cabezon. However, estuarine seafloor types were generally not mapped by the marine geologists during the initial data consolidation phase of the project. They are included as a separate mapped category of their own for inclusion in modeling efforts. The “habitat map” for the west coast is shown in Figure 2.

2.2.1.2 Physical substrate

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

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

<u>Level 1: Megahabitat</u>:

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

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

- Hard substrate;
- Soft substrate.

<u>Level 3: Meso/macrohabitat</u>:

- Canyon wall;
- Canyon floor;
- Exposure, bedrock;
- Gully;
- Gully floor;
- Ice-formed feature;

Landslide.

Level 4: Modifier:

Bimodal pavement;
Outwash;
Unconsolidated sediment.

Each unique combination of these four characteristics defines a unique benthic habitat type. For the west coast EFH project, 35 unique benthic habitat types have been delineated. These are plotted for illustrative purposes in Figure 2.

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

Habitat Code	Habitat Type	Mega Habitat	Habitat Induration	Meso/Macro Habitat	Modifier
Ahc	Rocky Apron Canyon Wall	Continental Rise	hard	canyon wall	
Ahe	Rocky Apron	Continental Rise	hard	exposure	
As_u	Sedimentary Apron	Continental Rise	soft		unconsolidated
Asc/f	Sedimentary Apron Canyon Floor	Continental Rise	soft	canyon floor	
Asc_u	Sedimentary Apron Canyon Wall	Continental Rise	soft	canyon	unconsolidated
Asg	Sedimentary Apron Gully	Continental Rise	soft	gully	
Asl	Sedimentary Apron Landslide	Continental Rise	soft	landslide	
Bhe	Rocky Basin	Basin	hard	exposure	
Bs_u	Sedimentary Basin	Basin	soft		unconsolidated
Bsc/f_u	Sedimentary Basin Canyon Floor	Basin	soft	canyon floor	unconsolidated
Bsc_u	Sedimentary Basin Canyon Wall	Basin	soft	canyon wall	unconsolidated
Bsg	Sedimentary Basin Gully	Basin	soft	gully	
Bsg/f_u	Sedimentary Basin Gully Floor	Basin	soft	gully floor	unconsolidated
Fhc	Rocky Slope Canyon Wall	Slope	hard	canyon wall	
Fhc/f	Rocky Slope Canyon Floor	Slope	hard	canyon floor	
Fhe	Rocky Slope	Slope	hard	exposure	
Fhg	Rocky Slope Gully	Slope	hard	gully	
Fhl	Rocky Slope Landslide	Slope	hard	landslide	
Fs_u	Sedimentary Slope	Slope	soft		unconsolidated
Fsc/ f_u	Sedimentary Slope Canyon Floor	Slope	soft	canyon floor	unconsolidated

Habitat Code	Habitat Type	Mega Habitat	Habitat Induration	Meso/Macro Habitat	Modifier
Fsc_u	Sedimentary Slope Canyon Wall	Slope	soft	canyon wall	unconsolidated
Fsg	Sedimentary Slope Gully	Slope	soft	gully	
Fsg/f	Sedimentary Slope Gully Floor	Slope	soft	gully floor	
Fsl	Sedimentary Slope Landslide	Slope	soft	landslide	
Rhe	Rocky Ridge	Ridge	hard	exposure	
Rs_u	Sedimentary Ridge	Ridge	soft		unconsolidated
Shc	Rocky Shelf Canyon Wall	Shelf	hard	canyon wall	
She	Rocky Shelf	Shelf	hard	exposure	
Shi_b/p	Rocky Glacial Shelf Deposit	Shelf	hard	ice-formed feature	bimodal pavement
Ss_u	Sedimentary Shelf	Shelf	soft		unconsolidated
Ssc/f_u	Sedimentary Shelf Canyon Floor	Shelf	soft	canyon floor	unconsolidated
Ssc_u	Sedimentary Shelf Canyon Wall	Shelf	soft	canyon wall	unconsolidated
Ssg	Sedimentary Shelf Gully	Shelf	soft	gully	
Ssg/f	Sedimentary Shelf Gully Floor	Shelf	soft	gully floor	
Ssi_o	Sedimentary Glacial Shelf Deposit	Shelf	soft	ice-formed feature	outwash

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

2.2.1.3 Estuaries

Estuaries are known to be important areas for some groundfish species, such as kelp greenling, starry flounder and cabezon. However, estuarine seafloor types were generally not mapped by the marine geologists during the initial data consolidation phase of the project. Only those habitats that are specifically mapped can be incorporated into the EFH model (Section 3.4). Specific substrates within estuaries are not mapped, however, because of their significance as groundfish habitat, estuaries are included as a separate mapped category of their own, so that they can form part of the area identified as EFH. The only drawback of this approach is that an entire estuary is either identified as EFH or not. It is not presently possible to identify only part of an estuary, because there is no information in the GIS to distinguish between one part of an estuary and another. As information becomes available in GIS format, however, this will change.

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

We encountered some challenges during the merging process due to the differences in shoreline boundaries used for the seafloor habitat and estuaries. There were both gaps and areas of overlap between the two data sets. Often these gaps or overlaps are not 'real', but artifacts of the mis-alignment between the layers (Figure 3). Because we did not have the resources for extensive manual editing to align these boundaries, we developed some decision rules for dealing with data inconsistencies in the areas of overlap. Gaps between the data sets remain because there was not an acceptable automated method for either filling or removing them.

Figure 2 shows the various combinations of seafloor habitat and estuary habitat codes that occur once the two data sets are combined. In a couple situations, one data set delineates an area as land (indicated by the code, 'Island'), and the other data set delineates the same area as potential EFH (either estuary or benthic habitat). Because terrestrial areas are not potentially EFH, land areas are removed prior to input to the EFH model. However, any areas that were ambiguous (i.e. at least one of the datasets identified them as potential EFH) were retained.

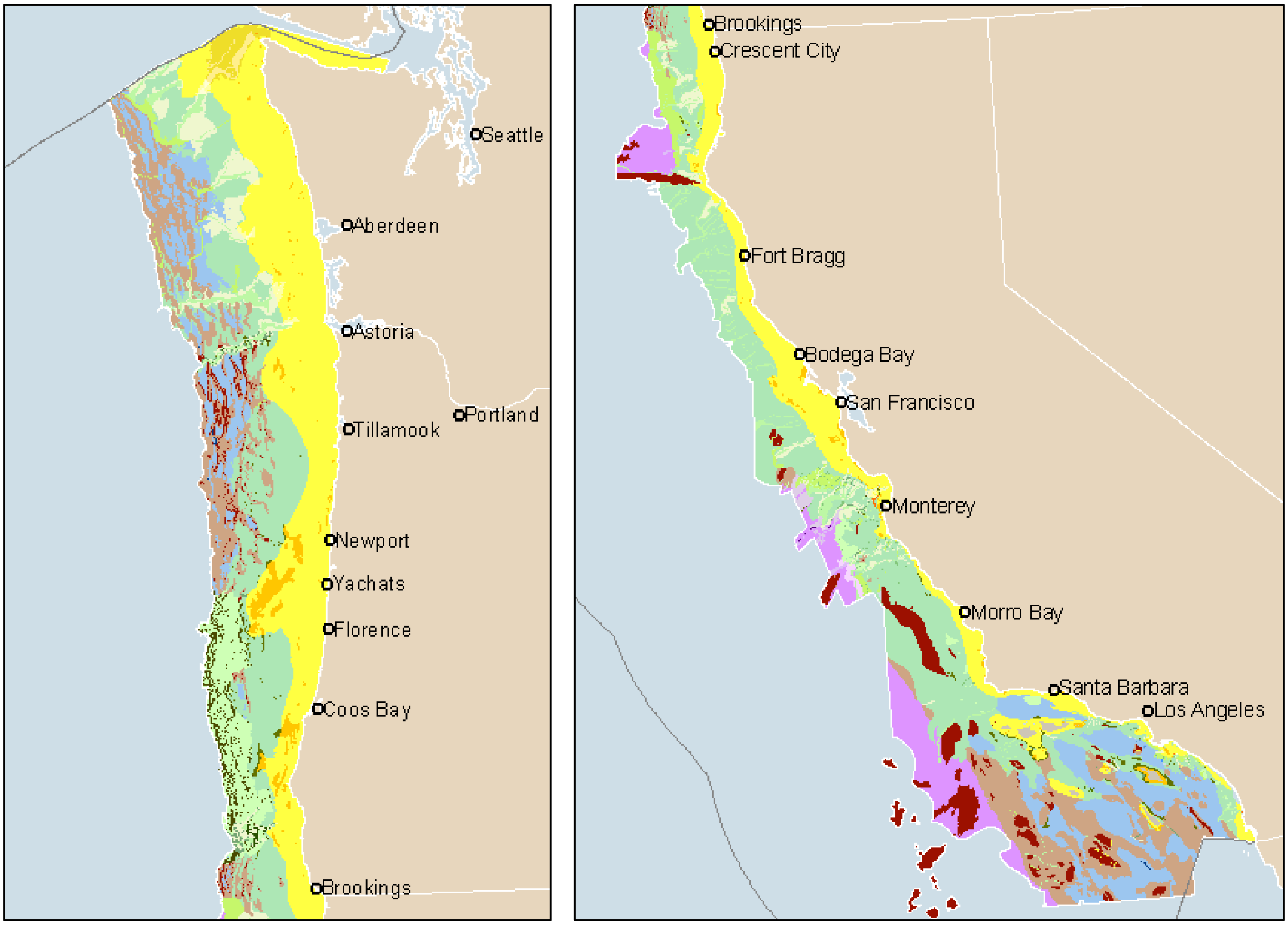

Figure 2. Thirty five (35) unique benthic types off the coasts of Washington, Oregon and California. Graphics created by TerraLogic GIS Inc. from data provided by MLML (CA) and OSU (OR, WA).

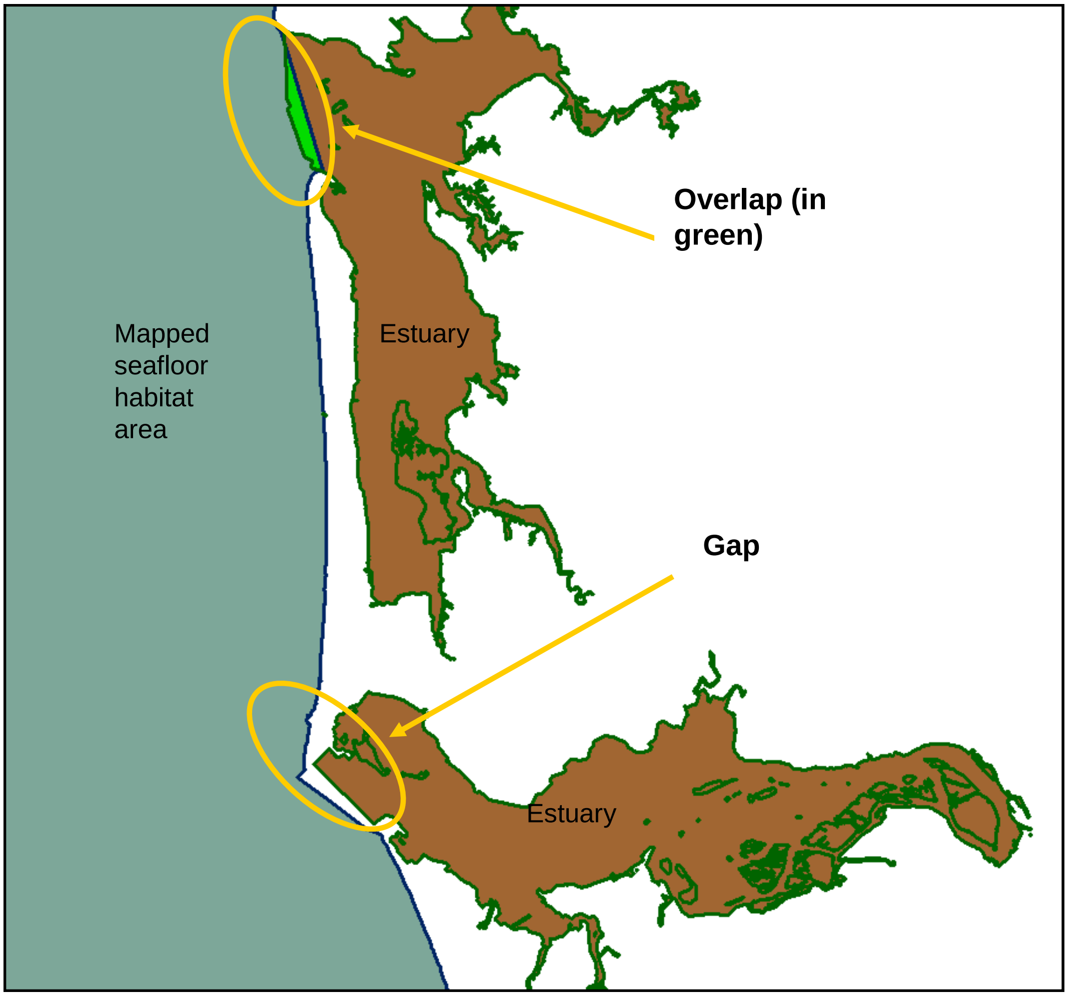

Figure 3. Examples of gaps and overlapping between data sets with respect to delineation of estuaries.

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

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

A Primer on Geographic Information Systems

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

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

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

2.2.1.4 Biogenic habitat

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

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

2.2.1.4.1 Canopy Kelp Beds

Kelp beds have been shown to be important to many groundfish species, including several rockfish species. GIS data for the floating kelp species, *Macrocystis* spp. and *Nereocystis* sp., are available from state agencies in Washington, Oregon, and California. These data have been compiled into a comprehensive data layer delineating kelp beds along the west coast. The kelp source data were provided for each state by the following agencies: Washington Department of Natural Resources (WDNR), Oregon Department of Fish and Game (ODFW), and California Department of Fish and Game (CDFG). Source data were collected using a variety of remote-sensing techniques, including aerial photos and multispectral imagery. Because kelp abundance and distribution is highly variable, these data do not necessarily represent current conditions. However, data from multiple years were compiled together with the assumption that these data would indicate areas where kelp has been known to occur. Washington state has the most comprehensive database, covering 10 years of time (1989-1992, 1994-2000), and surveying the Straits of Juan de Fuca and the Pacific Coast every year. Oregon did a coastwide survey in 1990, and then surveyed select reefs off southern Oregon in 1996-1999. A comprehensive kelp survey in California was performed in 1989, and additional surveys of most of the coastline occurred in 1999 and 2002. Distribution of kelp beds is shown in Figure 4.

2.2.1.4.2 Seagrass

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

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

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

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

In order to complete the EFH model by the required deadlines, acquisition of data on seagrass was ended in March 2004. Any data that were not made available by this date were could not be included in the coastwide seagrass GIS layer. The spatial distribution of seagrass data incorporated into the GIS is shown in Figure 5. Table 3 lists the geographic coverage, time period, and sources of the seagrass data sets that were compiled.

2.2.1.4.3 Structure-forming Invertebrates

Structure forming invertebrates, such as sponges, anemones and cold water corals, can be an important and potentially vulnerable component of fish habitat. An example within the US EEZ is the Oculina Bank on the Atlantic coast of Florida. On the West Coast, however, the significance of associations between structure forming invertebrates and groundfish species, in terms of being essential fish habitat, has not been clearly identified.

Information recorded in the habitat use database (see Section 2.3.4.2) indicates that one or more species in the Groundfish FMP have been recorded as occurring with 10 separate categories of invertebrates that could be regarded as structure forming, or habitat creating. These are basketstars, brittlestars, mollusks, sea anemones, sea lilies, sea urchins, sea whips, sponges, tube worms and vase sponges. This does not imply that fish use these structure forming invertebrates as habitat. It also does not assume that ALL species in the various groups form structure or that those that do form structure do so all the time. Further, this is most certainly only a partial list and is incomplete – some significant groups are missing, e.g., cold water corals, including gorgonians and antipatharians, and other octocorals that form structure to an elevation of 4 meters above the seafloor.

Data on the presence of sponges, anemones, and cold water corals (including gorgonians, black corals, and sea pens) are available from the NOAA Fisheries bottom trawl surveys on the West Coast shelf and slope (Figure 4). These data form the basis for the only coast-wide source of distributional information for structure forming invertebrates (see Morgan and Etnoyer, 2003).

However, there are some serious limitations to this information. Firstly, it should be noted that only presence data have been plotted in Figure 6; those trawl samples without structure forming invertebrates (i.e., absence data) have not been plotted. Secondly, the trawl samples are notoriously biased toward “trawlable”, soft bottom, low relief habitats, and therefore complex rock structure, which is known to be important habitat for many structure forming invertebrates, is not well represented. The coral category, denoted on the map in blue, includes both soft-bottom sea pen species and also species that occur primarily on complex rocky substrata.

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

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

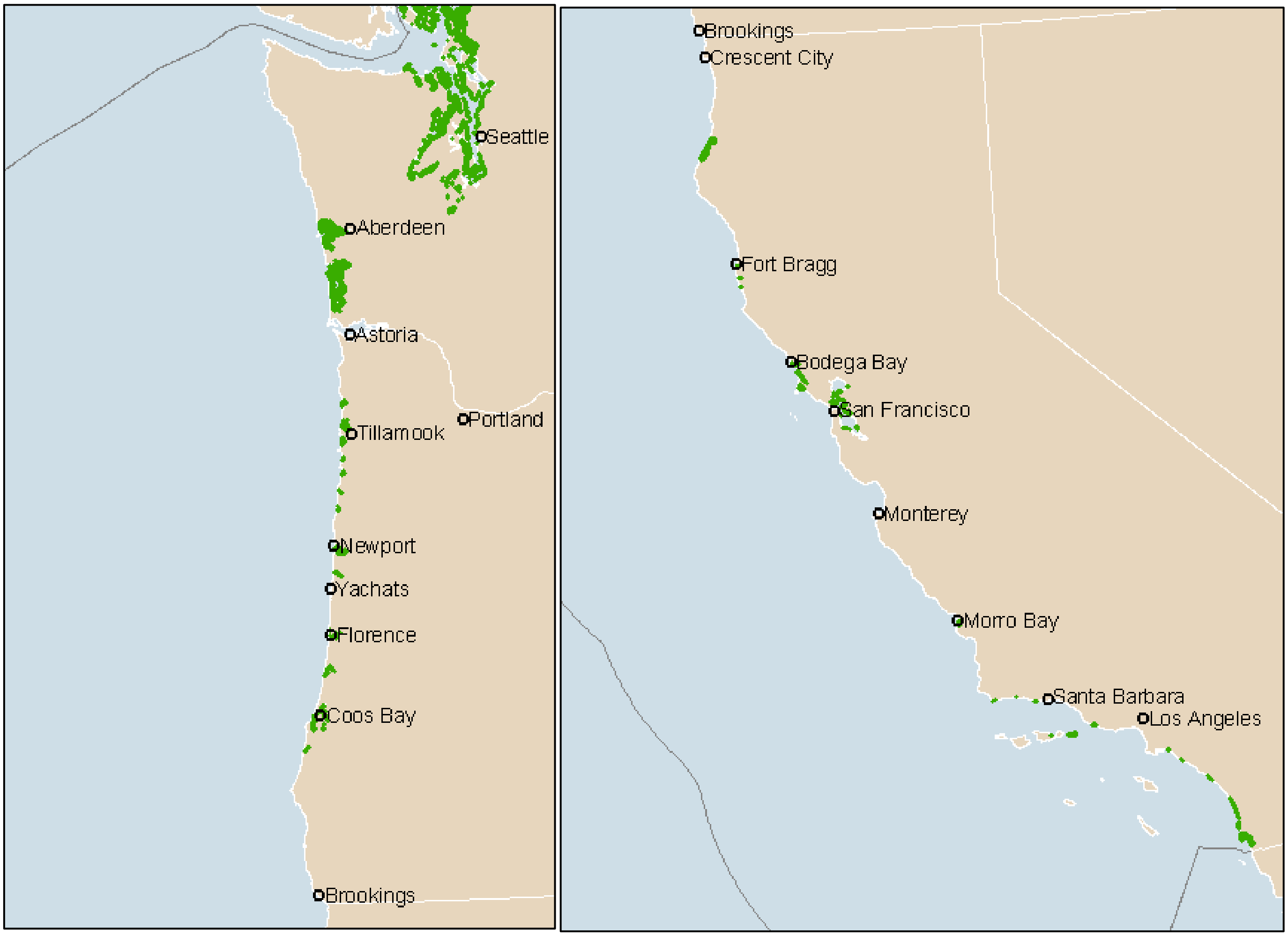

Figure 5 Distribution of seagrass along the west coast of the United States. Note: Seagrass polygons drawn with thick lines to allow visualization at this map scale. Seagrass data sources are listed in Table 3.

Table 3. Summary of seagrass data sets compiled as of February 2004.

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

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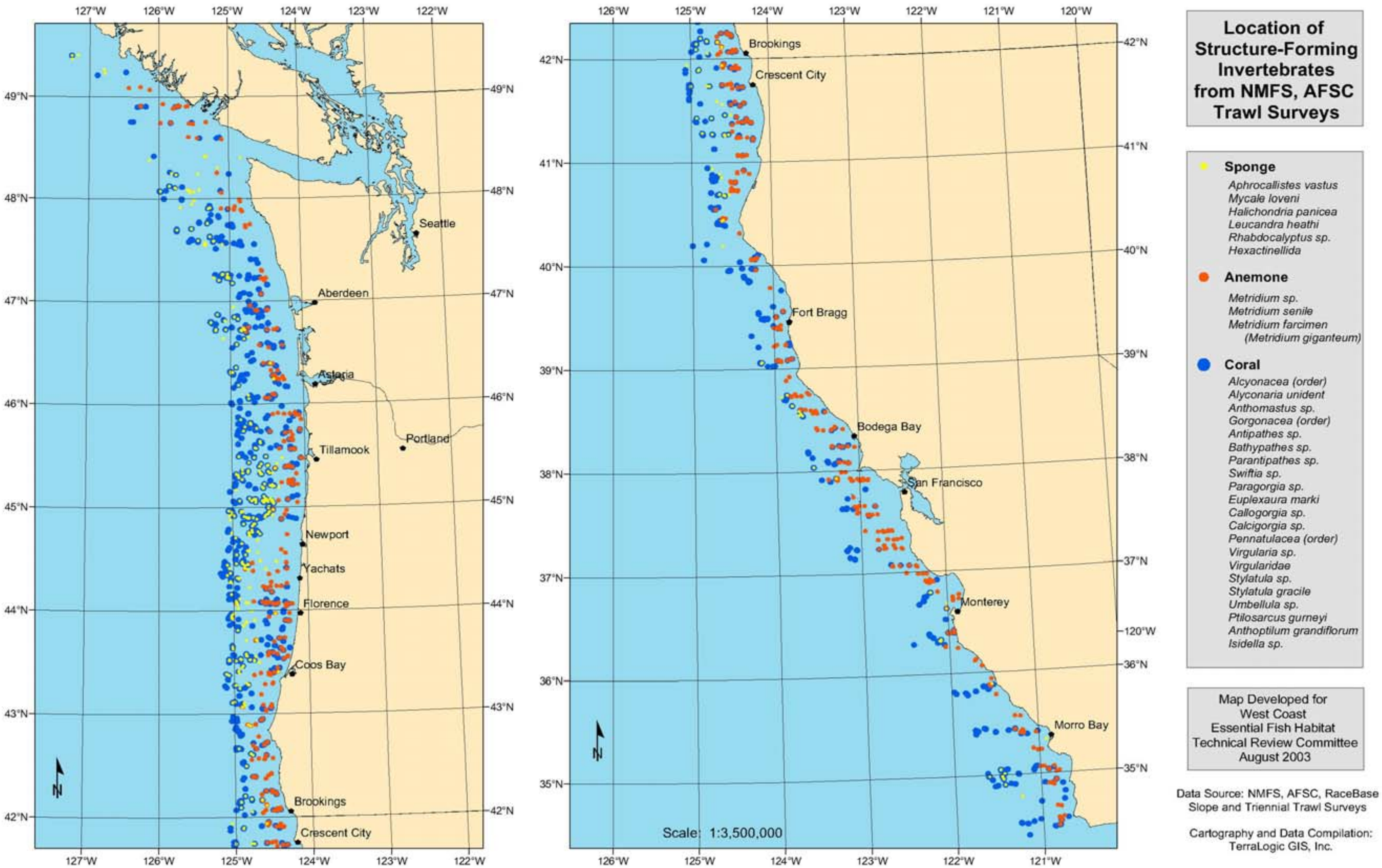

Figure 6. Locations of sponges, anemones and corals from NMFS AFSC trawl surveys.

2.2.2 Bathymetry

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

Moss Landing Marine Lab provided 10-meter depth contours for California. These contours were derived from a publicly-available 200-meter bathymetry grid from the California Department of Fish and Game, Marine Region GIS Unit. For Oregon, up to 46° latitude, Oregon State University provided 10-meter depth contours. These contours were generated from a 100-meter bathymetry grid developed by combining and resampling multiple in-house data sets. Data sources and processing procedures for these contours are described in Appendix 2 (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 to 200 meters across, was bridged by extending the contour lines to meet the shared boundary.

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

2.2.3 Latitude

Along with depth and substrate type, latitude is the third habitat characteristic used in the EFH Model to calculate habitat suitability probability values (Section 3.4). Initially, boxes delineating 1’ latitudinal zones were created and overlaid with bathymetry and benthic habitat data to create a set of unique physical habitat polygons. During the development of the EFH model, it was concluded that species distributions change more gradually over latitude, and that 10’ latitudinal zones would be a more appropriate level of detail. Therefore, a new GIS coverage depicting 10' latitude zones was developed and merged with other habitat components.

2.2.4 Pelagic Habitat

There are a number of species and life stages in the Groundfish FMP that occur in the water column, but do not have any association with benthic substrate. While the water column is likely to be much less sensitive to fishing impacts than benthic substrate it is still necessary to identify EFH for these components of the groundfish assemblage. There may, for example be non-fishing impacts such as pollution that may have adverse effects. However, mapping EFH in the pelagic zone is even more difficult and less exact than for the seabed. The features of the water column that are likely to be of importance include biological, physical and chemical oceanographic processes that are hard to map. Frontal boundaries, temperature regimes and biological productivity all vary on seasonal and inter-annual scales that make identification of a static two dimensional designation of a boundary such as is required for EFH problematic. We have not attempted to map these features in the GIS in the same way as for the benthic substrate at this stage. EFH for species and life stages residing in the water column is mapped instead on the basis of latitudinal and depth ranges reported in the literature.

2.2.5 Data Quality

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

2.2.5.1 Physical substrate

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

A 'data quality' GIS layer was developed to indicate the degree of certainty that the mapped seafloor type represents the 'real' seafloor type. For the Washington and Oregon benthic habitat maps, the Active Tectonics and Seafloor Mapping Lab at OSU provided a data quality layer created by developing four separate 100-meter grids for each data type (bathymetry, sidescan sonar, substrate samples, seismic reflection) and ranking the data sources on a scale of 1 to 10.

OSU geologists created an overall substrate data quality layer by summing the values from the four individual data quality layers, creating a new layer with values from 1-40. Detailed documentation about the Washington/Oregon data quality layer is provided as Appendix 4. For modeling purposes, these data were grouped into four categories of data quality corresponding to the values 1-10, 11-20, 21-30, and 31-40. Figure 7 shows the four-level data quality layer for Oregon and Washington. No data quality layer is available for benthic habitat in California.

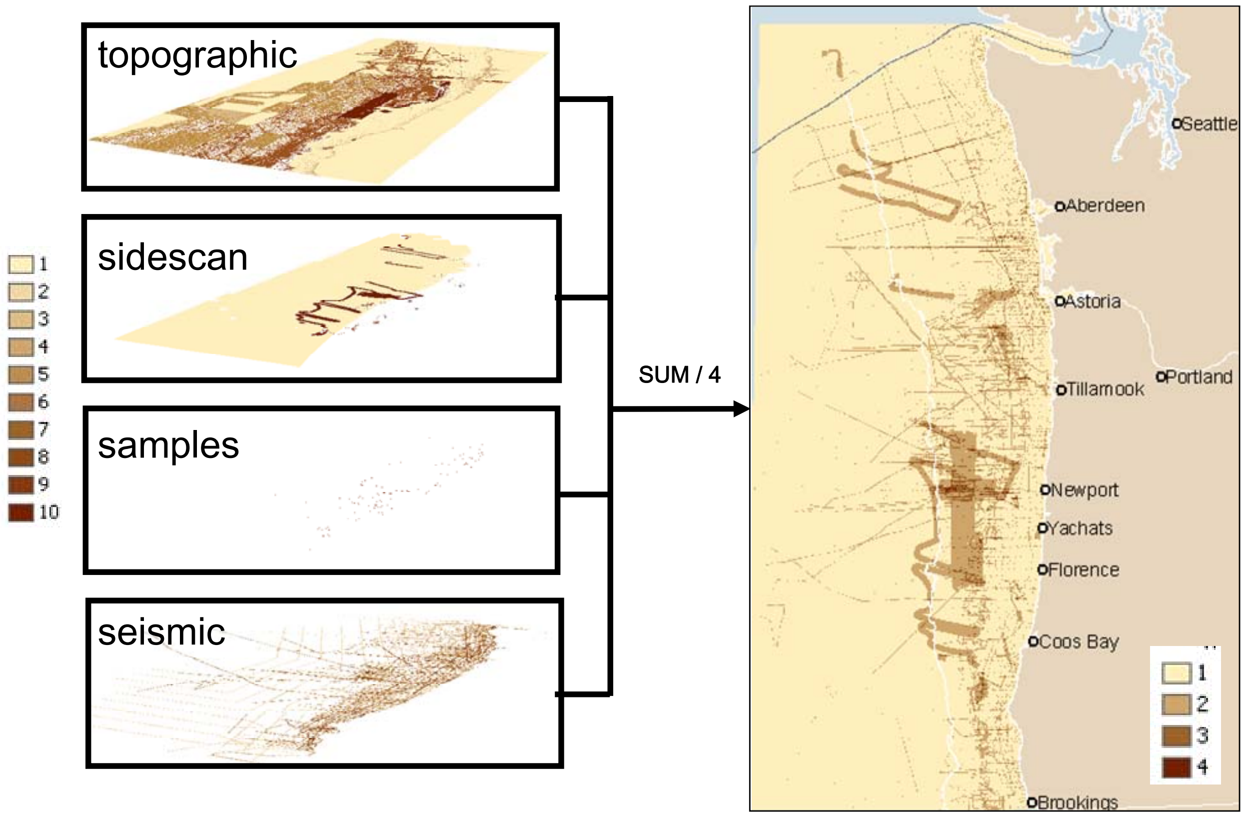

Figure 7 Four-level data quality layer for physical substrate off Oregon and Washington. Graphics prepared by TerraLogic GIS, Inc., from data provided by OSU, Seafloor Mapping Lab.

2.2.5.2 Bathymetry

Bathymetric data quality is affected by the source data's spatial resolution, spatial accuracy, and attribute accuracy and precision. A general data quality layer for bathymetry has been developed by TerraLogic GIS (Figure 8). The boundaries for each bathymetry data source have been delineated and the overall quality of each data source can be ranked on a relative scale. The bathymetry data from Oregon are the highest quality, the data from California are 2nd best quality, the 3rd quality level are the data from Washington (WDFW), while the lowest quality data is from the Naval Oceanographic Office used to fill gaps off Washington and Southern California. Within each data source, there are also variations in data quality. However, other than Oregon, there is not adequate information to delineate these within-source variations. Therefore, we used a single quality rank for each source.

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

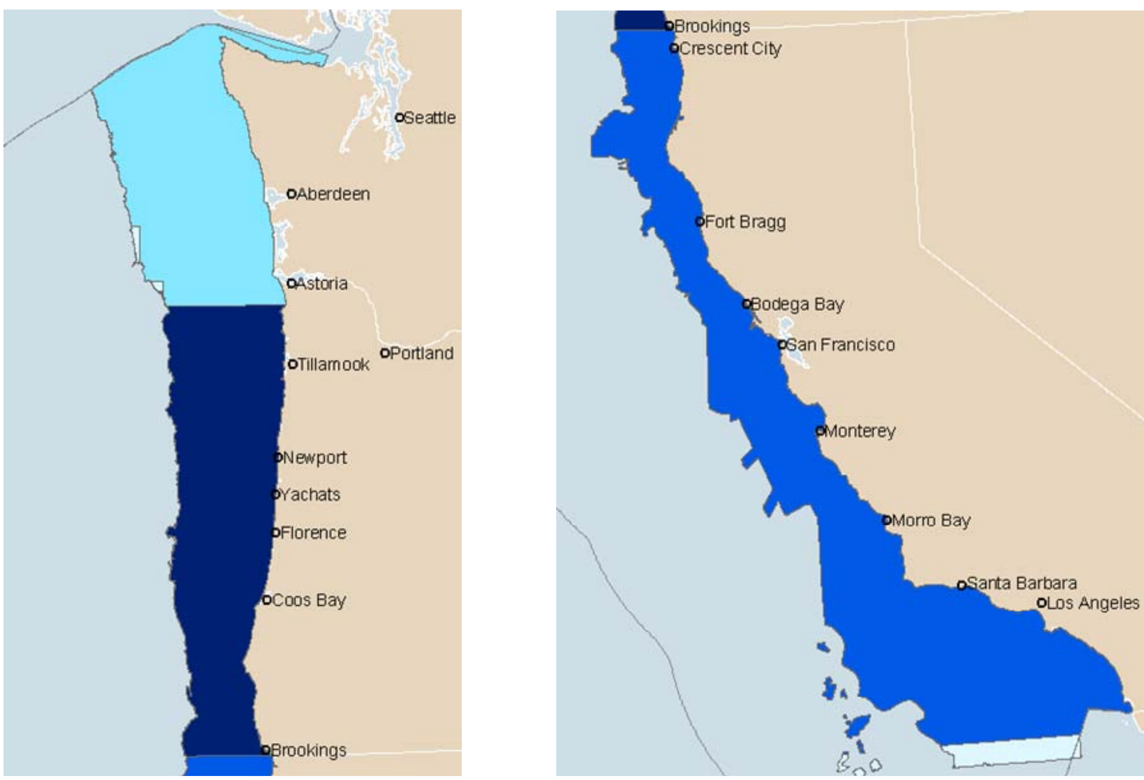

Figure 8 Relative data quality based on bathymetry data sources off Washington, Oregon and California

2.3 Use of Habitat by Groundfish

2.3.1 NMFS trawl surveys

Trawl surveys can provide valuable information on fish distribution, and hence provide source data for estimating the suitability of habitat within the area covered by the FMP. Bottom trawl surveys have been conducted on the continental shelf and upper slope off the west coast (Washington, Oregon and California) since 1977. These surveys provide the primary source of abundance and trend information for most stock assessments conducted on west coast groundfish. In all, there are three survey series that have operated in the study area, which are described below. A summary comparison of the details of these surveys in 2001 is provided in Table 4. Survey coverage is illustrated in Figure 9.

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

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

In 1998 the Northwest Fisheries Science Center (NWFSC), initiated a new bottom trawl survey of the commercial groundfish resources in the slope zone (100 - 700 fathoms). Conducted in the summer months, this survey uses chartered local West Coast trawlers ranging in size from 60 to 100 ft. In 1998, the survey covered the area from Cape Flattery, Washington (48°10' N), to

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

Morro Bay, California (35°N), between August 20 and October 16. This survey has been conducted annually since 1998. Although the survey aims to sample the slope, in 2001 the design was changed for one year to cover the shelf. The survey in all other years (1998 to 2000 and 2002) has been a segmented transect design that divides the US Pacific coast into 10deg, equidistant sections north to south & 10 east-west segments based on depth. The area covered in 1998-2000 was 34deg 15min to 48deg 15min latitude. In 2002, the area covered expanded at the southern margin to 32deg 30min (i.e. south of Point Conception) and contracted very slightly at the northern margin to 48deg 10min latitude.

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

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

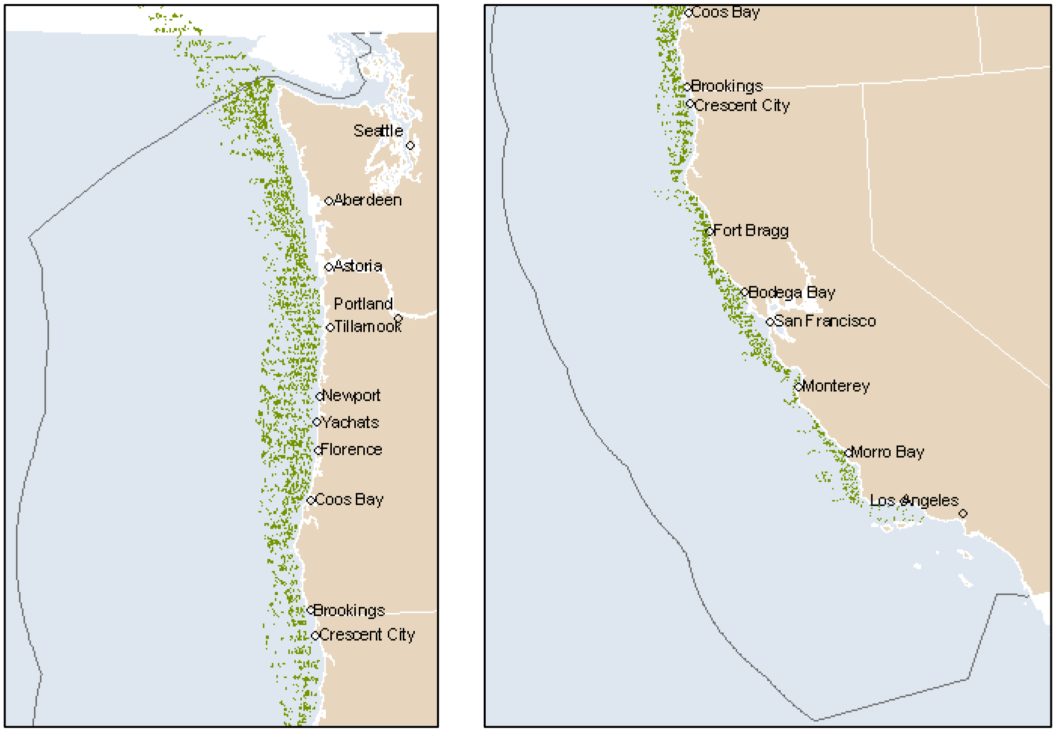
The survey data can also be analyzed to characterize the preferences of species and life stages for different components of the habitat. For example it is possible to explore the relationships between catch per unit effort (cpue) and habitat attributes such as latitude and depth (see Sections 2.3.4.3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

Table 4 Comparison of the three trawl survey series covering the west coast of the US. Information provided by NOAA Fisheries.

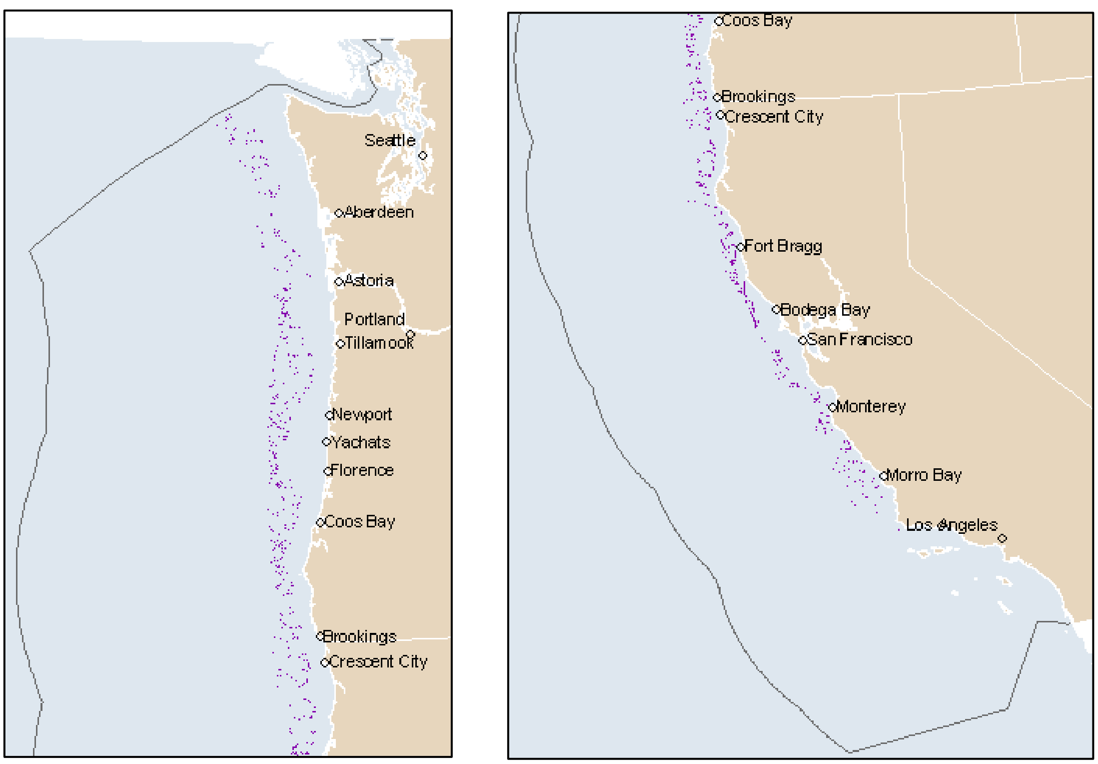
Item (year=2001)	**NWFSC Slope Survey**	**AFSC Triennial Shelf Survey**	**AFSC Slope Survey**
Vessel Type	Chartered West Coast trawler	Chartered Alaska Trawler	Fisheries Research Vessel
Period	1998-ongoing	1977-2001	1984-ongoing
Frequency	Annual	Triennial	Annual since 1988
Survey Type and depth	Slope (100-700 fathoms)	Shelf (30-200 fathoms)	Slope (100-700 fathoms)
LOA Vessel	68-92 ft.	125-128	225
Survey Design	Stratified by lat & depth/random by depth & proximity	Stratified by lat & depth, somewhat fixed stations	Stratified by lat & depth, somewhat fixed stations
Yearly use of same survey vessels	Yes in some instances but not intent of design	Yes, if possible	Yes
Survey Time of the Year	Summer	Summer	Fall
No of vessels available for hire	Approx. 40 (Have used 9 vessels to date)	At least 100	1
No of scientists on board	3	6	12
No of hours vessel worked/day fishing (daytime or round the clock)	14 (daytime only sampling)	14 (daytime only sampling)	24 (round the clock sampling)

Item (year=2001)	NWFSC Slope Survey	AFSC Triennial Shelf Survey	AFSC Slope Survey
Days At Sea (2001)	166	130	28
Average no of tows/day (2001)	2.01	3.89	7.43
Number of attempted tows (exclude experimental)	408	539	216
Number of valid tows*	334	506	208
Net Mensuration	Yes	Yes	Yes
All Fish Species Identified	Yes	Yes	Yes
Invertebrate Species ID	No, only crab identified	Yes, all invert spp.	Yes, all invert spp.
No of different length spp.	4 primary, 15 total	28 primary, 77 total	9 primary, total
Average no of lengths collected/tow	196	510	545
Average no otoliths collect/haul/vessel	18	15	40
Commercial fish retained?	Yes	No	No
Targeted Tow Duration	15 mins	30 mins	30 mins
Average lift off-lag time (minutes)	4.5	0.4	"almost immediately"
Range of Lift off-lag times	1-20 minutes	0-2 minutes	NA
Average no of weather days	0.5	0.75	0

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



(a)



(b)

Figure 9. Survey station locations for the AFSC Slope and Shelf Surveys (a) and the NWFSC Slope Survey (b). Graphics created by TerraLogic GIS Inc.

2.3.2 Ichthyoplankton surveys

In this section we describe surveys that have been undertaken that could provide some information on the distribution of planktonic phases of groundfish species. In fact, data from these surveys have not been used in the EFH model. They do not provide a comprehensive coast wide coverage and, where possible, fish habitat in the water column has been described using information on the latitude and depth ranges of the species and life stages in question (see Section 3.4.2.1).

2.3.2.1 CalCOFI Ichthyoplankton Surveys

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

2.3.2.2 NMFS Icthyoplankton Surveys

Research surveys extending from the Strait of Juan de Fuca to northern California and offshore to the boundary of the Exclusive Economic Zone (200 miles) were conducted periodically during the 1980s. They were intended to complement the egg and larval data obtained from the CalCOFI ichthyoplankton surveys and NMFS conducted these surveys cooperatively with the Soviet Pacific Research Institute. Survey methods and their results are described by Doyle (1992). Data on egg and larval distribution were used to develop the GIS maps of NMFS ichthyoplankton survey results in the 1998 EFH Appendix.

2.3.3 NOAA Atlas

In the late 1980’s, NOAA compiled information about several commercially-valuable groundfish species on the west coast. This information was synthesized into a hand-drawn map atlas format showing the species distribution for various life stages (NOAA, 1990). The source data for these maps included NMFS’ RACEBASE, commercial and recreational catch statistics, state or regional agency data, and expert review. The scale of these maps is generally 1:10,000,000. In the 1990’s these atlas maps were converted to GIS format. This conversion included clipping the species polygons with a 1:2,000,000 land polygon. The 13 groundfish species and life stages that are available in GIS format are listed in Table 5.

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

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

2.3.4 Fish/habitat functional relationships

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

2.3.4.1 The Updated Life Histories Descriptions Appendix

In 1998, A Life Histories Appendix to Amendment 11 to the Pacific Coast Groundfish FMP described the life histories and EFH designations for each of the 83 individual species that the FMP manages. The appendix was prepared by a team led by Cyreis Schmitt[2] (at the time, affiliated with the Northwest Fisheries Science Center). The primary sources of information for the life history descriptions and habitat associations were published reports and gray literature. GIS maps of species and life stage distributions generated in the format of ArcView were included.

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

The Life Histories Appendix was intended to be a "living" document that could be changed as new information on particular fish species became available, without using the cumbersome FMP amendment process. The EFH regulations state that the Councils and NMFS should periodically review and revise the EFH components of FMPs at least once every 5 years. In response to this requirement for periodic review, the life history descriptions were recently updated by Bruce McCain with assistance from Stacey Miller and Robin Gintner of the NOAA Fisheries, Northwest Fisheries Science Center (NOAA Fisheries 2003). The update was compiled by conducting literature searches using the *Cambridge Scientific Abstracts Internet Database Service* and by reviewing recently completed summary documents, such as the California Department of Fish and Game’s Nearshore Fishery Management, the Oregon Department of Fish and Wildlife’s Nearshore Fisheries Management Plan, and *The rockfishes of the Northeast Pacific* by Love *et al*. (2002). Within the updated appendix, the current 82 FMP groundfish species are sequenced alphabetically according to the common names (Appendix 5). This document also includes nine summary tables and a list of references cited.

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

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

2.3.4.2 The habitat use database (HUD)

The Life Histories Appendix (NOAA Fisheries 2003) also provides a valuable compilation of information on the habitat preferences of all the species and life stages in the Pacific Coast Groundfish FMP to the extent known. However, the text format in which the information is presented does not lend itself well to analysis of habitat usage across many habitat types or many species and life stages.

A Pacific Coast Groundfish Habitat Use Relational Database was therefore developed to provide a flexible, logical structure within which information on the uses of habitats by species and life stages could be stored, summarized, and analyzed as necessary. The database is designed primarily to capture the important pieces of information on habitat use by species in the Pacific Groundfish FMP as contained in the Updated Life History Descriptions Appendix compiled by NMFS (see Section 2.2.2.1). This Appendix contains information on each of the species in the groundfish FMP, and includes range, fishery, habitat, migrations and movements, reproduction, growth and development, and trophic interactions. Certain elements of this information need to be captured in a database format so that habitat use data can be analyzed both by species and habitat to provide input into various components of the analysis of EFH, HAPCs and fishing impacts (See Appendix 6 - Manual of the Habitat Use Database).

Below we present some examples of how the information in the database can be queried. These tables record the number of species with "strong" associations with the relevant habitat categories:

Level 1 Habitat	Number of Species
Coastal Intertidal	9
Estuarine	19
Shelf	81
Slope/Rise	40
Slope/Rise/Plain	18

This query shows that almost all species in the FMP associate at least some time in their life cycle with at habitats on the shelf. The next most important area, as measured by number of species is the slope/rise habitat. We note, however, that sampling effort is concentrated on the shelf.

Level 2 Habitat	Number of Species
Basin	2
Benthos	81
Intertidal Benthos	3
Submarine Canyon	3
Water Column	69

Not unexpectedly, this query shows that almost all species in the groundfish FMP associate with the benthos at some stage in their lifecycles. A large proportion of species also have pelagic stages – mainly eggs and larvae.

Level 4 Habitat Type	Number of Species
Algal Beds/Macro	21
Algal Beds/Micro	4
Artifical Reef	3
Bedrock	43
Boulder	25
Cobble	9
Current System	1
Drift Algae	5
Fronts	1
Gravel	3
Gravel/Cobble	3
Gravel/rock	1
Macrophyte Canopy	9
Mixed mud/sand	11

Level 4 Habitat Type	Number of Species
Mud	17
Mud/Boulders	7
Mud/Cobble	6
Mud/gravel	1
Mud/Rock	11
Oil/Gas Platform	1
Rooted Vascular	2
Sand	25
Sand/Boulders	1
Sand/Cobble	1
Sand/Gravel	2
Sand/Rock	12
Seawater surface	4
Silt	2
Silt/Sand	1
Soft bottom/Boulder	2
Soft Bottom/rock	3
Unknown	78

This query provides more detail in terms of finer scale habitat preferences of groundfish. Bedrock and bolder habitats are important hard substrates for many species, while mud and sand are important soft substrates.

Habitat Level 4	Eggs	Larvae	Juveniles	Adults
Algal Beds/Macro	1		13	9
Algal Beds/Micro			4	
Artifical Reef				3
Bedrock	2		27	38
Boulder	1		7	22
Cobble			1	7
Current System		1		
Drift Algae			5	
Fronts		1		
Gravel			1	3
Gravel/Cobble	2		1	2
Gravel/rock				1
Macrophyte Canopy		4	9	3
Mixed mud/sand	1		8	7
Mud	1		10	9
Mud/Boulders			2	4
Mud/Cobble			2	4
Mud/gravel				1
Mud/Rock			3	8
Oil/Gas Platform			1	
Sand	4		16	10
Sand/Boulders			1	1

Habitat Level 4	Eggs	Larvae	Juveniles	Adults
Sand/Gravel			1	1
Sand/Rock			9	3
Seawater surface	2	1		
Silt			1	2
Silt/Sand			1	
Soft bottom/Boulder				2
Soft Bottom/rock			2	1
Unknown	17	59	55	32
TOTAL	**23**	**60**	**73**	**72**

Taking the shelf habitat as an example, this query shows the number of species and life stages that associate strongly with each level 4 habitat. The most important habitats for adults are bedrock and boulders, while sand, mud and algal beds appear to be more important for juveniles than for adults. Note the smaller numbers of occurrences for eggs and larvae, indicating the poorer level of information on these life stages.

2.3.4.3 Habitat Suitability Modeling

Habitat suitability modeling (HSM) is a tool for predicting the quality or suitability of habitat for a given species based on known affinities with habitat characteristics, such as depth and substrate type. This information is combined with maps of those same habitat characteristics to produce maps of expected distributions of species and life stages. One such technique is termed habitat suitability index (HSI) modeling. A suitability index provides a probability that the habitat is suitable for the species, and hence a probability that the species will occur where that habitat occurs. If the value of the index is high in a particular location, then the chances that the species occurs there are higher than if the value of the index is low. HSI models use regression techniques to analyze data on several environmental parameters and calculate an index of species occurrence. This methodology has potential for use in designating EFH and HAPC, and an example application by scientists from the National Ocean Service (NOS) is described in Appendix 7. It is also described in more detail in various scientific publications (see for example Christensen *et al*. 1997, Clark *et al*. 1999, Coyne and Christensen 1997, Rubec *et al*. 1998, Rubec *et al*. 1999, Monaco and Christensen 1997 and Brown *et al*. 2000).

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

2.4 Effects of Fishing on Groundfish Habitat

2.4.1 Fishing gears

The PSMFC prepared a document that describes the fishing gears used on the west coast of the United States (excluding Alaska) and which components of those gears might affect structural habitat features (Appendix 8). This gear description is one part of a 'fishing gear impact analysis' that requires an understanding of the gears used, how gear 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 6 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 halibut, Pacific halibut, herring, market squid, tunas, and other coastal pelagic and highly migratory species) is similar to gear 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.

Gear types in the PACFIN database are listed on the PSMFC web site[3]. A copy of this list is provided in Appendix 9 for ease of reference. Gears used for salmon net pen aquaculture and Washington and California kelp harvest are not included in the analysis of the effects of fishing gears, but are described under the non-fishing effects section of the EFH environmental impact statement. A list of authorized gear types for the west coast is at 50CFR 660.322[4]:

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

[3] www.psmfc.org/pacfin/gr.lst

[4] http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/cfr_2002/octqtr/50cfr660.322.htm.

[5] Adapted from Goen and Hastie, 2002.

[6] Most fishing gears 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) are similar to those used to target groundfish. These gears

	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)

2.4.2 Fishing gear impacts: West Coast perspective

At its meeting on February 19-20, 2003, the Technical Review Committee reviewed the proposed risk assessment framework and recommended that PSMFC contract for development of a west coast perspective on fishing gear impacts.

There exist several literature reviews of the effects of fishing gears on habitat, but these rarely contain information specific to the west coast and there is no clear direction on how information from other areas should be applied there. There is a general lack of west coast specific studies

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.

and the TRC identified the need to determine specifically how to make inferences from studies that occurred in other parts of the world. A new review was therefore undertaken as part of this risk assessment and the results are presented in Appendix 10.

Johnson (2002) provides a major review of the national and international literature on fishing impacts on bottom habitats and was relied upon heavily for developing the west coast review. Other reviews that provided additional literature and/or interpretations of the literature were Watling and Norse (1998), Auster and Langton (1999), Dayton et al. (2002), National Research Council (2002), and Morgan and Chuenpagdee (2003).

More than thirty fishing gear types are used on the west coast (Recht 2003). There have been no studies on the impacts of most of these on bottom habitats. Those for which useful studies were found include eight gear types: otter trawls, beam trawls, shrimp trawls, New Bedford/scallop dredges, hydraulic dredges, oyster dredges, pots, and hand/mechanical harvesting. Only two studies directly on west coast gears were found to be useful. Hence, research from areas other than the Pacific coast provided most of the information on which the analysis was based. Presently there is very little quantitative information describing the relationship between habitat type, structure and function and the productivity of managed fish species. Hence impacts on habitat that cause adverse effects are hard to quantify. For purposes of the analysis, consistent with NOAA Fisheries EFH Final Rule defined adverse effects of fishing gear as “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).

Changes in the quantity of EFH can be measured, if there are time series of sufficient length. However, linking these changes to specific actions, either fishing or non-fishing can be difficult due to the scale of the available data on intensity (e.g. fishing effort). Measuring the quality of EFH is presently an inexact science and relies substantially on relative, and often qualitative rather than absolute and quantitative metrics.

Further details of the analysis and measurement of fishing impacts are provided in Section 4.2: the Risk Assessment and in Appendix 10.

2.4.3 Fishing effort

2.4.3.1 Commercial trawl logbooks

West coast commercial trawling effort has been recorded in logbooks and provided to state fisheries managers since the 1980s and earlier. 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. PSMFC created and maintains a comprehensive database (PACFIN) for commercial fishing data, which includes west coast trawl logbook data starting in 1987. Commonly, the commercial trawling data are summarized geographically by logbook blocks (Figure 10), which are primarily 10-minute latitude/longitude cells. Trawl logbook data from PACFIN are available on a tow-by-tow basis for 1987-2002. (At the time of data development, 2003 data were not yet complete in the database).

The data can be summarized in a multitude of ways, both temporally and spatially. The specific logbook data summaries developed as input for the Impacts Model are described in Sections 4.3 and 4.5.2.1. The logbook data are coastwide, however, prior to 1997, position data for trawls off California were provided by logbook block only, not by precise haul location. In addition, prior to 1998, the date specification was limited to year, rather than full date. This removes the potential to analyze seasonal patterns of effort. Finally, the gear types in the PACFIN database are more general categories than the detailed gear types in Table 6 would suggest. The gear type identifiers in the logbook data are: groundfish trawl, midwater trawl, roller trawl, flatfish trawl, and other trawl. The number of records by gear type in the PACFIN database is shown in Table 7.

Table 7. Use of different gear types recorded in the PACFIN database (1987-2002)

Gear type	Number of tows (percent of tows)
groundfish trawl	363709 (54.4%)
flatfish trawl	138856 (20.8%)
roller trawl	126478 (18.9%)
midwater trawl	33157 (5.0%)
other trawl	3674 (0.5%)
no gear given	2173 (0.3%)

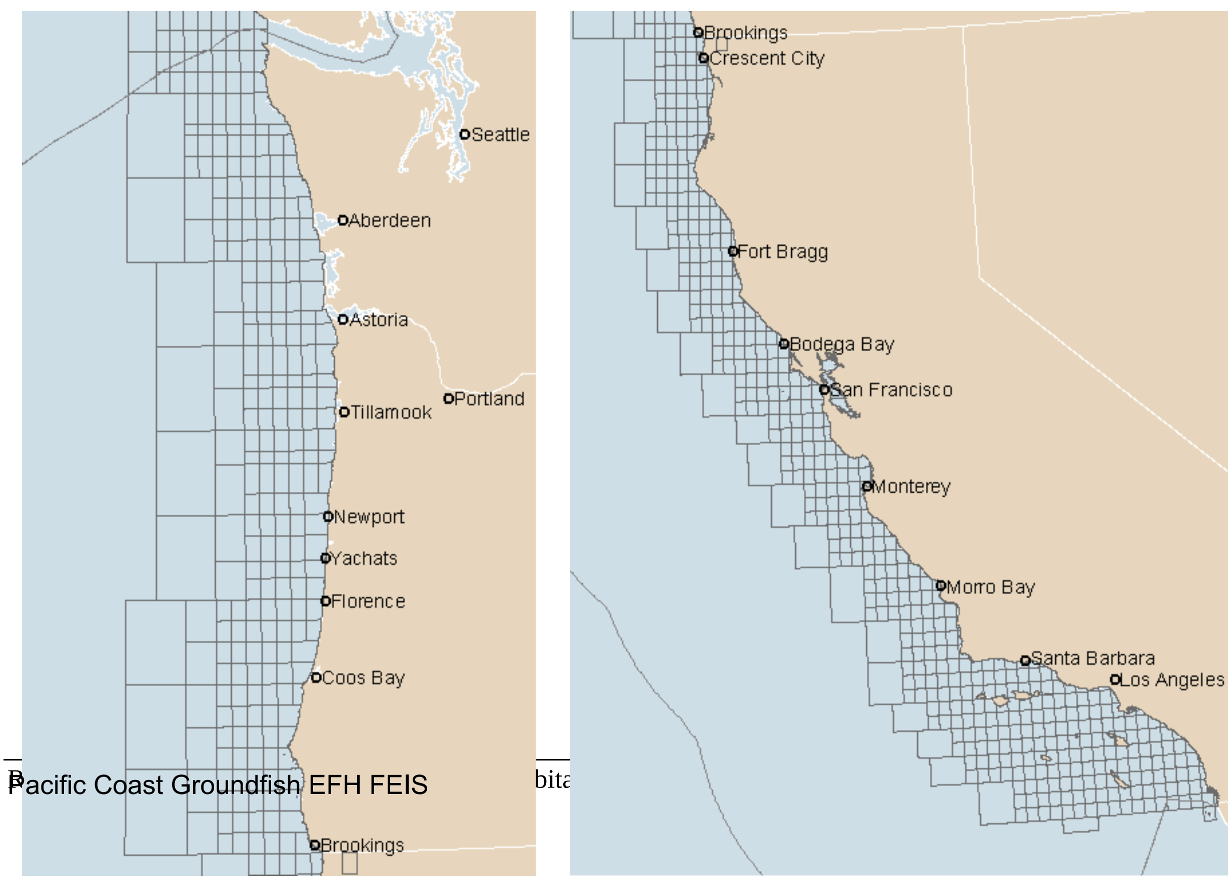


Figure 10 Trawl logbook blocks in the PACFIN database.

2.4.3.2 Non-trawl gears in the PACFIN database

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 in the PACFIN database include 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 square miles.

As part of a larger project[7], Ecotrust, Inc. has developed a predictive model to further resolve catch and effort data to levels consistent with the commercial trawl data (Ecotrust 2003). Using this predictive model, fishing activity is assigned to a specific 9 km block, summarized by 9 km block for 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.

2.4.3.3 Data from fishermen's focus groups

Another project, initiated as part of the EFH risk analysis, sought to collect fishing effort information retroactively directly from fishermen through focus groups. The project was initiated on the recommendation of the TRC to ground truth the Ecotrust product described in Section 2.4.3.2 by consulting with fishermen. The data collected covered current and historical fishing areas defined by the fishermen and fishing intensity for groundfish trawl and fixed gear fisheries within those areas. Due to funding constraints was only undertaken for a small section of the coast sufficient to complete groundtruthing of the Ecotrust product. The results are presented in Appendix 11.

The methodology for collecting this type of information was tested on a single NOAA nautical chart, number 18520, covering the area offshore of Oregon between the Columbia River and Yaquina Bay. Focus group participants drew polygons on the chart indicating known fishing areas for three eras: 1986-1999, 2000-2002, and 2003. In addition, they provided information on fishing intensity, including average number of boats in a polygon per day, as well as some indication of typical "units" of fishing, (such as average tows per boat and average tows per hour), which varied by gear type. Participants were generally quite comfortable drawing the boundary lines on the maps, but not very comfortable with estimating fishing intensity (i.e. effort). After the focus group sessions, the data were converted to GIS format using a 'heads-up' digitizing approach.

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

2.4.3.4 Using available commercial fishing effort data

All three sources of commercial fishing effort data have their strengths and weaknesses. The logbook data are extensive, both spatially and temporally, and are acknowledged to be the most comprehensive source of information on trawl effort currently available (SSC Groundfish Sub-committee review of Impacts Model, February 2004[8]). However, these data only includes information on trawl gear. The Ecotrust model and the focus group project both provide information on fixed gear. However, the Ecotrust model is predictive and quantifies revenue and catch, rather than effort. The focus group information is limited in spatial extent to a small section of the coast.

Appendix 12 provides a first order of comparison and validation of the three data sets described above. The focus group information was compared both to trawl logbook data and the Ecotrust model for spatial coincidence and consistency in estimates of the area impacted by fishing. Intensity measures were not compared at this stage – fishing effort was compared as a simple presence/absence variable.

The focus group polygons for bottom trawl fishing showed good spatial consistency with trawl logbook data, particularly when overlaid with the trawl set point locations. Unfortunately, the spatial coincidence and the consistency of fishing area estimates between focus group and Ecotrust results was fairly low for fixed gear types. Based on a review of this analysis, the SSC Groundfish Subcommittee recommended against using the Ecotrust model output in the impacts model[9] . In addition, the SSC review endorsed the use of the focus group approach for collecting coastwide fixed gear information. However, because the focus group information is limited to a small portion of the coast, it has not been included in the current version of the impacts model.

2.4.3.5 Recreational fishery

The recreational fishery sector comprises the commercial passenger fishing vessel (CPFV) fleet (charters), private fishing vessels, and other miscellaneous fishing activities. Appendix 13 provides a summary of available information on recreational fishing effort.

The Marine Recreational Fishery Statistics Survey (MRFSS) is a nationwide survey conducted since 1979, (with the exception of 1990-2) that collects information on all elements of the recreational fishery. Information is elicited through telephone surveys and 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. It has therefore not been possible to incorporate these data into the Impacts Model at this stage.

[8] Exhibit C.6.c, Attachment 1, Briefing Book for April 2004 Council meeting.
[9] Exhibit C.6.c, Attachment 1, Briefing Book for April 2004 Council meeting.

The California Department of Fish and Game also collects species information on CPFV fishing that is apparently available at a 10nm by 10nm resolution from 1936 through 1997.

2.5 Effects of Non-Fishing activities on Groundfish Habitat

2.5.1 Description of non-fishing impacts

In 2003, NOAA Fisheries prepared a detailed description of non-fishing impacts to essential fish habitat and recommended conservation measures (Appendix 14). The document is organized by activities that may potentially impact EFH occurring in four discreet ecosystems: upland, riverine, estuarine, and coastal/marine systems.

Non-fishing activities have the potential to adversely affect the quantity or quality of EFH designated areas in riverine, estuarine, and marine systems. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharge, water diversions, thermal additions, actions that contribute to non-point source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. For each activity, known and potential adverse impacts to EFH are described in the review document. The descriptions explain the mechanisms or processes that may cause the adverse effects and how these may affect habitat function. The review also provides proactive conservation measures designed to minimize or avoid the adverse effects of these non-fishing gear activities on Pacific Coast EFH.

2.5.2 Spatial data on non-fishing impacts

An initial survey of available non-fishing impact spatial data undertaken in the fall of 2003. Although the DEIS for the Gulf of Mexico EFH Project was used as a model, the 2003 Draft document ‘Non-Fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures’ and a phone conversation between TerraLogic, MRAG Americas and the NMFS Project Manager served to focus efforts for the west coast. A list of individuals to contact was generated during this conversation and served as the starting point for the collection effort.

To date, over 70 individuals at NMFS, USEPA, USACOE, MMS, USGS, Washington DNR, Washington DOE, Oregon DEQ, California Fish and Game as well as several private and non-profit organizations have been contacted (Appendix 15). The individuals on this list were identified during the calling effort with each phone call generating additional names to contact. The survey followed the resulting path. The list of collected west coast non-fishing impact data includes dredge disposal sites, shoreline hardening, marinas, land use land cover, oil and gas lease locations, Pacific cable information, etc. (Table 8)

In addition to the collection of available data, this process has yielded the added benefit of identifying numerous data gaps relevant to non-fishing impacts. While the generation of these various data sets is well beyond the scope and scale of this effort, it is hoped that this work will lead to additional initiatives that will start to tackle these gaps.

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

Due to the nature of the available data (varied spatial scales, lack of completeness, etc.) and the large data gaps identified, non-fishing impacts are not incorporated into the Impacts Model at this time. In essence, there is presently no common currency in which to express the impacts of both fishing and non-fishing activities and thereby consider their effects on a comparable scale. However, this collection of the best available data provides important information for the comprehensive risk assessment and hence policy development. While some of the data are not currently in a GIS format they can be converted if time and resources allow. Once the data all reside in a GIS, they can be used for data visualization and simple overlay analysis with other data sets as well as model output. This process will enable decision makers to take into account non-fishing impacts into the policy process to the extent that the available data allow.

Table 8. West coast non-fishing impact data

	Data Collected	**Geographic Extent**	**Limitations**
Upland			
Agricultural/Nursery Runoff	USGS LULC (1993)	WA, OR, CA	NOTE: 2003 Coastal Land Use/Land Cover is currently available for California but will not be available for Oregon and Washington until late summer/early fall 2004.
Silviculture/Timber Harvest	USGS LULC (1993)	WA, OR, CA	
Pesticide Application	USGS LULC (1993)	WA, OR, CA	
Urban/Suburban Development	USGS LULC (1993)	WA, OR, CA	
Road Building and Maintenance			
Riverine			
Mineral Mining			
Sand and Gravel Mining			
Organic Debris Removal			
Inorganic Debris Removal			

	Data Collected	Geographic Extent	Limitations
Dam Operation	Dam Locations	WA, OR, CA	Point data.
Commercial and Domestic Water Use			
Estuarine			
Dredging			
Disposal of Dredged Material	USACE	WA	Grays Harbor only.
Fill Material			
Vessel Operations/ Transportation/Navigation			
Introduction of Exotic Species			
Pile Driving			
Pile Removal			
Overwater Structures	Marinas	WA ,CA	Point Locations
Flood Control/Shoreline Protection	Shoreline Hardening	WA, CA	Washington shoreline segments are based on geologic features and then assigned an attribute indicating percent hardening. Do not delineate exact extent of hardened shoreline.
Water Control Structures			
Log Transfer Facilities/ In-Water Log Storage			
Utility Line/Cables/Pipeline Installation	Cable Locations	OR, CA	
Commercial Utilization of Habitat	Aquaculture	WA, OR, CA	Data contain areas that are approved/certified for harvest, but do not show actual active aquaculture areas.
Coastal and Marine			
Point Source Discharge			
Fish Processing Waste - Shoreside and Vessel Operation			
Water Intake Structure/ Discharge Plumes	water intake	CA	
Oil/Gas Exploration/ Development/Production	lease locations	CA	
Habitat Restoration/ Enhancement			
Marine Mining			

	Data Collected	Geographic Extent	Limitations
Persistent Organic Pollutants			

3 IDENTIFYING EFH

3.1 Guidance from the EFH Final Rule

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

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

3.1.1 EFH is described for the fishery

According to the M-S Act, EFH must be described and identified for the fishery as a whole (16 U.S.C. §1853(a)(7)). The EFH Final Rule clarifies that every FMP must describe and identify EFH for each life stage of each managed species. As further clarification, NOAA General Counsel has stated that "Fishery" as used in the M-S Act in reference to EFH refers to the FMU of an FMP. The EIS must therefore develop alternatives for EFH based on individual species/life stages aggregated to a single EFH designation for Pacific Coast Groundfish. In the EIS, a single map will be used to describe and identify EFH for the fishery. However, the analysis that produces that map will include the preparation of electronic maps of EFH for as many species and life stages as possible.

Designation of EFH for a fishery is therefore achieved through an accounting of the habitat requirements for all life stages of all species in the FMU. Prior to designating EFH for a fishery, the information about that fishery needs to be organized by individual species and life stages. If data gaps exist for certain life stages or species, the EFH Final Rule suggests that inferences regarding habitat usage be made, if possible, through appropriate means. For example, such inferences could be made on the basis of information regarding habitat usage by a similar species or another life stage (50 CFR Pt. 600.815(a)(iii)). All efforts must be made to consider each species and life stage in describing and identifying EFH for the fishery and to fill in existing data gaps using inferences prior to determining that the EFH for the fishery does not include the species or life stage in question. As explained in Section 2.1.2, the CEQ Regulations mandate a process for dealing with incomplete or unavailable information

While identification of EFH is carried out at the fishery (FMP) level, the determination of whether an area should be EFH depends upon habitat requirements at the level of individual species and life stages. Potentially, only one species/life stage in the FMU may be required to describe and identify an area as EFH for the FMP. Many areas of habitat, however, are likely to be designated for more than one species and life stage. The composite habitat requirements for all the species in the Pacific coast groundfish FMP are likely to result in large areas of habitat being described and identified as EFH, due to the overlay multiple species habitat needs. The FMP for the groundfish fishery includes 82 species (Appendix 5). Descriptions of groundfish fishery EFH for each of the 82 species and their life stages resulted in over 400 EFH identifications in the 1998 EFH Amendment. When these individual identifications were taken together, EFH for the groundfish FMP included all waters from the mean higher high water line, and the upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon and California seaward to the boundary of the U.S. Exclusive Economic Zone.

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

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

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

3.1.2 Levels of information for identifying EFH

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

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.
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.

3.2 Habitat characteristics of importance for fish

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

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

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

In developing a process for identifying EFH we have built a model that expresses the probability that a particular location contains suitable habitat for species in the groundfish FMP (see Section 0), based on our knowledge of the habitat conditions at that location and of the habitat preferences of those species. As recognized in the EFH Final Rule, the only true measure of habitat suitability is obtained through measurement of demographic parameters (production, mortality, growth, and reproductive rates – levels 4 and 3 described above). For example, EFH could be defined as areas with above-average survival, growth or recruitment (which for ease of exposition we will refer to as areas of high growth potential). However, data on these parameters across a range of habitats are extremely difficult to obtain. Fish population density, or even presence/absence in data-poor situations (levels 2 and 1 respectively) are often used as a proxy for growth potential. However, growth potential and density are not necessarily well correlated. For example, in source-sink systems, source populations may have lower densities than sink populations (because they are exporting propagules), even though they are the basis for the overall population's growth potential (Lundberg and Jonzen 1999a, b).

In a spatially heterogeneous system, in which source-sink dynamics are likely to be occurring, EFH should be protecting source areas, and not inadvertently protecting sink areas. There is a risk that this can occur if population density is used as a proxy for growth potential. The risk is further exacerbated under harvesting pressure, if source populations are being more heavily fished than sink areas (Tuck and Possingham 1994). Similarly, in a heavily perturbed system, in which external factors such as pollution may be distorting the natural spatial patterns of growth potential, current population density may be a poor proxy for EFH under protected conditions. The question then is whether EFH or HAPC designations should be acting to protect areas that would have high growth potential if protected, or whether they should be protecting areas that currently have higher growth potential regardless of their intrinsic value as EFH. By using data on presence/absence or population density that are collected in a perturbed system under current conditions, we are attempting to do the latter, but without a clear understanding of the relationship between density and growth potential.

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

There is an implicit link between the level of information available for species and life stages and the extent of EFH that is likely to be designated for that species/life stage. Figure 11 illustrates the expectation that on a relative scale, if information is available at level 4, it is likely to be possible to identify a smaller portion of the overall range of a species as EFH, than if we are relying on less precise or proxy information at lower levels. For example, an identification of EFH based on areas where of production rates are highest is likely to result in a smaller area than one based on basic distribution data, because production rates are unlikely to be at their highest level throughout the species range. Rather they will be highest where habitat conditions are optimal for the species and life stage in question.

Figure 11 is, however, an oversimplification. It is not always the case, for example, that the EFH identified based on the higher level of information will be entirely within the area identified based on the lower level. As indicated above in the discussion of source-sink dynamics, EFH identified on the basis of areas of highest density (level 2) might not necessarily encompass the areas of highest productivity for some life stages. It does demonstrate, however, that if we are relying on information at lower levels, it is important to use that information in such a way that it does provide sufficient contrast to offer a range of alternatives for identifying as EFH what are believed to be the most important parts of the range of each species and life stage in the FMP. Although identifying a large area as EFH would seem to be the most risk averse approach, it is not sufficient to do this without adequate justification. As mentioned previously, the EFH Final Rule (600.815(a)(1)(iv)(A)) requires that FMPs explain how EFH for a species is distinguished from all habitats potentially used by that species, in order to improve understanding of the basis for the designations.

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

If no information for a species/life stage is available at the lowest level (distribution) and it is not possible to infer distribution from other species or life stages, then EFH cannot be identified for that species designated (600.815(a)(1)(iii)(B)). CEQ regulations (1502.22) require agencies to make clear when information is lacking[10].

3.3 Types of information available for identifying EFH

There are two main categories of information available that can be used to describe and identify EFH:

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

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

Information at all four levels of detail described in the EFH Final Rule may exist in both of these categories. Examples of such are provided Table 9. Only the shaded cells of Table 9 contain information that is currently available for identifying EFH under the Groundfish FMP. Virtually no information exists at levels 3 and 4 and none of the information that does exist at these levels could be used to distinguish between different areas of habitat with sufficient contrast to indicate that one should be identified as EFH and another should not.

[10] A data gaps analysis is included in the Executive Summary to cover this requirement.

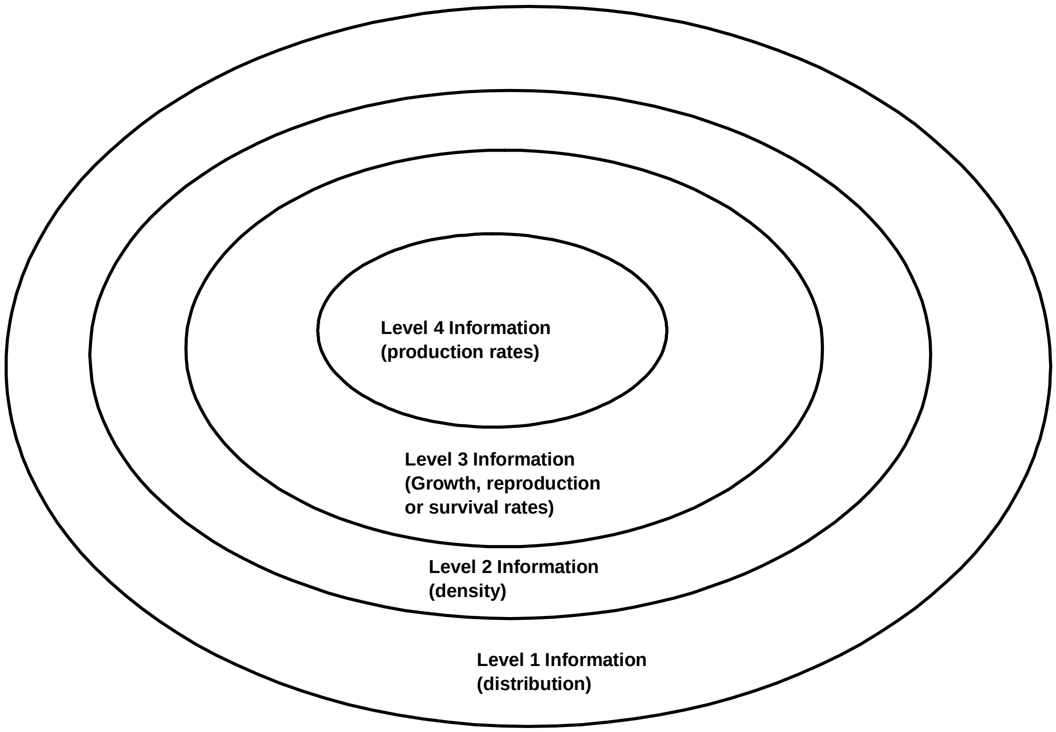


Figure 11. Diagrammatic representation of the effect of levels of information and the relative extent of the area of EFH likely to be identified for an individual species/life stage (not to scale).

Table 9. Types of information that could be used at the four levels of detail described in the EFH Final Rule (only the shaded cells contain information that is currently available for identifying EFH).

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

3.4 The EFH Model

3.4.1 Introduction

Robust methods need to be devised for identifying EFH in a climate of uncertainty. In this study, we have developed a modeling approach (called the EFH Model) for assessing the likely importance of habitats for each species and life stage in the FMP, to the extent that data are available to do so. This is done by evaluating the probability that particular habitats are suitable for particular species and life stages, based on available data sources; the NMFS groundfish surveys (Section 2.3.1) for as many species and life stages as possible, and information on habitat associations from the habitat use database (Section 2.3.4.2) for other species and life stages. The model is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing management alternatives for identification of EFH.

A Bayesian Belief Network (BBN), a particular type of network model, was chosen as a suitable analytical tool for developing the EFH Model. Background information on the essential features of BBN models and the reasons why this approach was used are described in Appendix 16, and sources of information on BBNs are listed in Appendix 17.

The EFH model takes information about the preferences of species/life stages for certain habitat conditions, and uses this to plot habitat suitability probabilities (HSPs - see Section 3.4.2) across the habitat parcels mapped in the GIS. Three habitat attributes or parameters are used to describe habitat conditions: depth, latitude and benthic substrate (from the GIS). Taken together, these three parameters are considered to provide a reasonable basis for predicting the HSP for all species and life stages in the groundfish FMP.

Of the various types of data that can be used for identifying EFH (Section 3.1.2, Table 9), the approach adopted in the EFH Model falls under the heading of spatial modeling of habitat suitability probability (Levels 1 and 2 under species-habitat relationship modeling in Table 9). The model has been designed to take advantage of the GIS data and available information on species distribution and habitat preferences. It was recognized at the outset that this assessment was occurring in a data-poor environment and therefore output had to be expressed in terms of probabilities rather than absolute numbers. Presentations of the methodology have been made to the TRC and the SSC of the Pacific Fishery Management Council. The methodology was implementation taking into account the input of these committees.

3.4.2 Calculating Habitat Suitability Probability (HSP)

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

HSP is a measure of the likelihood that a habitat with given characteristics is suitable for a given fish species/life stage or species/lifestage assemblage. It represents the quantitative link between habitat characteristics (habitat type, depth and latitude) and the probability of occurrence of species in the FMP (3.4.2).

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

National Ocean Service (NOS) scientists have developed draft habitat suitability models for 18 fish and 1 invertebrate for the biogeographic assessment of the three central California marine sanctuaries. Bathymetry (meters) and bottom substrate were used as the habitat parameters to examine habitat quality for benthic species. Mean sea surface temperature and bathymetry were used to model pelagic species (See Appendix 7 for details of the HSI methodology used by NOS). At the February meeting of the TRC, the possibility of using the NOS HIS data directly in the BN model was discussed. Although these data do provide a useful guide for the BN model, substantial additional work has been needed to develop a complete model of EFH for the FMP. The NOS HSI data cover only a few of the species in the FMP and the study was for a limited geographic area, and hence does not include the effect of latitude. Some concerns have also been expressed regarding the methodology used in the NOS model. The models of the relationships between abundance and habitat characteristics are somewhat rudimentary (e.g. a polynomial regression curve fit of mean log abundance (survey data) by categorical bathymetric class) and not always well representative of the data. Also, the combined HSI values are calculated using the geometric mean, which gives potentially unintended results when one of the individual indices is very low. A more detailed discussion of these issues is presented in Appendix 7.

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

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

- individual tows cover an area large enough to have a variety of different substrate characteristics;

- the survey records the location of the vessel, not the trawl and the variability in towing conditions makes it very difficult to estimate the actual position of the net on the bottom; and
- the location of sampling stations is not random with respect to substrate because the trawl cannot operate over some substrates (e.g. rocky terrains).

It was therefore decided to use the survey data to develop a model incorporating depth and latitude only and to add in the effect of substrate separately within the network model, based on information recorded in the habitat use database, and other expert opinion (see below). The basic relationships in the EFH Model are shown, in a slightly simplified form, in Figure 12.

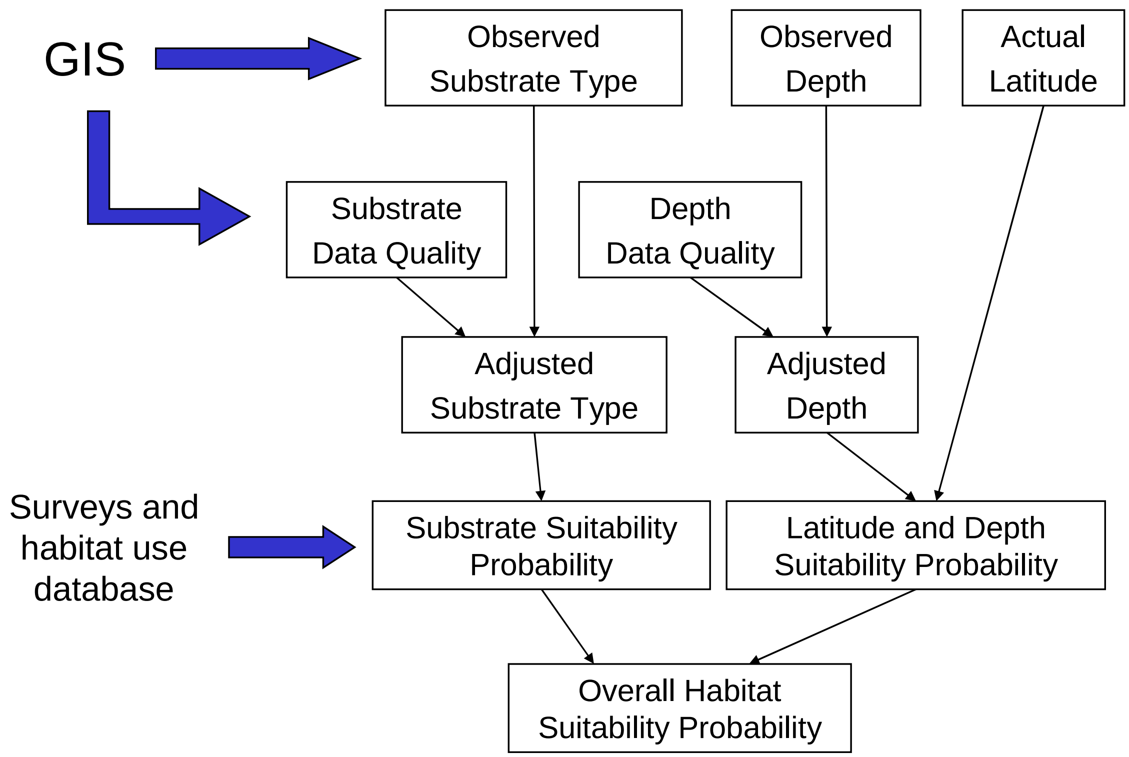


Figure 12. Simplified relationships in the BN model to identify EFH.

3.4.2.1 Depth and latitude

3.4.2.1.1 NMFS survey data

An extensive exploratory data analysis was undertaken to investigate the best approach to analyzing the NMFS survey data for the purpose of identifying EFH through the BN model (Appendix 18). Initial runs involved using GAMs to model the effects of depth and latitude on relative abundance (cpue)[11], however, a number of problems were encountered. The first few species analyzed revealed a problem with over dispersion in the cpue data, which are often characterized by a large number of zero values and a very few large values. As described in Section 3.1.2, population density may in fact be a poor proxy for growth potential. Rather than pursue the analysis of the cpue data, it was therefore decided to model the effects of habitat on the presence/absence of fish species in the FMP. In addition to avoiding the problems of over-dispersion in cpue data that were present for some species, this approach was preferred because fitted values are directly interpretable as probabilities that the habitat is suitable for the fish (based on the likelihood that the fish are present), and hence directly applicable to the identification of EFH (See Appendix 18).

Following discussion with the Council's SSC, it was noted that GAMs and GLMs that can accommodate zero catches have been commonly used to obtain indices of abundance using West Coast trawl survey data for stock assessment. There are limitations in using presence/absence information to infer the locations of EFH habit. For example, a species may have a broad depth or geographic distribution, but may only reach high densities in a limited area. The project team agreed, but had previously concluded that the use of presence-absence from a large number of surveys would provide the most robust result at this stage, even though technically it means that the model essentially discarded level 2 data in favor of level 1 data. While noting also that the analysis of depth and latitude ranges is only part of the input into the EFH model (it uses information on substrate preference also), EFH designations resulting from this analysis can be considered to be reasonable approximations that will need to be refined as additional information becomes available and more sophisticated analyses become possible. [12]

Preliminary results using GLMs to model presence/absence resulted in an over smoothing of the data, giving insufficient contrast in the probability profiles. It was therefore decided to use GAMs rather than GLMs due to the GAMs greater smoothing flexibility. A GAM incorporating a cubic smoother with 6 degrees of freedom was found to smooth the data most adequately [13].

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

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

In addition to describing the exploratory data analyses, Appendix 18 provides a report on the GAM analysis conducted for the 20 species that were completely covered by the survey data A

[11] There was also an expectation that there would be an interaction between the effects of depth and latitude, which was also investigated.
[12] We also note that the NMFS survey data were used for only a minority of the species and life stages mapped.
[13] These decisions regarding the modeling approach were taken by MRAG Americas in consultation with NMFS following discussions at the August 4 meeting of the TRC and subsequent discussions between MRAG Americas and NMFS.

further 40 species required additional expert opinion to complete their profiles, because the surveys did not sample in the 0-30 meters depth range. Spread sheets for these species were developed and sent out to experts requesting them to provide data independently for the 0-50 meters depth interval. The columns for 40 and 30 meters were compared to the output from the model and the data in the 20, 10 and 0 columns were incorporated in the partially completed profiles. In the time available, this procedure was completed for a further 16 species, thereby increasing the number of completed habitat suitability profiles for adults from 20 to 36.

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

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

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

An example of the modeling output (HSP) for depth and latitude is provided in Figure 13. In all cases, the interaction terms between these two explanatory variables proved to be statistically non-significant. This analysis therefore provides values of HSP given depth and latitude. The addition of the effect of physical substrate and biogenic habitat to the model is described in Section 3.4.2.2.

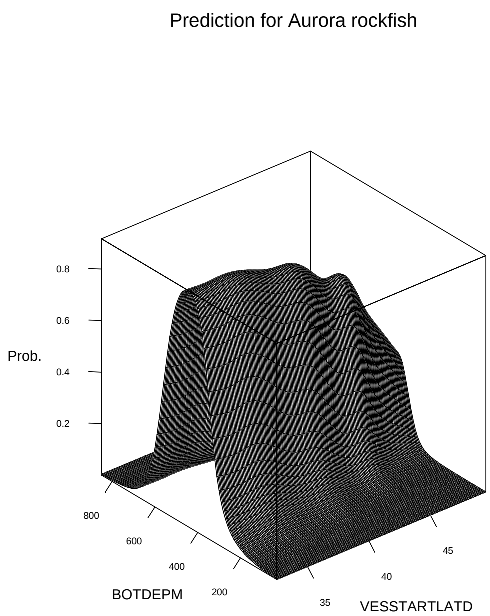


Figure 13. HSP for aurora rockfish.

3.4.2.1.2 Habitat Use Database (HUD)

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

As described in the previous section, out of these 328 possible profiles it was only possible to produce 36 complete from the NMFS trawl survey data (including those completed with additional expert opinion)[14].

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

[14] Note that the 36 profiles from the survey data were considered to be indicative of the HSP for only the adult life stages of the 36 species covered, because of the type of sampling gear used on the surveys. Size composition data are available for many groundfish from the surveys and these could be used to distinguish juveniles from adults in the survey hauls, however, such a detailed analysis was outside the scope of the current study and the size composition data were not used.

depth and latitude preferences in the HUD into HSP profiles that could be used in the EFH model. This is described in more detail in Appendix 18.

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

AbsMinDepth	Absolute minimum depth
PrefMinDepth	Preferred minimum depth
PrefMaxDepth	Preferred maximum depth
AbsMaxDepth	Absolute maximum depth

AbsMinLat	Absolute minimum latitude
PrefMinLat	Preferred minimum latitude
PrefMaxLat	Preferred maximum latitude
AbsMaxLat	Absolute maximum latitude

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

For simplicity, the discussion below will discuss the depth observations since the same principle will be applied to the latitude observations. Here we use Pacific Ocean perch (adults) to illustrate the approach, because it is a species for which we have both the survey data results and a full complement of data in the HUD. The optimum value in Table 10 is calculated as

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

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

Table 10: Observed values from the HUD and their assigned HSP index values for Pacific ocean perch Adults.

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

The five points (depth, HSP index) are then plotted in Figure 14 and four lines drawn between them (the line labeled “Habitat”). Data points are extracted from these four lines and fed to a GAM that smoothes the data (the line labeled “Smooth”). The line labeled “Survey” in Figure 14 is the profile that was produced from the GAM analysis of the survey data and is included in the plot to compare with the results obtained from the HUD data. The depth profile in Figure 14 (Smooth) is then extrapolated over the latitude 32 to 49 and the result is shown in Figure 15.

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

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

Note: these are not probabilities, but rather index values that are scaled up to “1” to be comparable to the probability profiles produced from the NMFS survey data. The final index profile is shown in Figure 16.

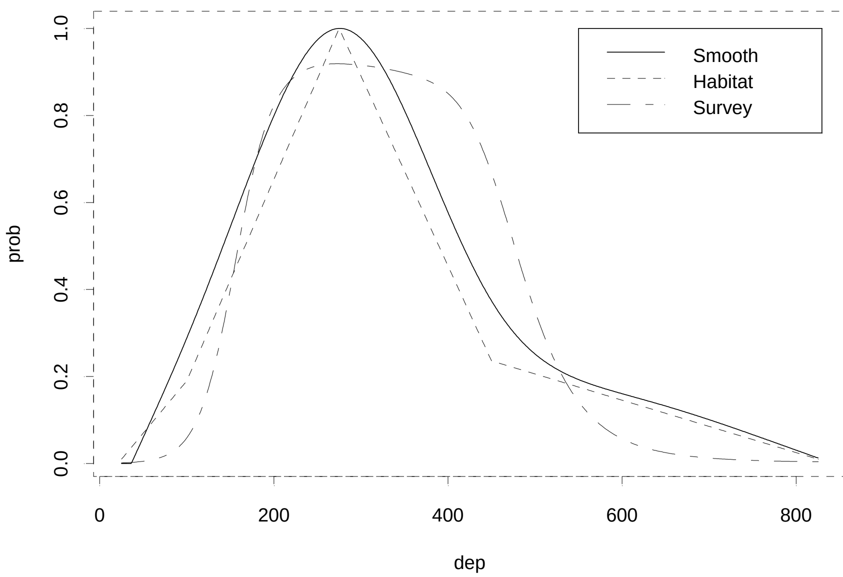


Figure 14: Comparison of probability profiles for depth based on the survey data and the HUD (smoothed and unsmoothed)

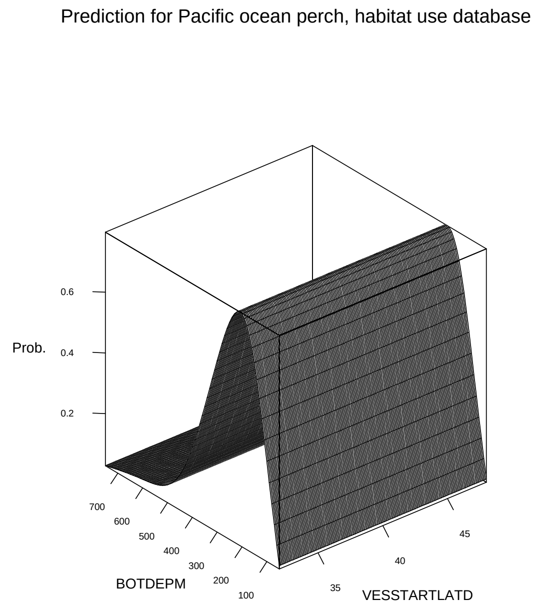


Figure 15: HUD depth profile extrapolated over the latitude interval 32-49 degrees.

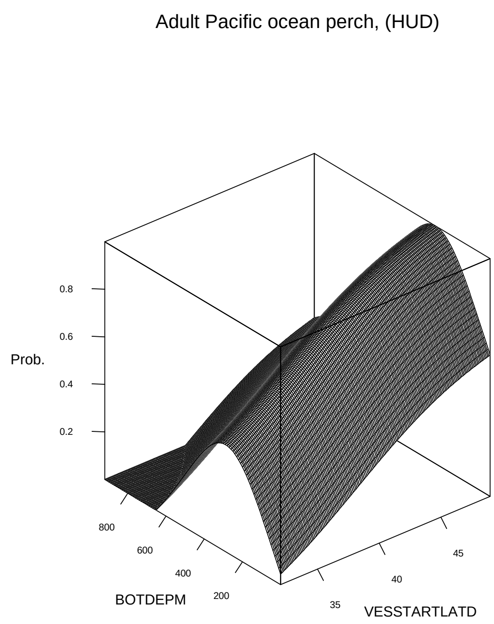


Figure 16: Index profile for adult pacific ocean perch, based on the observations in the HUD.

Table 11 shows a summary of the outcome of the modeling of depth and latitude profiles for species and life stages in the Groundfish FMP. Of the species/life stage combinations that have latitude/depth probability profiles there are three categories. The Survey category indicates that the profile was derived solely on the basis of survey data. The Survey+ category is for species/life stages that needed expert opinion to complete their profiles that were otherwise completed using survey data. HUD signifies those species that could not be modeled using survey data, but had profiles developed on the basis of the information in the HUD. The distinction between these categories has important implications for the interpretation of the results and their use in the development of alternatives for identifying EFH. In particular, the depth/latitude habitat suitability profiles derived from survey data can be regarded as true probabilities, but those interpreted from the HUD data represent relative indices only. We note, however, that the calculation of the final Habitat Suitability Probabilities includes information on substrate preferences interpreted from the HUD, and therefore it is debatable whether any of the HSPs produced can be regarded as true probabilities. This is discussed further in Section 5.1.3.

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

Table 11 Summary of sources of information on the species and life stages in the Groundfish FMP used for the EFH Model.

For the latitude/depth profiles, 20 came from the surveys (Surveys), 16 from the surveys with expert opinion to fill in the gaps (Survey+), 124 came from the HUD, 94 had too few data in the HUD, and 74 had no data at all. The values in the substrate columns indicate the maximum level of habitat classification in the HUD in each case (4 being the highest, see Table 12). 162 were classified to level 4, 88 to level 3, 4 to level 2. No data on substrate associations were available for 74 species/life stage combinations (note that species are classified in the HUD as being associated with the water column, where appropriate).

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

Table 11 Cont.

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

3.4.2.2 Benthic substrate

3.4.2.2.1 Extracting information from the HUD

The HUD (Section 2.3.4.2.) contains data on the types of substrates used by species in the FMP. This strength of the link between species/life stages and the each substrate with which it is known to associate is measured in terms of a four point scale: unknown, weak, medium and strong. In order to incorporate information about substrate preferences into the BN model, the four point scale was translated into habitat suitability probabilities as follows: unknown = 0.33[15], weak = 0.33, medium = 0.66 and strong = 1. These probabilities differ from the probabilities derived from the surveys in that they are subjective and not based directly on actual observational data. They are, however, based on the best scientific evidence available in the literature and currently represent the best available data for including substrate in the BN model. As part of the future analysis, the sensitivity of the output to the assumed probability levels should be investigated, along with the possibility of including a measure of uncertainty into the model. This could be achieved, for example, by expressing the probabilities as ranges or distributions rather than fixed points.

The substrate classification system in the HUD is on four levels, based on the Our Living Oceans habitat classification and is shown in Table 12. However, substrate is not classified to the fourth level in all cases (see Table 11). For some species and life stages, the level of information only allows us to make a link to a substrate at a higher level of classification. Nevertheless, the represents the best information available and all such links between species and substrates were used in the EFH model.

3.4.2.2.2 Reconciling the substrate classifications in the HUD and the GIS

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

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

Table 12 Four level classification of substrate types (geological and biogenic) in the habitat use database, based on the OLO classification system.

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

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

The habitat codes in the GIS data comprise four levels as shown in Table 2: Mega Habitat, Habitat Induration, Meso/Macro Habitat and Modifier. These are copied here for ease of reference:

Mega habitat:

A	Continental Rise
B	Basin
F	Slope
R	Ridge
S	Shelf

Induration:

h	Hard
s	Soft

Meso/Macro habitat :

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

Modifier:

u	Unconsolidated
b/p	Bimodal
o	Outwash

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

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

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

Both c (Canyon) and c/f (Canyon Floor) map to Submarine Canyon in the habitat use database. The other Meso/Macro Habitat values have no obvious corresponding values in the habitat use database, but can be treated as Benthos. The habitat use database does not have any Basin or Canyon data, so it is unclear whether to put this with Basin or Slope Canyon.

The correspondence used between the two databases is as follows:

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

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

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

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

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

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

Figure 17 shows the EFH Model use to calculate HSP for a GIS polygon with observed values of substrate type, depth and latitude.

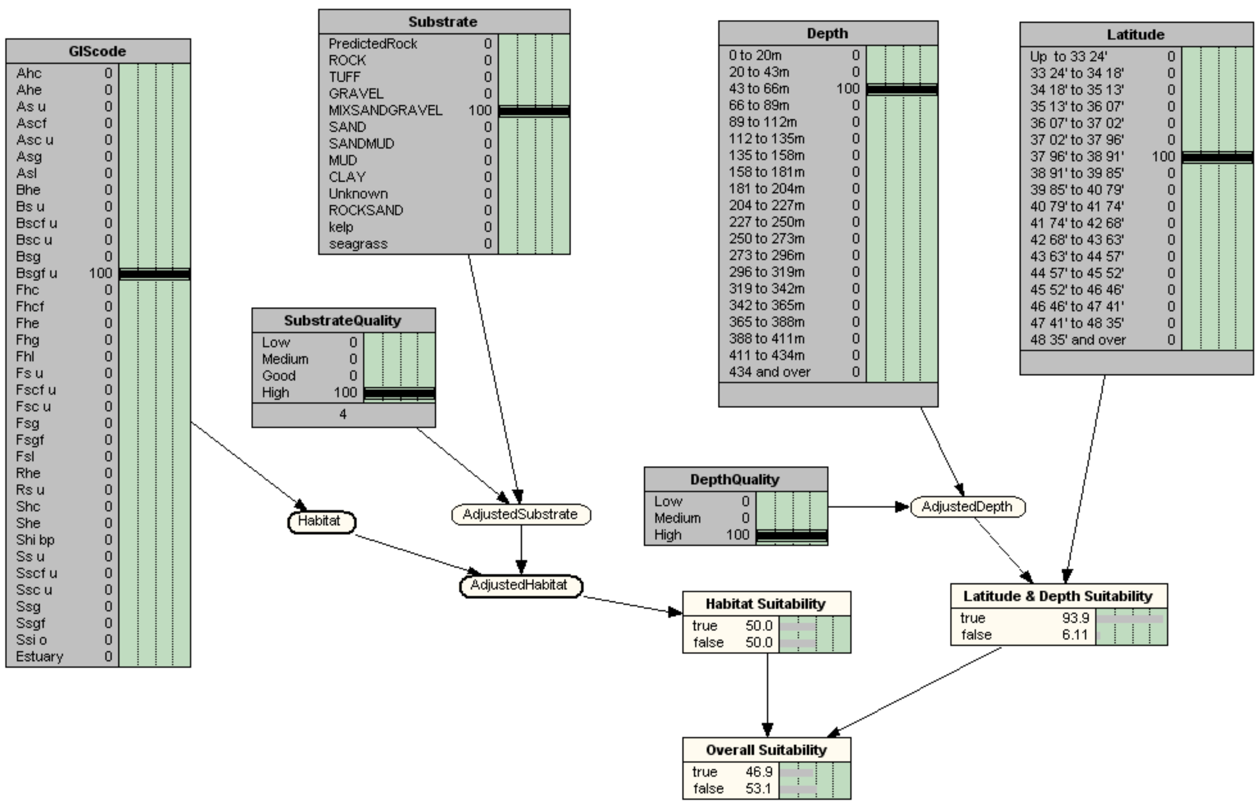


Figure 17. The EFH Model showing substrate, depth, latitude and data quality nodes

For the given GIS polygon, the habitat code, substrate, depth and latitude are entered into the appropriate nodes in the BN. The model includes the facility for allowing measures of uncertainty in habitat characteristics, as described in Section 2.2.5, to be included explicitly. Uncertainty in the substrate classification is accommodated by means of the *SubstrateQuality* node which represents the quality of the substrate data (low/medium/good/high). This assigns a probability distribution (elicited from expert judgments) of possible true substrates, given an observed substrate. The resulting substrate type is in the *AdjustedSubstrate* node in the BN. There is a similar facility that allows for uncertainty in depth observations. However, neither of these facilities is effectively activated in Version 1 of the model, because it has not been possible yet to fully develop the data quality metrics, not text their effects on the model outputs. This is achieved by permanently setting the substrate and depth data quality indicators to “High”, which leaves the data in the *AdjustedSubstrate* and *AdjustedDepth* nodes the same as those in the *Substrate* and *Depth* nodes respectively.

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

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

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

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

HSP values are calculated for a given species/life stage for all the habitat polygons in the GIS, which are uniquely identified by their substrate type, depth range (every 10m) and latitude range (every 10 minutes). Figure 18 provides a snapshot of part of the west coast around Monterey to illustrate what the polygons look like.

A computer program written for the project reads the polygon data from a GIS based data file, passes them efficiently to the model, which calculates the HSP values, and writes these values back to the GIS data file. These HSP values are then plotted for the entire coast in the form of a contour plot. Ways of identifying EFH from these plots and data are discussed in Section 5.1.3

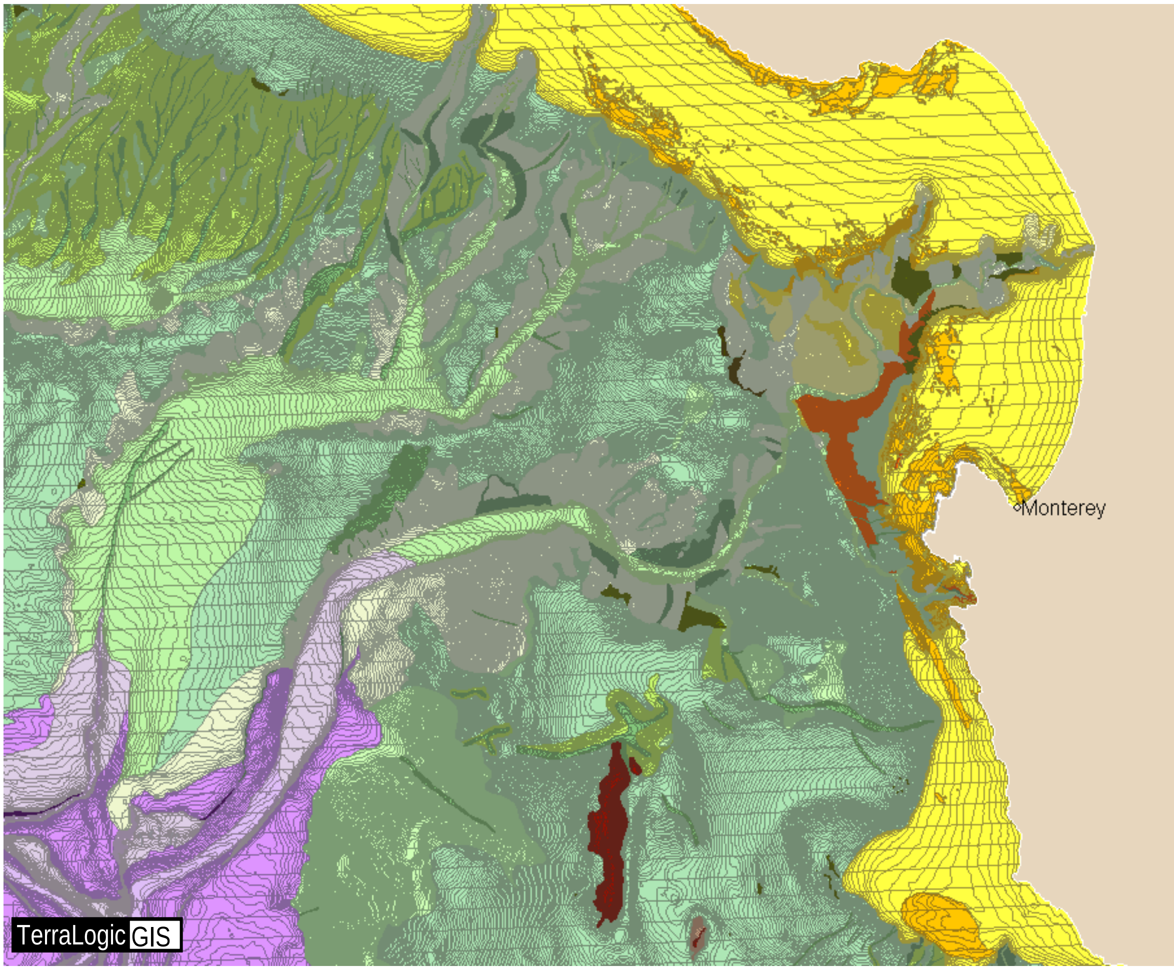


Figure 18. Portion of the Pacific Coast showing the division of the study area into polygons of unique habitat characteristics. the colors represent different substrate types.

4 ASSESSMENT OF IMPACTS

4.1 Guidance from the EFH Final Rule

The EFH Final Rule (50 CFR 600.815(a)(2)(ii)) 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 developing alternatives that mitigate 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.

The EFH Final Rule establishes a threshold for determining which fishing activities warrant analysis to address 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."

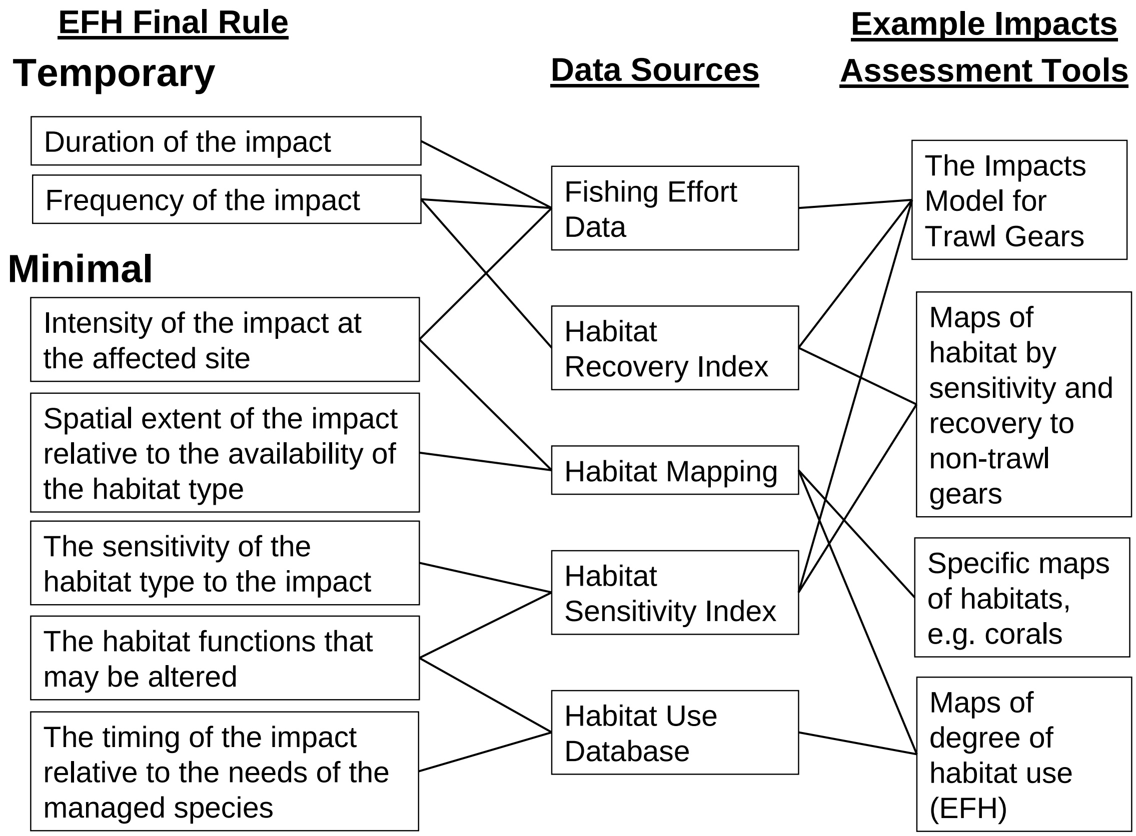
As discussed in the preamble to the EFH Final Rule at 67 FR 2354, management action is warranted to regulate fishing activities that reduce the capacity of EFH to support managed species, not fishing activities that result in inconsequential changes to the habitat. The "minimal and temporary" standard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



The measurement of impacts to EFH caused by fishing gears is clearly a complex process requiring substantial amounts of information. The diagram above indicates some of the relationships between the factors listed in the EFH Final Rule, the types of data we have available and the types of impacts assessment tools that could be derived from these. The narrative below describes these relationships in more detail, however, it is worth noting at the outset that there remain two major limitations in our understanding of the process by which fishing and non-fishing activities can impact EFH; the first is the relationship between fishing effort and habitat modification (i.e. how much modification of the habitat occurs for a given unit of fishing effort), and the second is the relationship between habitat modification and ecosystem productivity, more specifically the productivity of fish (i.e. how does a given amount of habitat modification impact the growth and/or reproductive success of fish). Presently there are very little data to fill either of these gaps. It was therefore necessary to find innovative ways of expressing the risk of impacts using the best information available.

4.2 Measuring fishing gear impacts: habitat sensitivity and recovery

In an effort to provide a quantitative measure of the degree of habitat modification resulting from a unit of fishing effort, two notional indices were developed: the Sensitivity Index and the Recovery Index. The Sensitivity index provides a relative measure of the sensitivity of habitats to the action of fishing gears. The Recovery Index provides a measure of the time taken for a habitat to recover to a pre-impacted state. These indices were constructed based on available literature, much of which reports on the results of studies conducted on benthic habitats outside the West Coast region (see Section 2.4.2). Information on the effects on pelagic habitats has not been pursued to date. The indices themselves are presented in Appendix 10 along with detail on the interpretive decisions made in their construction.

Development of the indices was accomplished in three phases, each building upon the preceding phase. Phase 1 consisted of defining levels of sensitivity and recovery based on information in the literature, and the identification of habitat types and gear types to be used in the analysis.

The Sensitivity Index is matrix of fishing gears and habitats, with each cell scored using a four level (0, 1, 2, 3: see table below) measure of the expected effect resulting from the potential interaction of the gear with the habitat. The sensitivity level may be based on an actual effect measured in a specific location, or inferences from experimental evidence, but when used in the Impacts Model, it is regarded as a predicted effect. When and where a specific interaction between gear and habitat has actually occurred depends on the fishing effort data (see Section 2.4.3) and it is the combination of the fishing effort data and the sensitivity that determines the predicted impact.

Sensitivity Level	Sensitivity Description
0	No detectable adverse impacts on seabed; i.e. no significant differences between impact and control areas in any metrics.
1	Minor impacts such as shallow furrows on bottom; small differences between impact and control sites, <25% in most measured metrics.
2	Substantial changes such as deep furrows on bottom; differences between impact and control sites 25 to 50% in most metrics measured.
3	Major changes in bottom structure such as re-arranged boulders; large losses of many organisms with differences between impact and control sites >50% in most measured metrics.

This predicted impact, however, is not static; fishing effort is variable over time, and impacted habitats may recover between impact events. When a habitat is subjected to an impact, the way in which it supports and benefits the groundfish that associate with it is changed. A combination of physical, chemical and biological processes subsequent to the impact may then bring about a process of recovery of that habitat towards its pre-impacted state. However, exactly what is meant by a pre-impacted state is rather difficult to define, given the limited information on how specific habitats support specific life states of specific species. Nevertheless, there are studies in the literature that describe and have attempted to measure this process. Relevant studies are reviewed in Appendix 10 and have been used to develop the Recovery Index. This is measured in time and is used in the model to allow habitat potentially to recover its pre-impacted function, at some assumed rate, if it is not subjected to a further impact.

Approximately 30 gear types are used in west coast fisheries. All of these were considered in the analysis initially, but studies have been done on only a few. Gear types therefore had to be summarized into five major gear types:

• dredges	New Bedford Dredge
	Hydraulic Clam Dredge
	Oyster Dredge
• trawls	Otter Trawl
	Shrimp Trawl
	Beam Trawl
	Midwater Trawl
• nets	Demersal Seine
	Round Hall Seine
	Gillnet
	Trammel Net
	Dip Net
	Salmon Reef Net
• traps & pots	Pots
• hook & line[16]	Hook & Line
	Bottom Longline
	Pelagic Longline
	Handline, Jig
	Stick (Pipe)
	Rod & Reel
	Vertical Hook & Line
	Mooching

Similarly, there was insufficient information to distinguish, in terms of sensitivity and recovery, between all of the benthic habitat types identified in the GIS (about 47), and these therefore had to be summarized into just nine categories. These nine initially comprised biogenic, hard and soft substrates, each in estuarine, shelf, and slope megahabitats. However, based on information collected during the course of the study, it was later possible to subdivide the biogenic category into the following categories:

- in estuaries: macrophytes, shellfish,
- on the shelf: macrophytes, shellfish, sponges, and corals
- on the slope: sponges and corals

Phase 2 was a detailed review of the global literature (using major recent reviews), culminating in the construction of tables that summarize, on a study-by-study basis, the sensitivity levels and

[16] The hook & line category is a combination of longline and recreational gear such as rod/reel, however, we note that there is a severe paucity of information in the literature regarding these gear types and their effects on EFH on the west coast. We note that Appendix 8 discusses hook & line gear (e.g. rod/reel) used both commercially and recreationally only from the commercial perspective.

recovery times by gear type and habitat type, to the extent that these were available at the time of writing. Phase 3 was the construction of the sensitivity and recovery matrices themselves.

Using the literature summary tables from Phase 2, statistics were calculated for sensitivity levels and recovery times for various combinations of gear and habitat types. In the final draft index (Phase 3), ranges representing the mean + or - one standard error were determined for each gear-by-habitat combination for which empirical data were available. For others, ranges were derived using the empirical ranges combined with the relative rankings by gear and habitat types given above.

The general trends shown by this analysis when organizing habitats from most to least sensitive, and gears from most to least impacting, were similar to previous assessments. In terms of major habitats, biogenic habitats are more sensitive than hard bottoms (although we note that the former may occur on the latter) and these are much more sensitive than soft bottoms.

In terms of the major gear types, dredges are most impacting, followed by bottom trawls, and these are much more impacting than nets[17] which are more impacting than pots & traps and hook & line (including longlines).

Recovery times ranged mainly from 0 to 5 years, although these may be much longer for slow growing biogenic habitat such as corals and sponges, and the overall trends by gear and habitat types were similar to the trends indicated by sensitivity levels.

While these indices provide a useful first step in the quantification of fishing gear effects on habitat, they have some obvious limitations at this stage. The sensitivity index provides a relative measure of the likely changes to habitat caused by interactions with various fishing gears. However, it is not explicit that the changes described in the index result from a single contact with the gear, nor what happens with subsequent contacts. The relationship between fishing effort and habitat change (impact) is likely to be complex and almost certainly non-linear. The process of recovery is similarly difficult to quantify. At this stage, however, we have no empirical data from which to develop such relationships. A first attempt is made, however, in the development of the Impacts Model, described in Section 4.5.

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

It is most often assumed that there will be some change in functionality and that that change is likely to be proportional to the physical change; i.e. in the case described above, there would be a 25 to 50% change in the utility of the habitat. However, as with fishing effort and impact, this relationship is also likely to be complex and non-linear. It is likely, for example, that changes in

[17] Meaning here seine, gill, dip, trammel and salmon reef nets.

habitat will affect its utility differently for different species and life stages, depending on the function or functions it provides. The timing of the impact is also important. For example, impacts at spawning sites during the spawning season compared to different times of the year may have profoundly different effects on the spawning process. In addition, changes that are important at a small scale may be less important if we consider impacts across a wider spatial scale. Is it possible, for example, for some fraction of an area of habitat to be impacted and to remain in an impacted state without significantly affecting the overall utility of the whole area as habitat for managed species?

Finally, it has also been pointed out that while evidence suggests that most changes caused by fishing gears are likely to be detrimental to habitat function, it may be that for some habitats and some species, the function is not changed, or is even enhanced.

4.3 Fishing effort

At the core of an analysis of the actual effects of fishing gear on specific areas of habitat is the need to understand where and when the gear comes into contact with the seabed. This requires detailed data on fishing locations and tracks of mobile gears on a haul by haul basis. Fishing effort could then be allocated, in terms of area effected, by individual habitat polygon. This would enable estimation of the impact of each gear to each unique habitat type. Knowledge of the footprint of the gear would begin to provide a common measure of fishing effort that would allow consideration of the cumulative effects of different gears operating in the same location.

However, in reality, there is a large degree of uncertainty in the spatial component of the fishing effort data. This uncertainty is particularly large for fixed gears, for which no detailed location information is available, other than home or landing port. Without this information, it is not possible to predict, with any reliability, even relative impacts between different locations. By contrast, the trawl logbook data provide set points on a haul by haul basis. This is substantially more useful, but still far from ideal, because the database does not record trawl end points, and certainly does not record actual trawl tracks. Nevertheless, we have made an attempt to develop a quantitative model for bottom trawls that will assist the Council in making decisions about possible management alternatives for fishing impacts (see Section 4.5).

Ideally, the trawl effort would be summarized by habitat polygons in order to estimate the impact to each unique habitat type. This is theoretically possible using trawl set points, but due to the lack of information about the actual trawl track, there remains a large degree of spatial uncertainty about the location of each tow.

For those tows starting in a particular polygon, a portion of them will end outside, and some fraction of those tows would take place outside of that polygon, in a neighboring polygon. The converse is also true, that some trawls starting outside the polygon will end inside. The importance of this effect will depend on a number of factors. These include polygon size, relative to the length of a tow and habitat type of the polygon and its neighbors, relative to the habitat type that the fishermen are trying to fish on. We were therefore seeking a scale of area to 1.

minimize overrun errors (unit of area should be large) [18] and 2. achieve a reasonable spatial resolution (unit of area should not be too large).

As indicated above, our first instinct was to simply overlay trawl start points on habitat map and using habitat polygons as the units of area. However, habitat polygons cover a wide range of different spatial scales; some are small relative to trawl hauls, making the overrun errors potentially significant. In addition, the assumption that the overlay would correctly match up a given trawl with a given piece of habitat needs detailed analysis. As we know, PACFIN does not contain end points of hauls, hence we only have a single point from which to estimate the location of the tow. Added to this, not all trawl positions in the database are genuine start points[19], habitat data quality varies greatly (see Section 2.2.5.1) and we had decided during the formulation of the EFH Model that, such an overlay would not be valid for survey data (see Section 3.4.2); for commercial data it may be even less valid.

We therefore chose to represent the effort data on a grid of dimensions of the order of two average trawl lengths, representing a reasonable compromise in terms of the optimal size. An average trawl tow length of 11.8 km was calculated from trawl set and haul point data provided by Marlene Bellman for several study sites off Oregon (Appendix 19). This would give a grid with square cells of side 23.6km, or 12.74 nautical miles. We also considered that a grid delineated by lines of latitude/longitude would be most consistent with convention for reporting fisheries spatial data, despite the fact that a latitude/longitude grid cell is not square and cell size changes with latitude[20]. Using these criteria, a 15-minute latitude/longitude grid was initially chosen as the preferred size. However, this grid is larger than the 10-minute generally used to summarize logbook data (Figure 10), and causes difficulty when summarizing historical logbook data because the edge of the 15-minute grid is exactly at the center point of many of the trawl logbook blocks. We therefore relaxed the average tow length criterion and selected the 10-minute latitude/longitude grid for trawl effort data summaries. A 10-minute grid cell is approximately 18.5 km in the north/south direction, and 12.2 km in the east/west direction at 49 degrees N. latitude and 15.7 km in the east/west direction at 32 degrees N. latitude.

A 10-minute latitude/longitude grid was developed for the entire West Coast EEZ, and then subset to include only grid cells that overlap with existing GIS habitat layers, given we are interested in the interactions between bottom trawls and benthic habitat. The trawl set points were overlayed with the l0-minute grid to assign a grid cell to each data row. Trawl effort data summaries included the total number of tows and total duration by month for each grid cell for the five years for which there is complete date information, i.e. 1998-2002. Midwater trawls were excluded from the summary assuming that they do not impact bottom habitat. The monthly time step allows for seasonal analysis in the impacts model. In addition, the same data were summarized for the full logbook time series, 1987-2002, by year.

[18] In essence this means that we are assuming that the effects of tows starting inside the grid and ending outside are balanced by the effects of tows starting outside and ending inside.
[19] Prior to 1997, position data for trawls off California were provided by logbook block only, not by actual haul start point.
[20] Cell increase in size as you go from north to south in the study area.

In order to provide habitat-specific information for the sensitivity and recovery elements of the impacts model, the merged EFH habitat data were overlayed with the grid cells. For each grid cell, we calculated the area occupied by each benthic habitat type and the total area of the grid cell, to provide the proportion of each cell occupied by each habitat type.

For cells along the edge of the habitat information, there were two types of special cases. First, the deepwater case is where we know there is potential fish habitat outside of the mapped area, but we do not have mapped habitat information. In this case, all of the trawl start points in the cell and the area of the entire cell was used for calculating effective fishing effort. Second is the shoreward case, where we know that the area outside of the mapped habitat area is upland, and therefore not an area where either fishing effort or EFH would occur. In this case, the area to which the fishing effort is applied is only the area of that grid cell that comprises potential EFH. An additional GIS overlay of the shoreline with the grid cells was performed in order to provide a list of cells along the shoreward edge of the habitat data.

4.4 Non-fishing impacts: sensitivity index

There is information available on non fishing impacts on the west coast, but the spatial and temporal resolution of these data presently precludes a quantitative analysis. Different types of impacts can be overlaid in the GIS to show their spatial overlap, but it is not possible to develop a quantitative evaluation of the cumulative effects of fishing and non fishing impacts on EFH at this time. We have, however, made a first attempt to develop a sensitivity index of non-fishing activities analogous to the sensitivity index for fishing activities.

The major information source for this analysis was the technical report *Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures* compiled by NMFS staff from the Alaska, Northwest, and Southeast Regional Offices (Boland et al. 2003). This report reviews the literature on the potential impacts of a wide range of non-fishing activities that occur on the Pacific coast, and is organized by general location of the activities: Upland, Riverine, Estuarine, and Coastal & Marine. It does not, however, provide any straightforward guidance for quantifying the impacts of each activity even in a relative manner. Hence, we needed to develop a set of rules for assigning overall relative impact levels for each activity as well as relative impacts by habitat, before the draft impact matrix could be derived.

Table 13 summarizes the rules used to assign overall impact levels to non-fishing activities. Three major points need to be made concerning the development of this table. First, a range of 0 to 3 was chosen to reflect uncertainties in assigning numbers to the impacts, in effect representing a "low," "medium," "high" view, as was taken for the fishing gear impacts assessment. The impacts of human activities of all kinds typically have a net effect that is dependent on the intensity of the activity. For example, the application of pesticides can have local effects ranging from non-detectable to catastrophic, depending on the amount and manner of application. Assigning a relative impact level independent of the intensity of the activity can only be pushed so far quantitatively. Secondly, the present analysis required consideration of impacts on "waters," "substrate," "benthic organisms, prey species and their habitat" with respect to potential effects on EFH (see above). Hence, the potential impact of each activity on all these environmental components was considered in developing the rules listed in Table 1. Finally, the present analysis required assessment of the initial impacts as well as the potential for recovery after the activity ceased. Therefore, the rules in Table 13 include direct, indirect, and recovery considerations.

Table 13 Levels of impacts (direct and indirect adverse effects and their descriptions) for non-fishing activities on EFH functions of bottom habitats.

Direct and Indirect Effects	
Level of Impact	**Description/Rules for Assigning Levels**
0	No detectable direct or indirect adverse effects on EFH functions would be expected.
1	Minor impacts that potentially only affect fish or benthos in short-term manner. Minor or no impacts on physical structure of habitat. Recovery of EFH functions likely in months to a few years if activity ceased.
2	Moderate impacts that potentially kill fish and benthos, and cause some changes in physical structure of habitat. Recovery of EFH functions likely within several years if activity ceased.
3	Major impacts that potentially kill fish and benthic fauna, and cause serious alterations in physical structure of habitat. Recovery of EFH functions not likely unless restoration efforts conducted, or will require many years if activity ceased.

Appendix 10 provides the draft index of adverse impacts for non-fishing activities. Each impact is given as a range to reflect uncertainty in the values. As an example of how the rules were applied, consider the "Upland" activity "Agricultural/Nursery Runoff" which was assigned an impact level of "1". Runoff from such activities is typically regulated by the states so that various "best management practices" are encouraged or required to minimize impacts on receiving waters. Also, the impacts do not necessarily alter the physical habitat of receiving waters such that characteristics related to EFH are impaired. Finally, if such activities are ceased it is likely that many EFH functions will return in a relatively short time as the land returns to a more natural condition, or is actively restored. In contrast, consider "Urban/Suburban Development" which was assigned an impact level of "3." This activity ranges from low density residential developments to high density urban commercial development with complete replacement of natural ground cover by impervious surfaces. Compared to Agricultural/Nursery Runoff, there is typically much more impervious surface and accompanying runoff that can carry similarly harmful pollutants. And after such development occurs, it typically remains causing long-term impacts. The removal of many kinds of urban developments requires active and expensive restoration efforts. This general approach was followed in assigning each non-fishing activity an impact level that reflects its potential impact on EFH relative to other non-fishing activities on a scale of 0 to 3.

The ranges given were based on the impact level for each activity, and a consideration of the general location (Upland, Riverine, etc.) where the activity normally occurs relative to the megahabitat (Estuarine, Shelf, Slope, etc.) potentially affected. Basically, each range given in Appendix 10 is the value for that activity plus or minus 50% for the megahabitat nearest the typical location of that activity. Each range is decreased by about 50% per megahabitat moving away from the activity. For example, Agricultural/Nursery Runoff was assigned a range of 0.5-1.5 (the value of 1, plus or minus 50%) for all Estuarine substrate x macrohabitats because these activities can occur adjacent to estuaries and would be expected to have their full impact in these habitats. The range was halved for each move from megahabitat to megahabitat proceeding offshore. Each non-fishing activity was assigned a range of impact levels for each megahabitat x substrate x macrohabitat in this manner.

4.5 The Impacts Model for trawl gears

4.5.1 Introduction

A Bayesian Network model for examining fishing impacts has been developed. This model provides a framework for the quantitative consideration of habitat status and the effects over time of different management regimes based on the available data. These data are, in essence, the sensitivity and recovery matrices and the fishing effort data.

The model is required to provide a scientific method for assessing Pacific coast groundfish habitat and developing alternatives for management scenarios that are designed to mitigate specific risks to habitat and ecosystem function. While the presentation of information in the GIS can provide a first order indication of areas of habitat that may be under threat and in need of protection, a quantitative approach is needed to bring together information from a variety of sources to better understand the processes involved.

The methodology was implemented with the goal of answering the questions listed in the introduction (Section 1) for Pacific coast groundfish, to the extent possible. Limitations on answering these questions were encountered, particularly in regards to the availability of data for model parameterization.

As will be seen, additional work will need to be undertaken to investigate in detail how the sensitivity index and fishing effort data can best be used to evaluate impacts on a scale that has some relevance in an absolute sense to the status of the habitat, in terms of its functionality for managed species. With improved data, the utility of the impacts model for the management process could be substantially enhanced.

4.5.2 Impact function

We seek a mathematical representation of the impact of fishing effort on a given portion of seabed. Impact is measured on a scale 0 to 1 and can be thought of as proportion impacted, with 0 representing a pristine state and 1 totally functionally destroyed.

A family of functions with suitable properties is provided by

$$f(x) = \frac{1-(1-s)^x}{1+(1-s)^x}$$

where x is fishing effort measured on an appropriate scale (see below), and s is sensitivity measured on a scale $0 < s < 1$[21]. This function is a version of the generalized logistic function and can be written

$$f(x) = \frac{1-e^{-\beta x}}{1+e^{-\beta x}} = \tanh\frac{\beta x}{2}$$

where $\beta = -\log(1-s)$ (so that $\beta > 0$).

It has the following properties, which make it suitable as a basis for modeling impact:

(a) $0 \le f(x) \le 1$

(b) $f(0) = 0$ and $\lim_{x\to\infty} f(x) = 1$

(c) $\lim_{x\to\infty} f'(x) = 0$ and $f'(0) = \frac{\beta}{2} = -\frac{1}{2}\log(1-s)$

Note that property (c) implies that the slope of the impact function for zero effort increases with sensitivity. In other words, the impact on pristine habitat increases more rapidly for greater sensitivity, as required.

4.5.2.1 Measurement scale for fishing effort

For a given area, the basic measure of fishing effort for ground-trawls is estimated from logbook data as the total duration of all tows that start in the area during the period under consideration.

This measure suffers from a potential upward bias resulting from the inclusion of tows which start in the area but end outside it. A partial correction for this error is automatically provided by the exclusion of tows which start in neighboring areas. The extent of the bias also clearly depends on the magnitude of the area, smaller areas tending to produce greater errors. An area which is roughly a square of with width equal to twice the mean tow length should produce a minimal error. This can be achieved by choosing units of the order of 15 minutes of latitude and longitude. This choice would result in a fairly low resolution grid for representing maps of fishing impacts. In the event, a 10 minute cell size was adopted, mainly for practical reasons (See Section 4.3).

[21] This is a simple conversion from the four point scale described in Section 2.4.2.

The distribution of total duration (Figure 19) suggests that a log-scale may result in greater discriminating power. To allow for zero effort, log (*duration* + 1) was used.

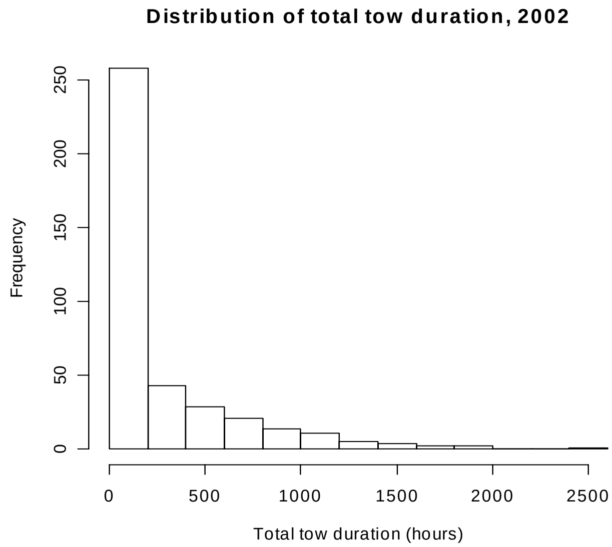


Figure 19. Distribution of total tow duration, 2002

4.5.2.2 Modeling the relative impacts of fishing effort

There appears to be no sound empirical basis to relate a given quantum of fishing effort to a measurable impact on the habitat. Consequently, the aim of the present modeling exercise was limited to representing *relative* impacts. To allow some flexibility in calibrating impact with effort, a tuning constant k has been included in the scaling of effort, so the variable x in the impact function is effectively

$$x = \frac{1}{k}\log_{10}\left(duration + 1\right)$$

A suitable value of this constant will depend on the range of values of the total duration, and hence on the period being modeled. For a period of one year, values in the range 0.1 to 0.5 seem reasonable. Figure 20 shows a family of impact functions for various sensitivity levels with the tuning constant fixed at k = 0.25. Figure 21 shows the same plot for a range of values.

Choosing the Tuning Constant

Suppose we are to compare n cells (or times).

Data: total durations $d_1,\ldots,d_n$

CEE values are $x_i = \frac{1}{k}\log_{10}(d_i + 1)$

First set ymax = 0.95, say.

smin = lowest sensitivity among the n cells to be compared.

Calculate $$x_{max} = \frac{\log\left[(1 - y_{max})/(1 + y_{max})\right]}{\log(1 - s_{min})}$$

Choose the scale factor k so that

$$x_{max} = \frac{1}{k}\log_{10}(d_{max} + 1)$$

so that

$$k = \frac{\log_{10}(d_{max} + 1)}{x_{max}}$$

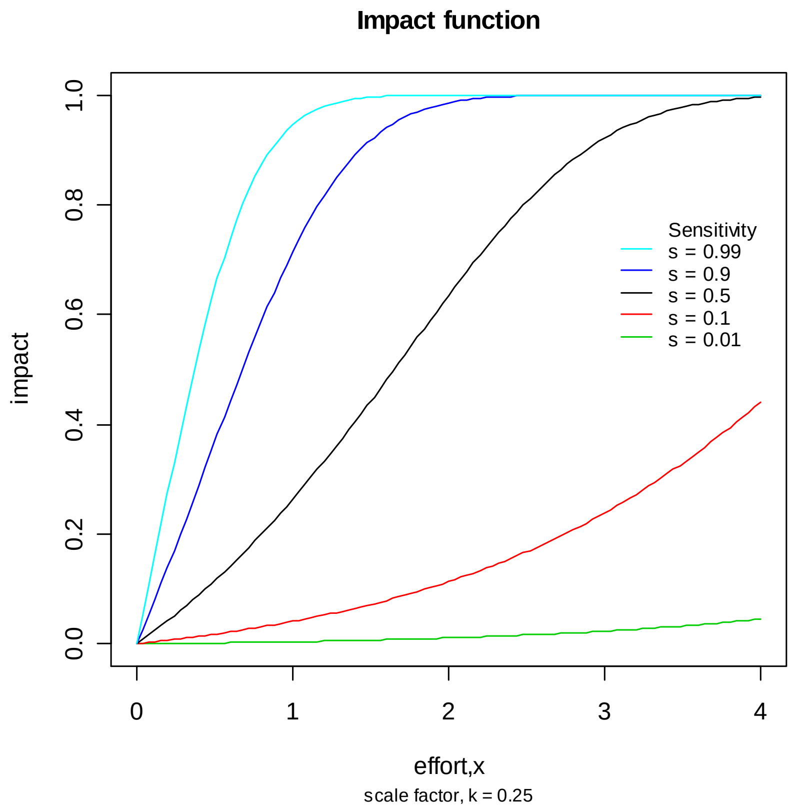


Figure 20. A family of impact functions for various sensitivity levels with the tuning constant fixed at $k = 0.25$

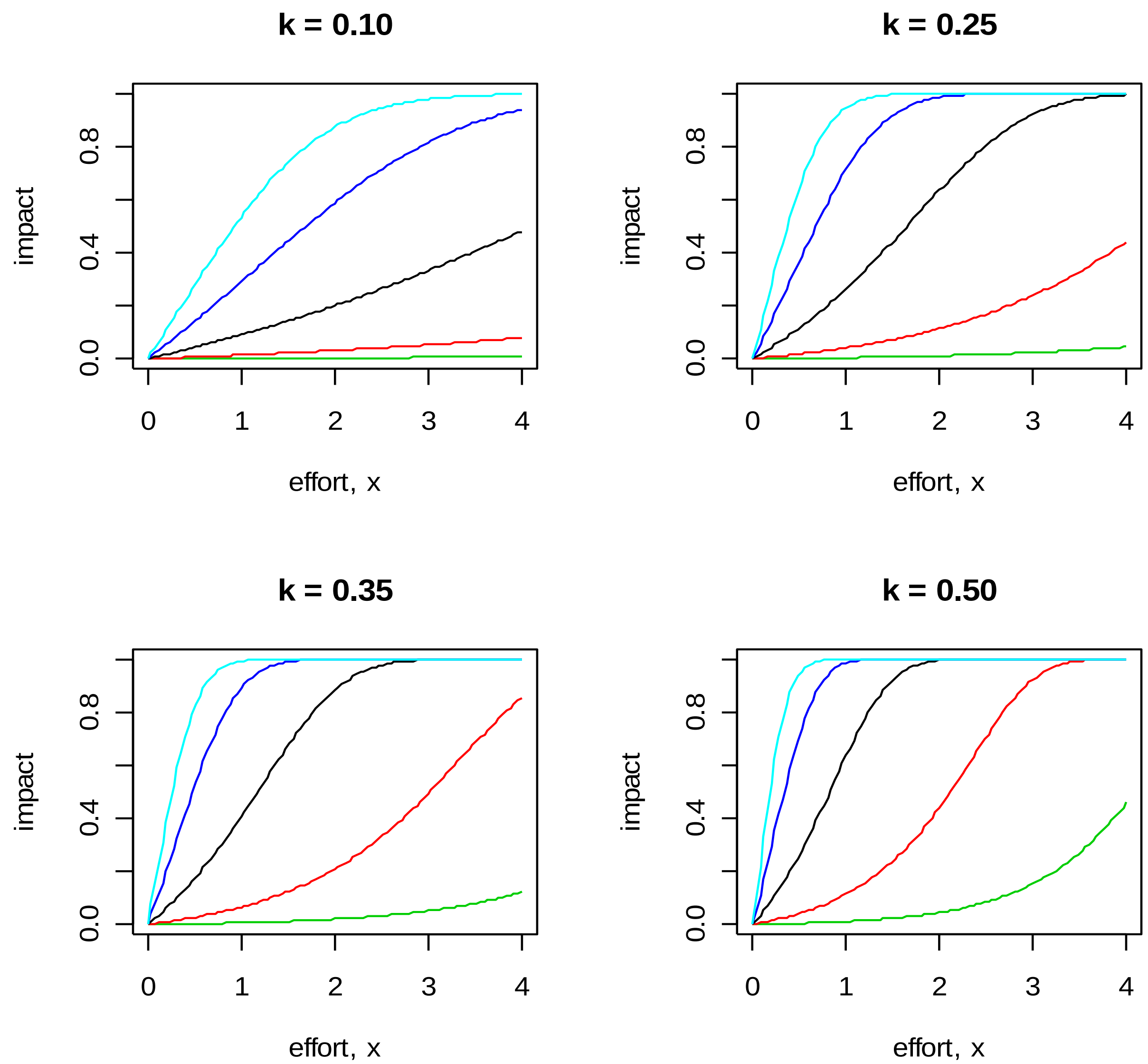


Figure 21. Figure 5 plotted for various levels of the tuning constant *k*.

4.5.2.3 Cumulative effects of fishing impacts and recovery

A convenient paradigm for concurrently modeling the cumulative effects of recurrent fishing activity and recovery is to imagine translations up and down the *x* scale, described above as $x = \frac{1}{k}\log_{10}\left(duration + 1\right)$. A recovery event moves down this scale, while extra fishing effort moves up. We can think of this *x*-scale as an indirect measure of impact, in the sense that in any time period, additions to *x* occur when there is new fishing effort; reductions on the *x*-scale correspond to recovery. Modeling in discrete time, we measure the net impact by first locating the appropriate position on the *x*-scale by adding new effort and accounting for recovery during the preceding time period. Only then do we calculate the actual impact from the function $f\left(x\right) = \frac{1-\left(1-s\right)^x}{1+\left(1-s\right)^x}$, where *s* is the sensitivity score ($0 < s < 1$). Thus the *x*-scale is a kind of proxy measure for impact - the scale on which we do out accounting for new fishing and recovery. We can call it the *cumulative equivalent effort (CEE).*

To account for recovery on the CEE scale, we need a maximum value from which to recover. This function is an idealized mathematical model and the limiting value of 1 (meaning the area is totally functionally destroyed) is attained only as effort $\rightarrow \infty$. We therefore define a notional maximum value $x_{\max}$ of CEE to be that value of *x* for which impact is some high impact value I^*, say 0.9 or 0.95: $f\left(x_{\max}\right) = I^*$. Inverting the impact function,

$$x_{\max} = \frac{\log\left[(1-I^*)/(1+I^*)\right]}{\log\left(1-s\right)}$$

When CEE is *x* = 0, the impact is zero, i.e. $f\left(0\right) = 0$. If *r* represents the mean recovery time (in years) for a given habitat type, we take this to mean that on the CEE scale, it takes *r* years to move from $x_{\max}$ back down to 0. In the event that the current impact, as measured on the CEE scale is some other value $x < x_{\max}$, then the recovery in one year is $\Delta x = \frac{1}{r}x_{\max}$, or in a period *T* years is $\Delta x = \frac{T}{r}x_{\max}$. (Note that *T* may be fractional, say half a year.) If it happens that $x - \Delta x < 0$ then we truncate at zero. If the current period is *t* and we are modeling impact every successive *T* years, we write the current cumulative net CEE as $x^{(t)}$, and denote the new fishing effort (on the *x*-scale) during the period *t-T* to *t* as $e^{(t-T,t)}$. We then have the recurrence relation

$$x^{(t)} = \max\left(x^{(t-T)} - \frac{T}{r}x_{\max}, 0\right) + e^{(t-T,t)}.$$

This relationship forms the kernel of a dynamic Bayesian network in which the actual impact at time *t* is estimated by substituting the above value $x^{(t)}$ of CEE into the impact function $f\left(x\right) = \frac{1-\left(1-s\right)^x}{1+\left(1-s\right)^x}$.

4.5.3 The Bayesian Network for the Impacts Model (Version 1)

A diagram of the Bayesian Network is given in Figure 22. For clarity, this shows only four time periods, but in principle any number of periods can be added to the model, provided they follow each other successively in time, such that the start of period t+1 immediately follows the end of period t. The model is for bottom trawl gears only, a separate version being required for each gear type.

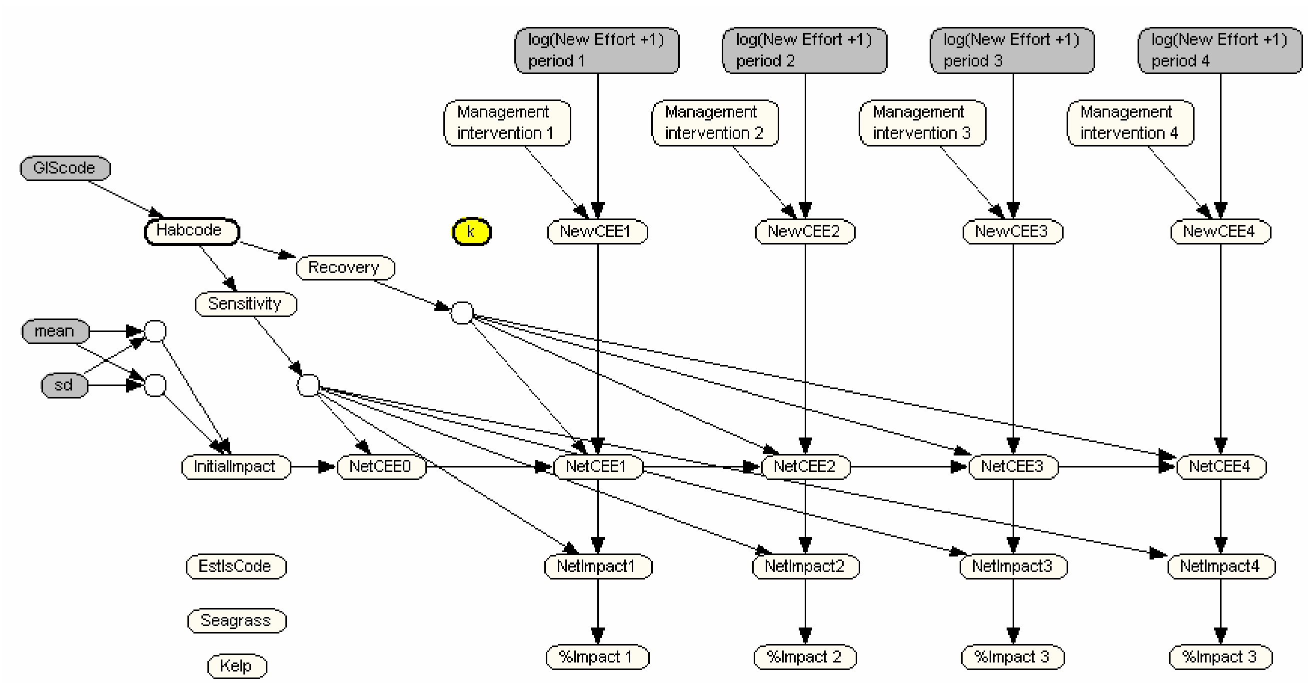


Figure 22. Bayesian Network to model relative spatial impacts of fishing gears over time.

The node labeled “GIScode” contains the habitat descriptor codes as used in the GIS. These are mapped onto the appropriate corresponding codes, in node “Habcode”, that are used in the sensitivity and recovery indices. Sensitivity and recovery values, as given for each combination of gear type and habitat in Appendix 10, are re-scaled to 0-1, as required by the impact function. These values are assumed constant over time.

Initial impact is modeled by a beta distribution to represent prior uncertainty in knowledge of the initial state of the habitat. This information can be entered either by specifying the two parameter values for the standard beta distribution, or by specifying the mean and variance. As an alternative to a probability distribution, an actual value can be entered. The initial impact value is converted to the CEE scale by the inverse of the impact function.

New effort for each period is entered as log(duration + 1) in the top node. This is modified by any management intervention and rescaled to the CEE scale. Net CEE is computed by accounting for recovery from the previous CEE. Net CEE is then converted to the impact scale and finally summarized in the % Impact node, by its expected value.

The entire process is replicated for each time period, resulting in a dynamic Bayesian network. Note that the time interval between successive periods is arbitrary; a feature which enables the modeling of seasonal effects.

5 RESULTS AND DEVELOPMENT OF ALTERNATIVES

5.1 EFH Model output

5.1.1 Database and maps of habitat suitability

The primary output of the EFH Model is in the form of a database of HSP values by species and life stage for every benthic habitat polygon in the GIS. A total of 160 species/life stage combinations have been analyzed to date out of a possible total of 328. The remaining 168 species/life stages have not been completed due to insufficient data. All of the Adult and most of the juvenile stages have been covered either by the survey data, or by the information in the HUD. Of those remaining, 69 cases are eggs (84% of species), 66 are larvae (80% of species) and 33 are juveniles (40 % of species). Of these, 94 have some data available, but not enough to develop HSP profiles. There are no data at all for an enormous 68% (56 species) of egg stages. 17 species have no data available for their larval stages. It is therefore mainly eggs and larvae for which information is lacking on habitat associations.

The HSP data are presented in contour plots produces by the GIS (e.g. Figure 23 and Figure 24). These are produced separately from this document to preserve image quality, and are available on a CD ROM.

5.1.2 Validation of model results

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

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

In addition, Appendix 20 provides a preliminary comparison between the HSP values from the EFH Model and the habitat preferences described in the NMFS Life Histories Appendix (Section 2.3.4.1) and comments on the final combined probability profiles. These comparisons are for the species whose depth/latitude profiles were developed from the NMFS trawl survey data.

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

As of this date, additional validation is expected to be accomplished by the Council's TRC before the Draft EIS is published. The TRC has members with expertise in geology, fish ecology, and commercial fishing (among others) that make up the ideal skill-set for this type of review. While it is impossible to predict the results of validation, it is reasonable to assume that it will influence the final model results.

5.1.3 Using the EFH Model output to identify EFH

The final result of the EFH analysis is maps by life history stage for each groundfish species that show on a qualitative scale the importance of different habitat to that species. There are various ways in which these maps can be used to identify EFH in a more or less inclusive way. The decision whether to adopt an inclusive or narrow definition of EFH should be considered from a policy standpoint. Adopting an inclusive definition may be appropriate given the incomplete and indirect nature of the information used to identify EFH.   However, developing workable alternatives to reduce fishing impacts may be difficult if EFH is defined broadly. Adopting a relatively narrow EHF definition may make it easier to develop effective precautionary alternatives.

One of the most obvious ways of using the maps would be to select the area of habitat for each species and life stage within which the HSP value is higher than some predetermined threshold value. A low value would produce a broad or inclusive identification of EFH, while a high value would reduce the area identified as EFH (e.g. Figure 25).

In using the maps, however, it is important to remember that, while they look similar in terms of a product of the analysis, the type, accuracy and precision of the information that has gone into each is highly variable. They should not, therefore, be treated all with the same level of confidence.

Table 11 is a very important table in that it provides a summary of the levels of information that have gone into the estimation of HSPs for each species and life stage. In the case of depth and latitude, the GAM models that used survey data estimated true probabilities of the survey encountering species across the area they covered. However, the profiles based on the HUD data are based on far fewer data that can be regarded to give a relative scale of likelihood at best. One important product of this difference is that the depth and latitude profiles derived from the HUD were scaled to have a maximum value of one, while profiles from the survey data can have a maximum value considerably less than one, particularly for rare species where the probability of occurrence in the survey catches is low everywhere.

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

It is important to remember when using these results to identify EFH, therefore, that a method that is considered to be appropriate for one species/life stage may not necessarily be appropriate for others. Having said that, it is possible to summarize the species and life stages into various groupings that would make the task of identifying EFH for the whole FMP (accounting for all the species and life stages it contains, to the extent possible) easier than dealing with each one individually. Such groupings should take into account both the variable data inputs and hence variable levels of uncertainty in the outputs, and other considerations, such as the status of the stocks (e.g. depleted, overfished, experiencing overfishing etc.), species guilds, or species complexes used for management (e.g. Figure 26)

An alternative for identification of EFH proposed by the SSC would identify the best 10% (or 20%, 30% …etc) of habitat over entire assessed region for each groundfish species/lifestage, based on the HSP maps, and then combine these areas for all species and life stages for an overall definition of EFH (e.g. Figure 27). Such an approach would neatly avoid the problem of the variable scales of the outputs based on the Survey and HUD datasets, but it would be necessary perhaps to consider variable levels of the percentage of the area depending on the level of uncertainty, and possibly the stock status of the species in question.

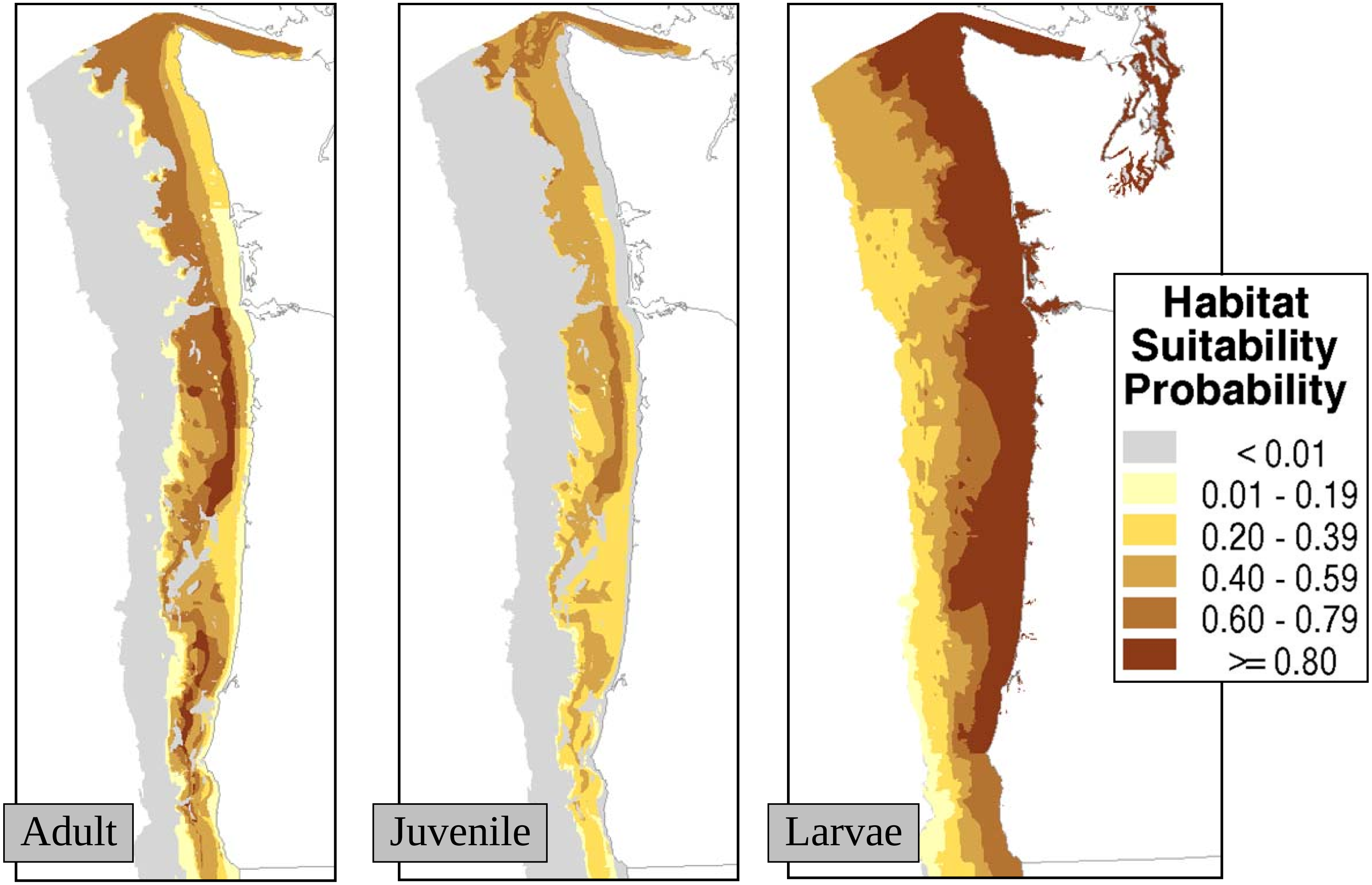


Figure 23 HSP contour plots for Arrowtooth Flounder: adults, juveniles and larvae.

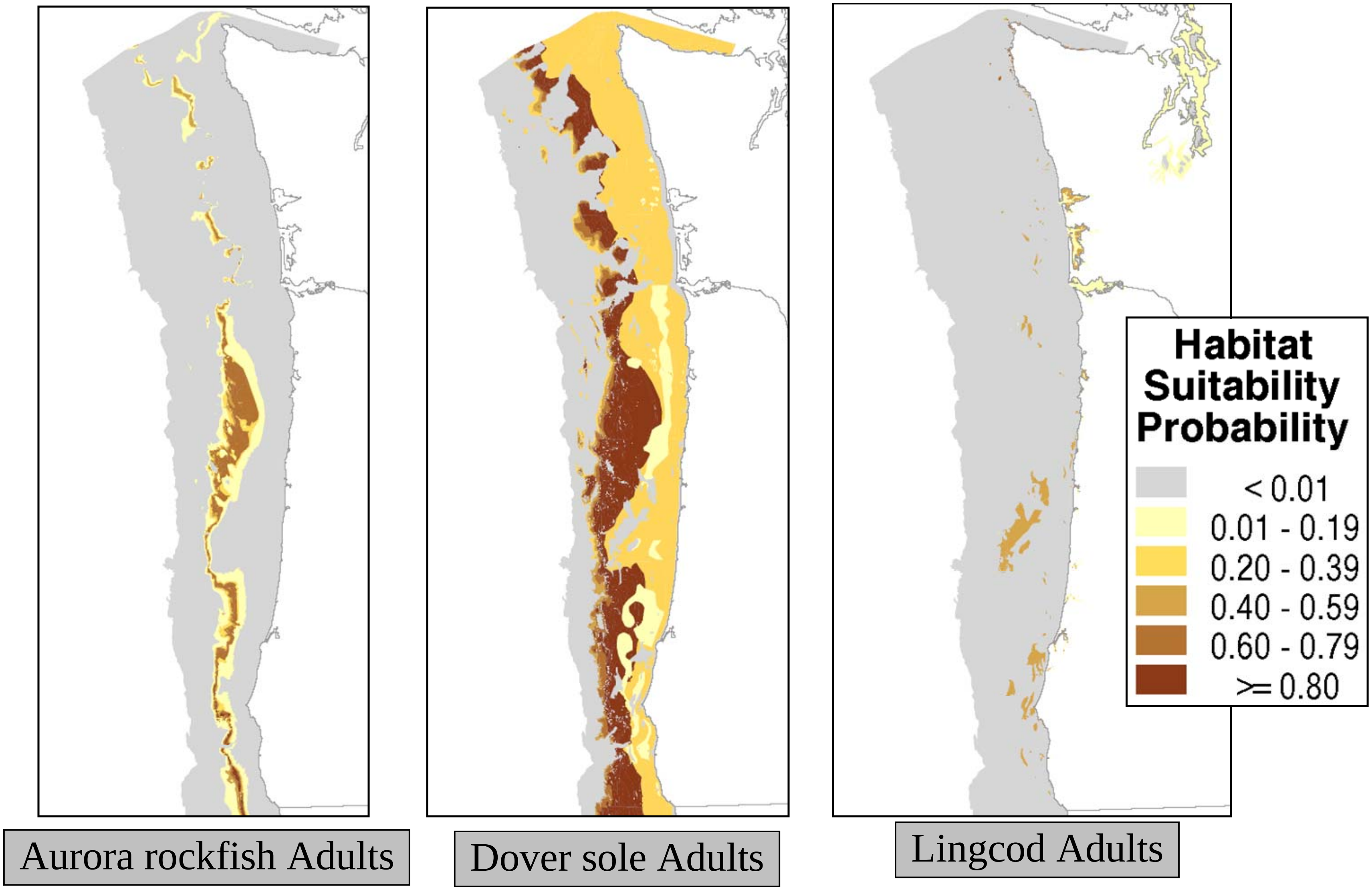


Figure 24 Example HSP contour plots for the adults of three species of groundfish.

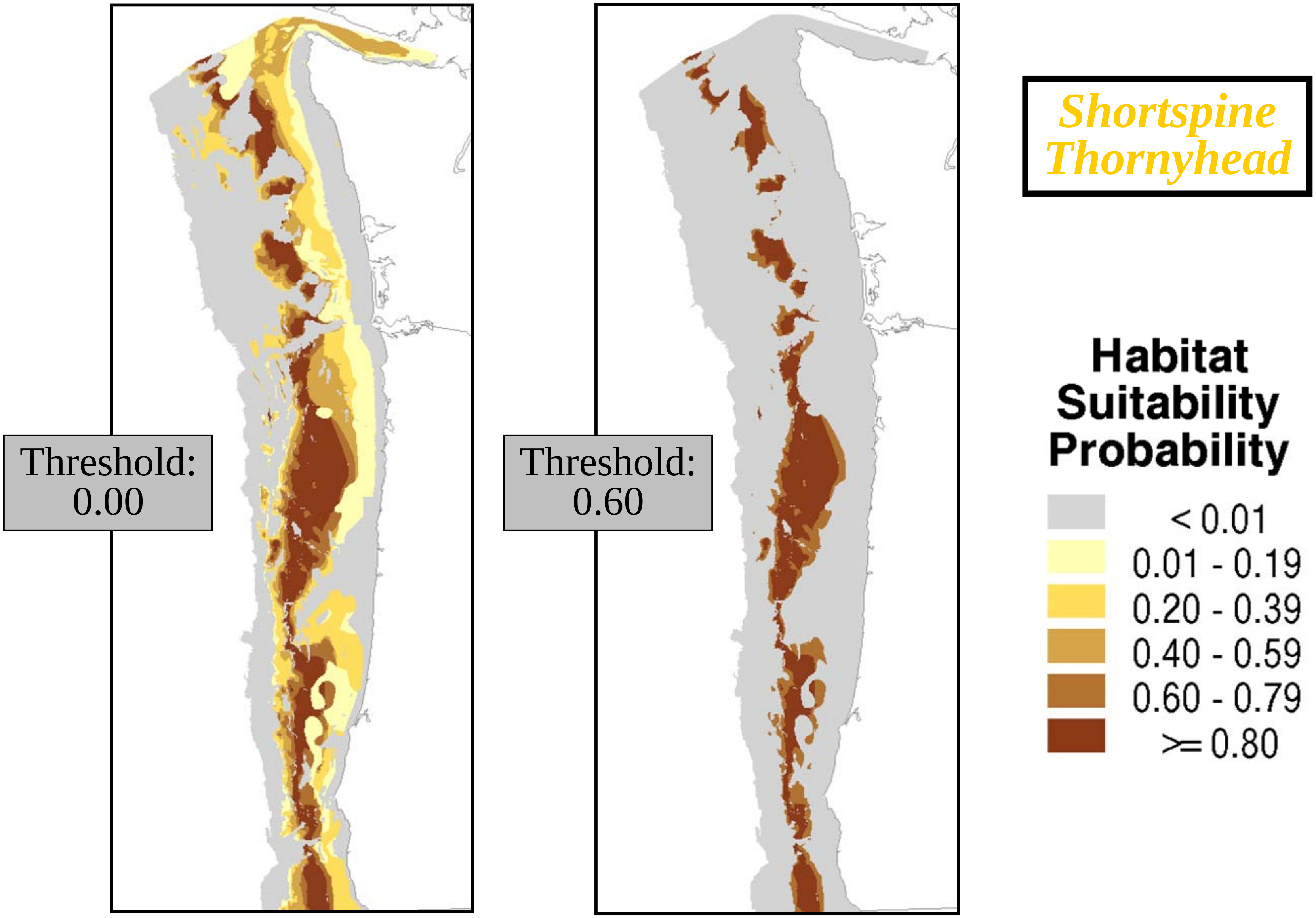


Figure 25 Example HSP contour plot for shortspine thornyhead showing the effect of selecting different threshold levels of HSP.

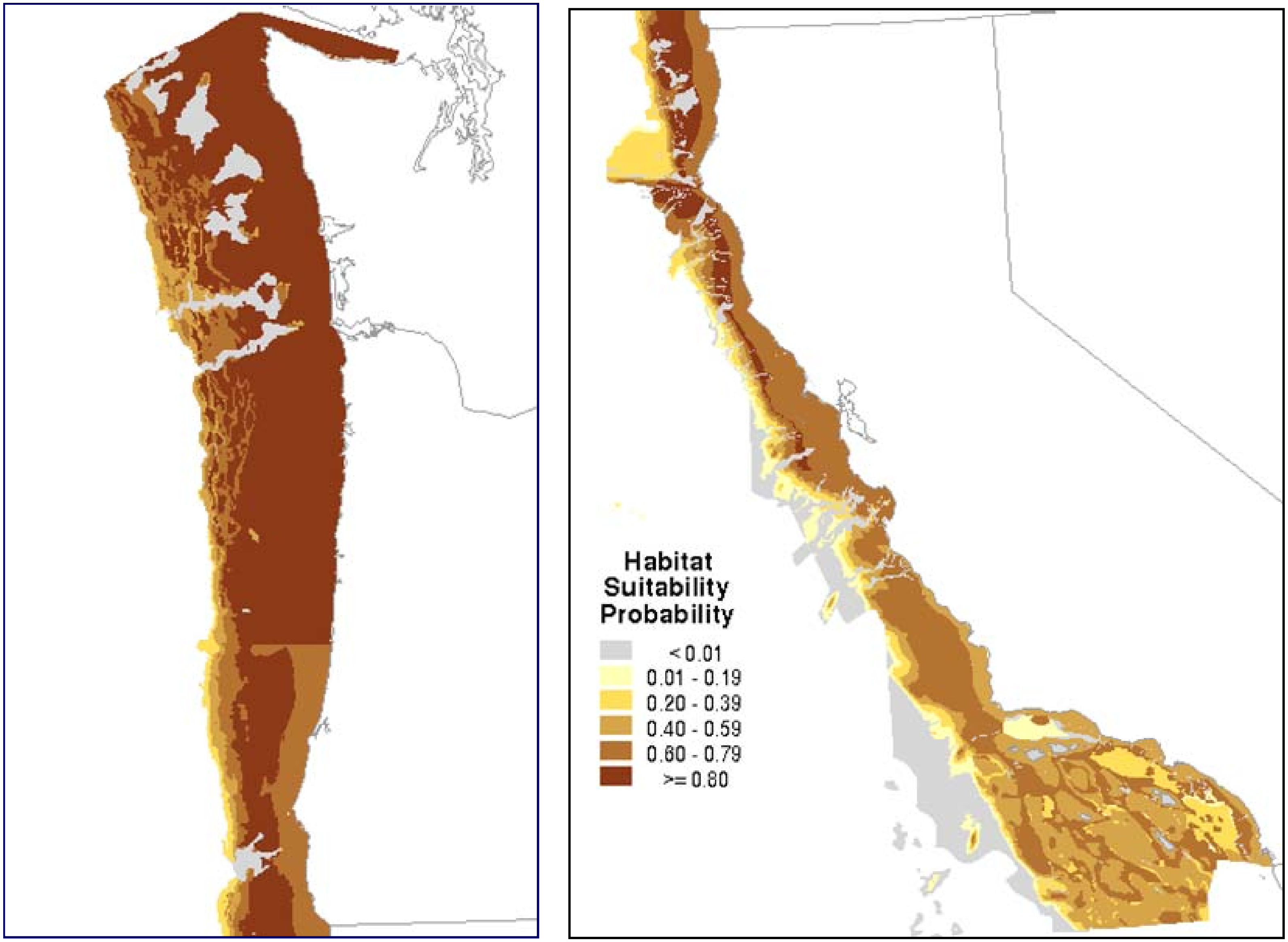


Figure 26 Example HSP contour plot for the slope assemblage adults

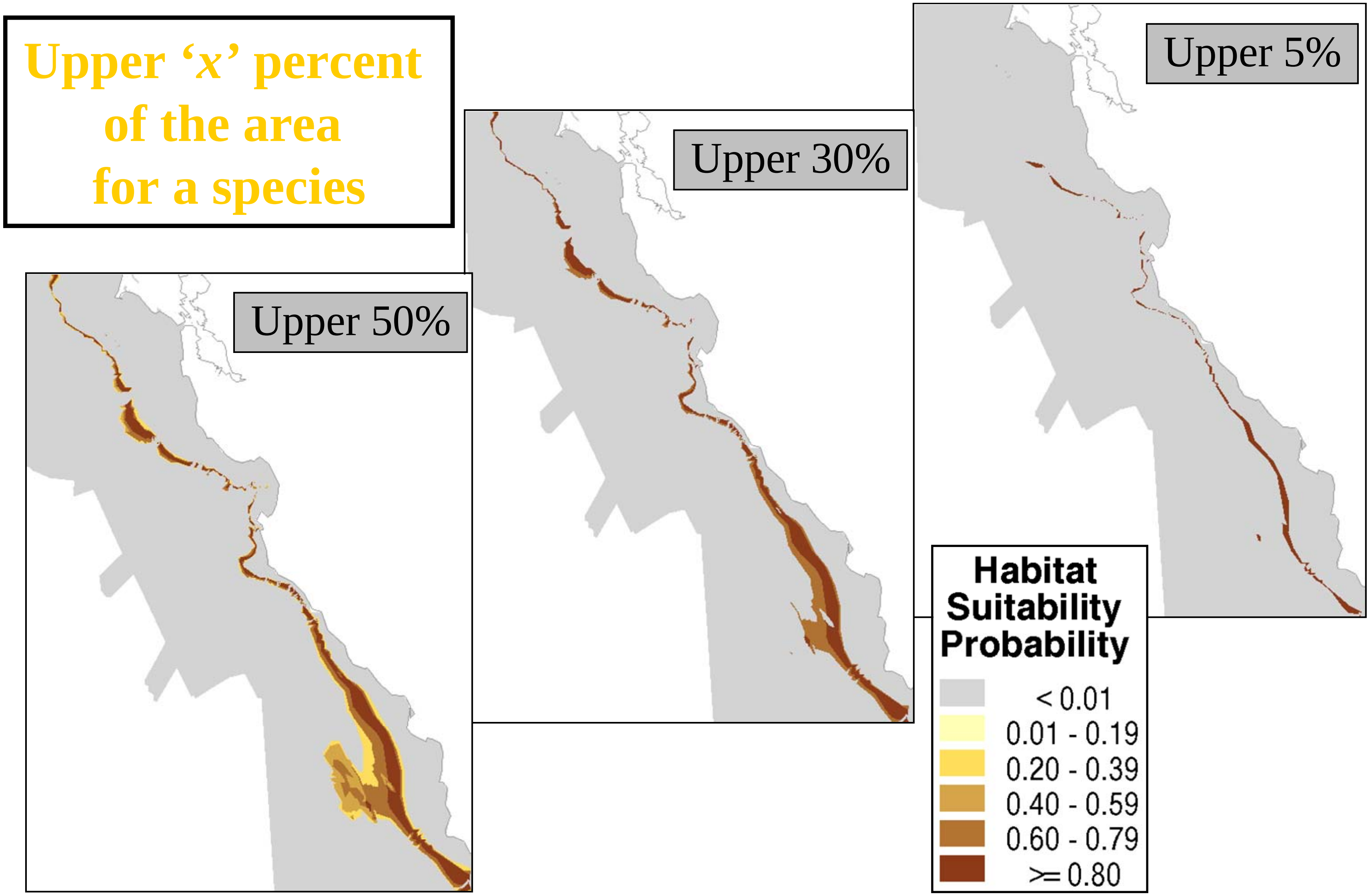


Figure 27 Example HSP contour plots showing the effect of selecting different proportions of the total area of EFH (i.e. where HSP > 0)

5.2 Impacts Assessment Outputs

5.2.1 Potential Council actions

This section describes the types of actions that the Council might consider when developing fishing impacts alternatives to prevent, mitigate, or minimize potential adverse impacts by a fishing gear on a habitat. Many different actions are possible for each gear, but they fall generally under possible five concepts: no action, gear modifications, time/area management, reduced fishing effort and full prohibition of a fishing gear. These concepts are described in more detail in Table 14.

The concepts described in Table 14 are all types of input controls on the fishery. The Council could consider a range of approaches to implement such controls. Perhaps the most traditional would be straightforward regulation through the FMP. However, such action might prove unpopular and therefore difficult to implement and regulate. A more effective implementation might be achieved through the use of more cooperative action. For example, participants in the fishery could be encouraged to develop their own approaches to mitigation (e.g. through gear modification) that would be tested against performance criteria set by the Council.

The Council might also wish to consider the role to be played by habitat restoration, perhaps in conjunction with one or more of these input controls. For example, if an area of degraded habitat is to be closed to fishing, then subsequent natural improvements to habitat quality and quantity could be accelerated through specific actions such as the installation of artificial reef structures. Such action might be particularly relevant in cases where recovery of habitat function for managed species is expected to progress slowly.

Table 14. Concepts that can be applied in the development of management alternatives to prevent, mitigate, or minimize the adverse effects of fishing on EFH

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.

Concept	Description
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.
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.

5.2.2 GIS Map overlays

All the data that have been compiled to date can be accessed and visualized in the GIS environment. This enables geo-referenced overlays of information from different sources to identify areas of habitat that may be particularly in need of protection.

For example, output from the impacts model can be overlayed with Habitat Suitability Probability (HSP) polygons produced by the EFH model for a particular species or group of species to look for areas of importance to that species that are at particularly high risk from fishing impacts. In addition, the data that are available for non-fishing impacts can be visualized together with these other layers.

Existing marine managed areas, such as sanctuaries or federal fishing regulation areas (Section 5.2.2.2), can also be overlayed to look for existing protections. Multiple layers can be viewed together as needed to assess both risks and protections for areas of interest. In addition, multiple layers of information can be combined to create new spatial boundaries as needed.

5.2.2.1 Sensitivity and recovery indices

Sensitivity and recovery indices have been developed for the full range of fishing gears used on the west coast, to the extent that these are supported by the literature. These values are gear and habitat specific, and can therefore be plotted using the GIS – one map per gear type. An example for a portion of the west coast is shown in Figure 28. Similarly, Figure 29 shows the mean recovery time for three gear type categories across the same portion of the coast.

The Council could, if it desired, consider management actions for these gears based only on the information depicted in these maps. Some gear/habitat interactions may be identified as sufficiently undesirable, based on this information, that the Council does not need a detailed quantitative risk analysis to take action. It would clearly be more desirable to be in a position to implement the Impacts Model for all gears, and to look at cumulative impacts on a single quantitative scale, but for reasons explained in this report, this is not presently possible. This should not, however, preclude using information outside of the Impacts Model to develop management alternatives.

There are several habitat types which are included in the sensitivity and recovery matrices that are not fully mapped in the GIS, i.e. they do not have shape files indicating the extent of the areas covered by those habitats. In particular, there are certain types of highly vulnerable biogenic habitats that are mapped either incompletely (e.g. seagrasses and kelp) or only in a very rudimentary way (e.g. corals and sponges). To the extent that there is information available on these habitats, the Council may want to consider alternatives to provide them with necessary protection. It may not be possible to develop alternatives if it is not possible to identify where the habitats occur. However, the Council may be able to consider alternatives that, for example, prohibit certain gears from operating in areas of particular habitat types, such as corals, to the extent that these are known. As new information becomes available on the distribution of those habitats and they can be mapped, such alternatives would come into effect.

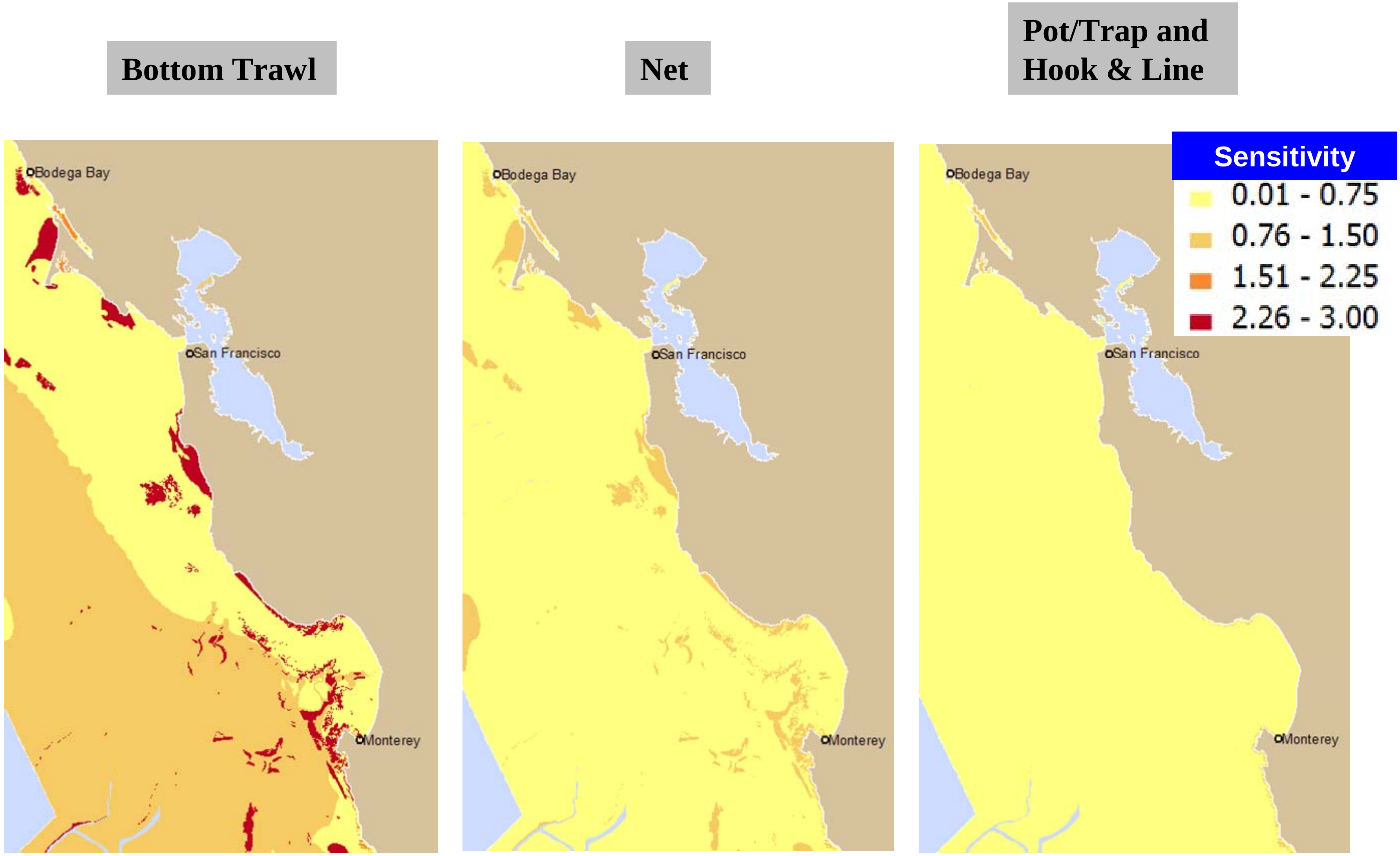


Figure 28 Mean Habitat Sensitivity by gear type for a portion of the west coast

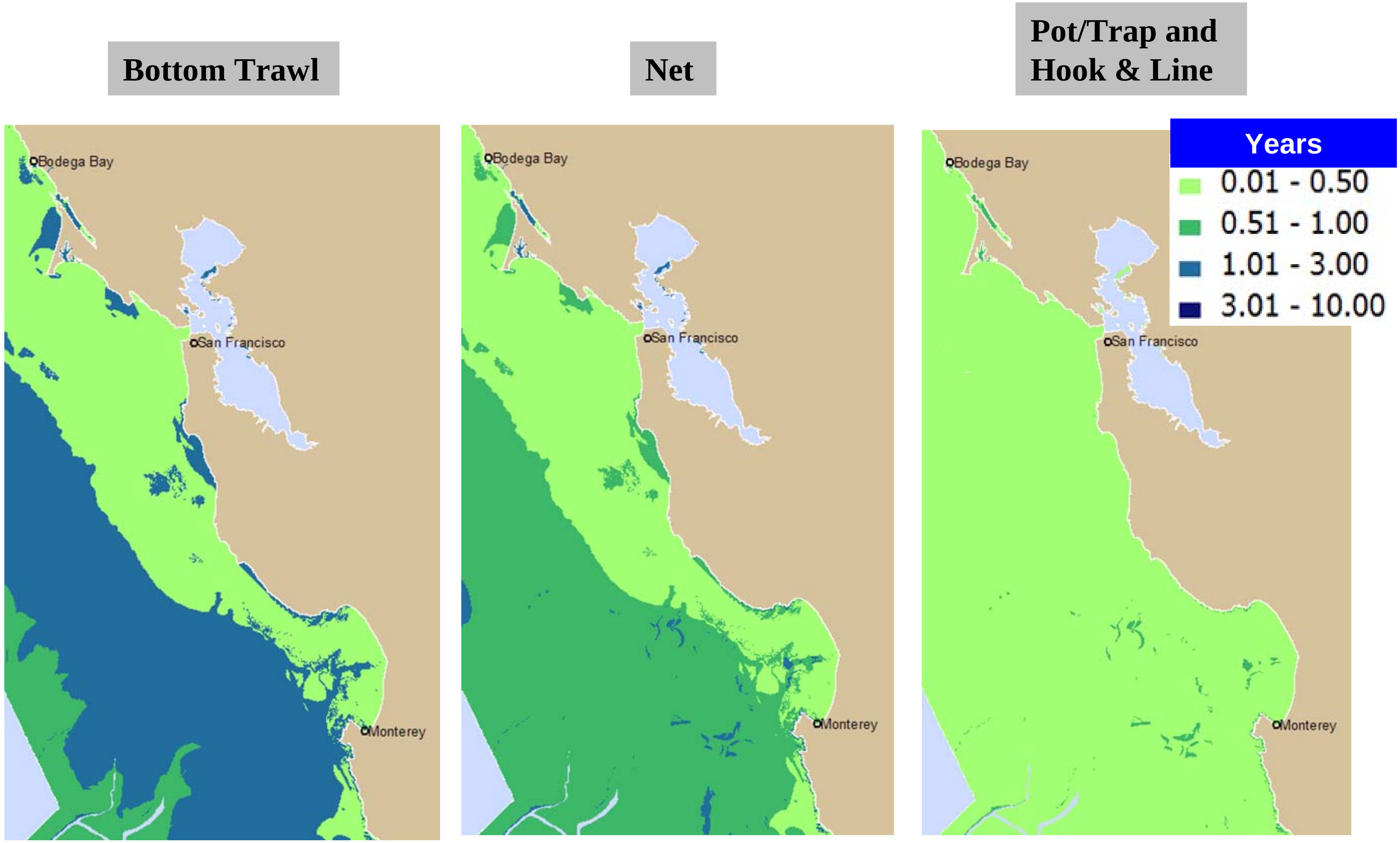


Figure 29 Mean habitat recovery time (years) by gear type for a portion of the west coast

5.2.2.2 Existing habitat protection

The groundfish EFH project has served as a catalyst to compile information on existing spatial habitat protection measures not previously available on a coast wide scale. This is a twofold effort: the first involved compiling boundaries of marine managed areas and the second is developing a GIS coverage depicting existing federal regulations including identifying areas that are closed to some or all fishing gears for some or all of the time. These boundaries are not explicitly included in the impacts model because we have information about actual fishing effort, and therefore any areas closed to fishing would be reflected in the location of fishing effort.

GIS data delineating Federal marine managed areas have been acquired from the Marine Protected Area (MPA) Center's Marine Managed Areas Inventory [22]. These areas include National Parks, National Wildlife Refuges, National Marine Fisheries Service Areas (Pacific Whiting Salmon Conservation Zones, only), National Marine Sanctuaries, and National Estuarine Research Reserves (Figure 30). Although the MMA Inventory provides information regarding habitat protection, the types of protection identified in the inventory are extremely generalized and may not contain all the information necessary for EFH purposes. Additional information about the type of habitat protection afforded at each of these sites has been researched by Fran Recht of PSMFC and is presented in Appendix 21.

Compilation of GIS data layers for marine protected areas in state waters was not completed for this phase of the project. The MPA center is currently compiling this information, and we did not want to duplicate their efforts. Data for Oregon have been completed in the MMA inventory, and data collection for Washington and California is in process. If the need for protected areas information in state waters becomes a high priority during the EFH policy development and EIS process, this information could be compiled.

As for fishing regulations, GIS data delineating existing and historic federal fishing conservation areas have been created from coordinates published in the Federal Register and on the Groundfish Management website of the NMFS, Northwest Regional Office[23]. Guidance for the interpretation of the regulations has been provided by Yvonne DeReynier and Carrie Nordeen at NMFS, Northwest Regional Office. Polygons delineating Rockfish Conservation Areas, Yelloweye Rockfish Conservation Area, Cowcod Conservation Area, and Darkblotched Rockfish Conservation Area from 2001 to the present time have been developed (Figure 31). In addition, boundaries for statewide closures to trawling in Washington and California have been delineated. Spatial boundaries for other state-specific fishery regulations have not been collected due to time and resource constraints. Also, due to the rate of change of the Rockfish Conservation Area boundaries (approximately every two months), we have currently compiled RCA boundaries only through August 2003. Because these boundaries were not explicitly included in the Impacts model, as described above, they were given a lower priority for scarce project resources. The additional boundaries could easily be compiled as needed, and it is expected that current RCA boundaries will be needed during the development of EIS

[22] http://www.mpa.gov/inventory/inventory.html
[23] http://www.nwr.noaa.gov/1sustfsh/groundfish/gConservAreas/

alternatives. Specific descriptions of the fishing regulations in these areas are provided in Appendix 21.

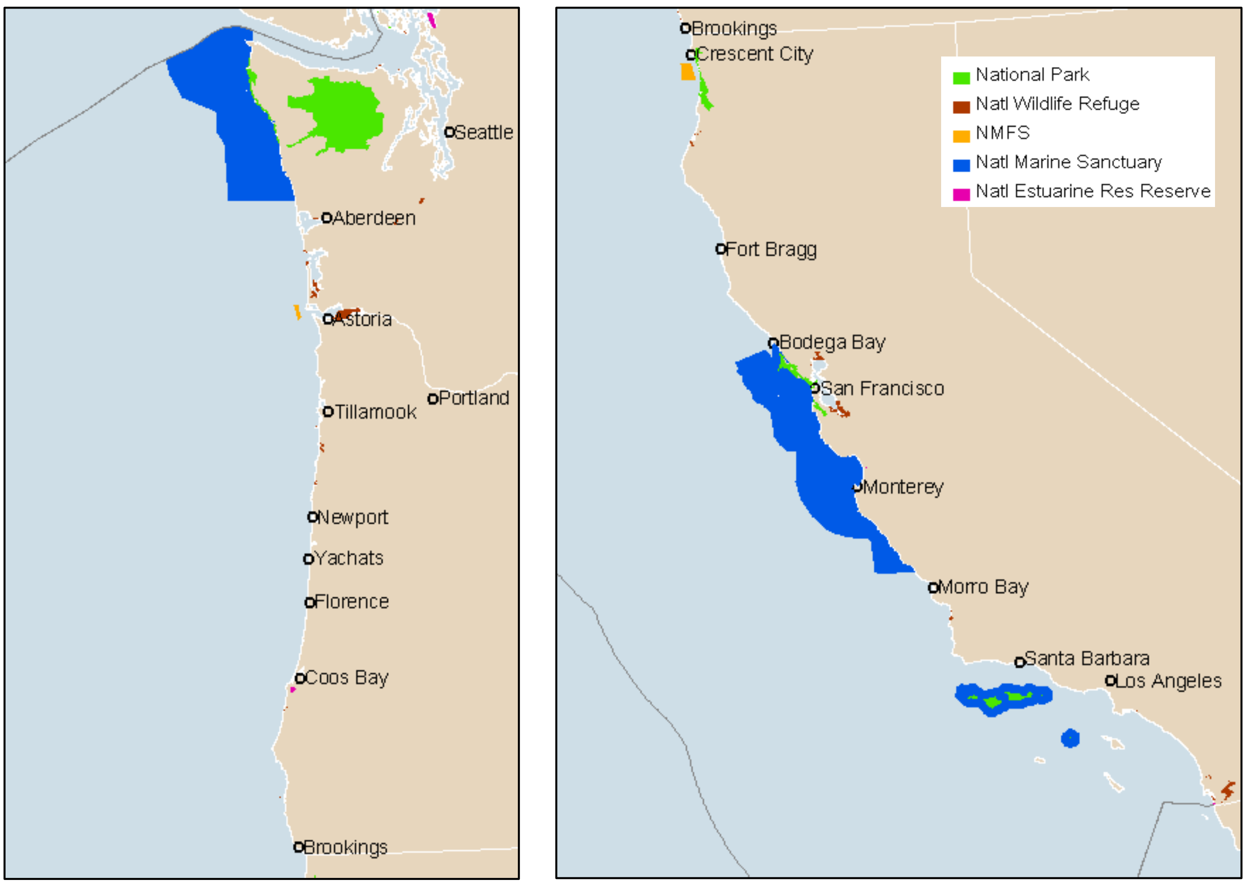


Figure 30. Federally managed areas on the west coast of the U.S.

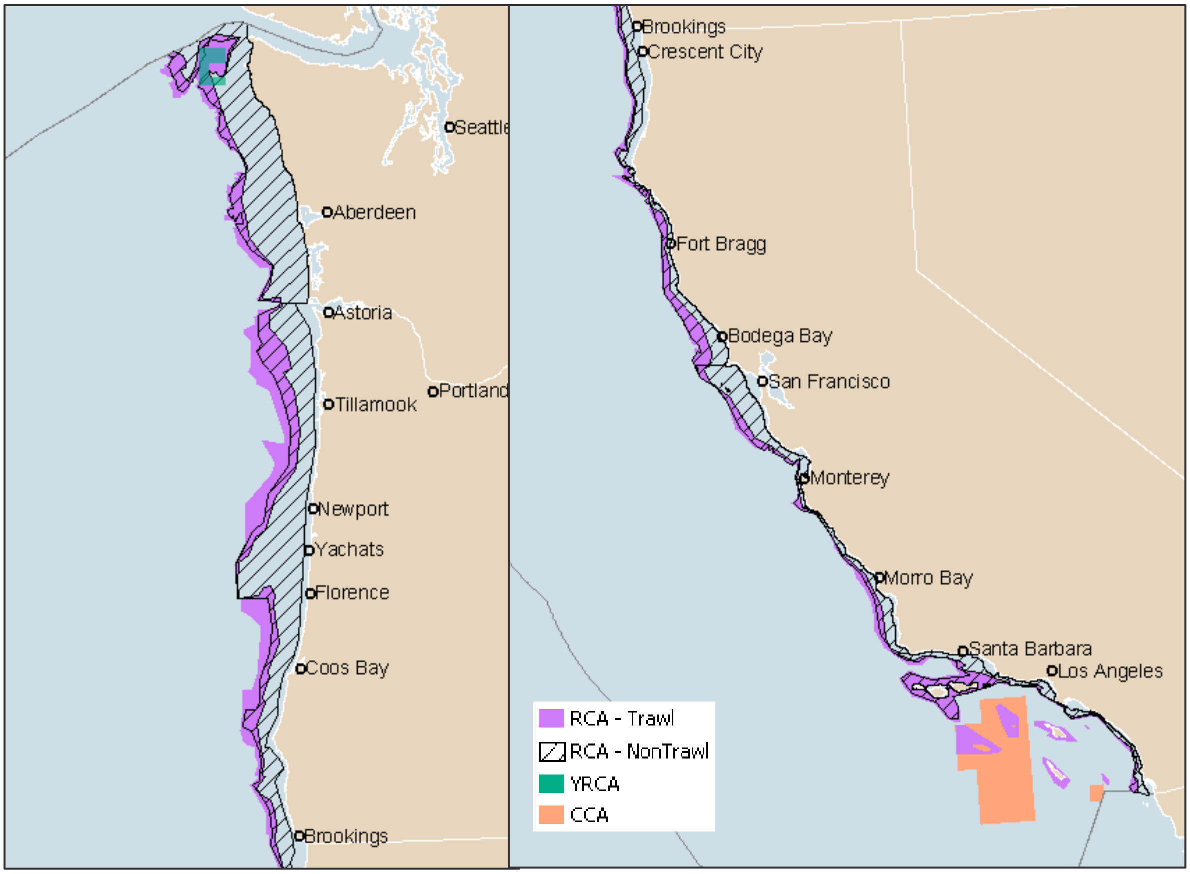


Figure 31. Polygons delineating Sample Rockfish Conservation Areas (RCA trawl and non-trawl), the Yelloweye Rockfish Conservation Area (YRCA), and the Cowcod Conservation Area (CCA).

5.2.3 Using the Impacts Model for trawl gears

5.2.3.1 What the Impacts Model (Version 1) can do

5.2.3.1.1 Graphic output of the net cumulative impacts measure

The Impacts Model provides a quantitative assessment of the biological impacts to EFH caused by bottom trawls. The model is dynamic and treats fishing impacts both spatially and temporally. It is intended to be used to investigate relative changes over time and space in the relative level of impacts to EFH resulting from different management regimes or different intensities of gear use. These management regimes may either be in the past, in which case the model is used to investigate existing levels of impact and hence the current relative status of EFH, or they are alternative strategies for future management, in which case the model is used to investigate potential changes in impacts level resulting from management interventions. An example output from the Impacts Model is shown in Figure 32.

On the face of it, Figure 32 looks to provide very useful information on relative impacts resulting from historical use of trawl gear across the study area. However, as explained in Sections 4.2 and 4.5, we currently have no empirical basis for associating a quantum of fishing effort with a measurable impact on habitat. Hence, while Figure 32 provides an interesting comparison of the potential impacts from one area to another, we have no idea whether any, or all, of these levels of impacts are high enough to warrant mitigating action, or so low and benign that they represent no threat to species in the FMP.

With current information, we can only hope to model relative impacts, but it may be possible to provide some kind of calibration of the scale such that the output is at least informative in some sense. To enable this possibility, the scaling or tuning constant k was introduced into the Impacts Model to allow some flexibility in calibrating effort with impact. As described in Section 4.5.2, due to the non-linear relationship between effort and impact, the choice of k has an important effect on the model outputs. Figure 33 illustrated the effect of different levels of k on the Impacts Model output for a portion of the west coast. As k decreases, the level of impact predicted for a given level of effort increases. Thus cells on the map are shown to be increasingly dark.

At this time there are no data available to provide an empirical calibration of the model, however, Section 4.5.2 does provide a methodology that calculates a value for k that provides the greatest contrast in the impacts scale. Essentially this takes the maximum range of effort and sets k to the value that provides the commensurate maximum range of net cumulative impact. The result of applying the described method for calculating k for the area of coast depicted in Figure 33 is illustrated in Figure 34.

This still does not tell us whether the highest, of some other level of impact is significant, but, if impacts that are detrimental to managed species are resulting from trawl gear fishing effort, it does show where they are most likely to be occurring. It also shows us, if mitigating action is going to be taken, where it is likely to have the greatest benefit.[24]

5.2.3.1.2 Answering the questions posed at the start of the project

At the start of the proof of concept phase of this project, six questions were posed that the analysis would be designed to address, to the extent practicable. These six questions are set out below, with a brief appraisal of the extent to which it has been possible to address them.

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

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[24] We note, however, that such benefit will depend greatly on many factors that are not included in the model, such as the behaviour of fishermen in response to regulation.

This question is addressed through the implementation of the EFH Model, which was presented to the Council at its April 2004 meeting: Identification of Essential Fish Habitat for the Pacific Groundfish FMP, Exhibit C6 in the April 2004 Briefing Book, available at www.pcouncil.org

- 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?

  It is not currently possible to provide a quantitative assessment of this probability due to the lack of a quantitative link between habitat condition and function for west coast groundfish habitats. The model does, however, provide trajectories of the cumulative impact of trawls on the condition of Pacific coast groundfish habitat, based on the available sensitivity, recovery and fishing effort data and an assumed value of the tuning constant k. It also provides a spatial comparison of impact levels within a given scenario, such that if degradation of habitat has occurred, we can see where it is most likely to have taken place.

  The model can also be used to demonstrate relative expected changes in fishing gear impacts that result from specific management interventions such as gear modifications, or area closures. However, due to the shape of the impacts function (this is non-linear), and uncertainties regarding the value of k it is difficult to be categorical about the magnitude of these changes. As the net cumulative equivalent effort increases, so the impacts function tends towards an asymptote. What this is saying is that an area that is heavily fished over a period of time will eventually reach a stage at which subsequent fishing will make very little marginal difference to the condition of the habitat; an intuitively sensible feature of the model. The corollary of this is that for areas that have reached this level of impact, a modest decrease in effort is likely to yield very little benefit in terms of a reduction in impact.

  However, there are several problems in interpreting these results. Firstly, while it seems obvious that the habitat will have been altered to some degree at the level of impact where the curve flattens out, we cannot tell at this stage to what degree the functionality of habitat has actually been impaired by this impact. Areas that have been regularly fished over along period of time and continue to yield reasonable catch per unit effort, suggest that it is possible for an area to reach this level of impact, but remain functionally productive. However, there is no available experimental evidence to support and/or explain this in a biological sense. Secondly, because impacts are modeled relatively, while we can tell if an area is more or less impacted, we cannot tell categorically whether a particular area is close to its asymptote or not. Depending on the selection of the value of k, a given level of effort will place us on different parts of the impacts function curve (Figure 21). It is, however, possible to develop some objective criteria for setting k (Section 4.5.2.2)

- 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?

The habitat map (Figure 2) and trawl logbook data provide the basis, through the application of the Impacts Model, for a spatial and temporal assessment of risk to habitat from bottom trawls. Other fishing gears and non-fishing inputs are not available at sufficient spatial resolution to be used in the model at present. In addition, there is presently no common metric with which to measure the relative and cumulative impacts of different inputs. Data on inputs that are not incorporated in the model are presented in the best available format (e.g. GIS layer maps or descriptions) so that they can be used in a qualitative assessment of risk to support the development of impacts alternatives.

- How might trends in habitat function be affected by altering anthropogenic inputs and regulatory regimes?

  These effects will be examined using the model in the development and assessment of management alternatives to prevent, mitigate, or minimize adverse effects from fishing.

- 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?

  These effects will be examined using the model in the development and assessment of management alternatives to prevent, mitigate, or minimize adverse effects from fishing.

- What are the scientific limitations of assessing habitat?

  The development of the Bayesian Network Model for fishing impacts has demonstrated a number of specific limitations in the information available to assess the status of habitat and the risks posed by various anthropogenic inputs. These limitations are discussed in 5.2.3.2.

5.2.3.1.3 Evaluating the consequences of alternatives

The main data inputs into the Impacts Model are fishing effort, habitat sensitivity and habitat recovery. Fishing effort is defined on a spatial and temporal scale, as described in Section 4.3. The sensitivity and recovery indices are defined as matrices of fishing gears and habitat types. Management measures that bring about changes in these input data can be evaluated in terms of changes in the model outputs.

Area or time measures can be mapped in the GIS, in terms of assumed future distributions of fishing effort. These scenarios can be fed into the model to show changes in the spatial distribution of expected impacts, and changes in time trajectories. At present there is no specific modeling of fishermen’s behavior in response to management interventions, but this could be done external to the model and the results analyzed in the same way. In a future iteration of the Impacts Model, it would be highly beneficial to develop an integrated capability that could look at such changes in behavior, and resulting changes in impacts.

Similarly, changes in gear configuration that reduce the impact that a fishing gear has on habitat would be manifested in terms of a change in the sensitivity and/or recovery scores for particular gear/habitat combinations. These changes can also be fed into the model and the results plotted as previously described.

The scale on which the effects of gear modifications can be considered is, however, relatively coarse at present. For example, in 1999 there was a management intervention that reduced the size of the footrope gear on bottom trawls. This had the effect of reducing fishermen's capability to fish in hard bottom, high relief areas (to reduce catches of canary rockfish and lingcod), and hence had an influence on the spatial distribution of habitat impacts. For a given amount of effort, a trawl with a "small" footrope is also likely to cause less impact on a given habitat than one with a "large" footrope (See Appendix 8, page 13). However, the impacts literature review presented in Appendix 10 suggests that we are not yet able to show scientific evidence to support such a difference. In fact, the literature does not yet support subdivision of bottom trawl gears into the component types listed in Appendix 9, nor do the trawl logbook data currently distinguish between these different types of bottom trawl.

5.2.3.2 What the Impacts Model (Version 1) cannot do

Formulation of the Impacts Model and analysis of available data has been undertaken under constrained funding and timelines associated with a legal settlement (AOC vs. Daly). There are consequently several limitations to the utility of the model for supporting decision-making with respect to alternatives for mitigating impacts to EFH. First and foremost, the model currently treats only at part of the cost/benefit equation. It is being used to investigate, in a relative sense, past impacts on habitat caused by bottom trawl gear and the potential for recovery from those impacts under various management scenarios. It does not (and was not intended to) consider directly the economic consequences of management measures, and it therefore cannot be used by itself to investigate quantitatively notions of practicability.

With respect to impacts, the model cannot provide an assessment of the absolute status of groundfish habitat either prior to fishing, at the present day, or following possible management interventions in the future. We are not aware of an objective scale on which to measure this status, other than what has been used to develop the sensitivity index. There is no absolute quantitative link between an amount of fishing effort, an impact on habitat and a consequent change in the productivity of managed and other fish species. The metrics of fishing effort and non-fishing activities are not on comparable scales, and it is therefore not possible to demonstrate quantitatively either the relative importance of fishing and other anthropogenic activities in bringing about changes in habitat status, or the cumulative effects of multiple impacts.

One of the most significant constraints to the utility of the Impacts Model is the resolution of the fishing effort data. There are no reliable spatial data available for non-trawl gears, nor for recreational gears, for the whole west coast. There are also limitations in the trawl logbook data that have been used in this first version of the model. The logbook database contains information on the start position of each haul, and the duration of the haul. There is no information on the speed and direction of the tow, nor the estimated width of the ground gear. At this stage, it is therefore not possible to plot the footprint of the trawl gear in the GIS. Regarding speed and direction, the logbooks themselves do contain end position of tows, but these data have not been entered into the database. Regarding the width of the gear, it is possible to estimate this information for different gear types, but it is quite variable, depending on the specific rigging of the trawl, and the way in which it is fished.

The benefits of fishery management measures would need to be evaluated in the context of impacts arising from non-fishing activities that themselves may or may not be mitigated once identified.[25] However, the benefits of specific actions to protect or restore habitat are not all readily quantifiable in the same units as the costs. This is in part due to uncertainty in the direct effects of fishing gears and non-fishing impacts on habitat function and the lack of information on the relationships between habitat function and productivity. This uncertainty and lack of information is both a consequence of and exacerbated by the complexities of the ecological relationships and processes involved.

Habitats that make up EFH are subject to varying degrees of natural disturbance. The sensitivity and recovery matrices developed for the Impacts model categorize habitat types using the methodology adopted for the GIS. This distinguishes implicitly, to some extent, between habitats in high and low energy environments (e.g. shelf, slope, basin floor), but this distinction is limited. Currently there is no explicit accounting for natural disturbance in the evaluation of the significance of fishing impacts in terms of effects on the utility of EFH for managed species.

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

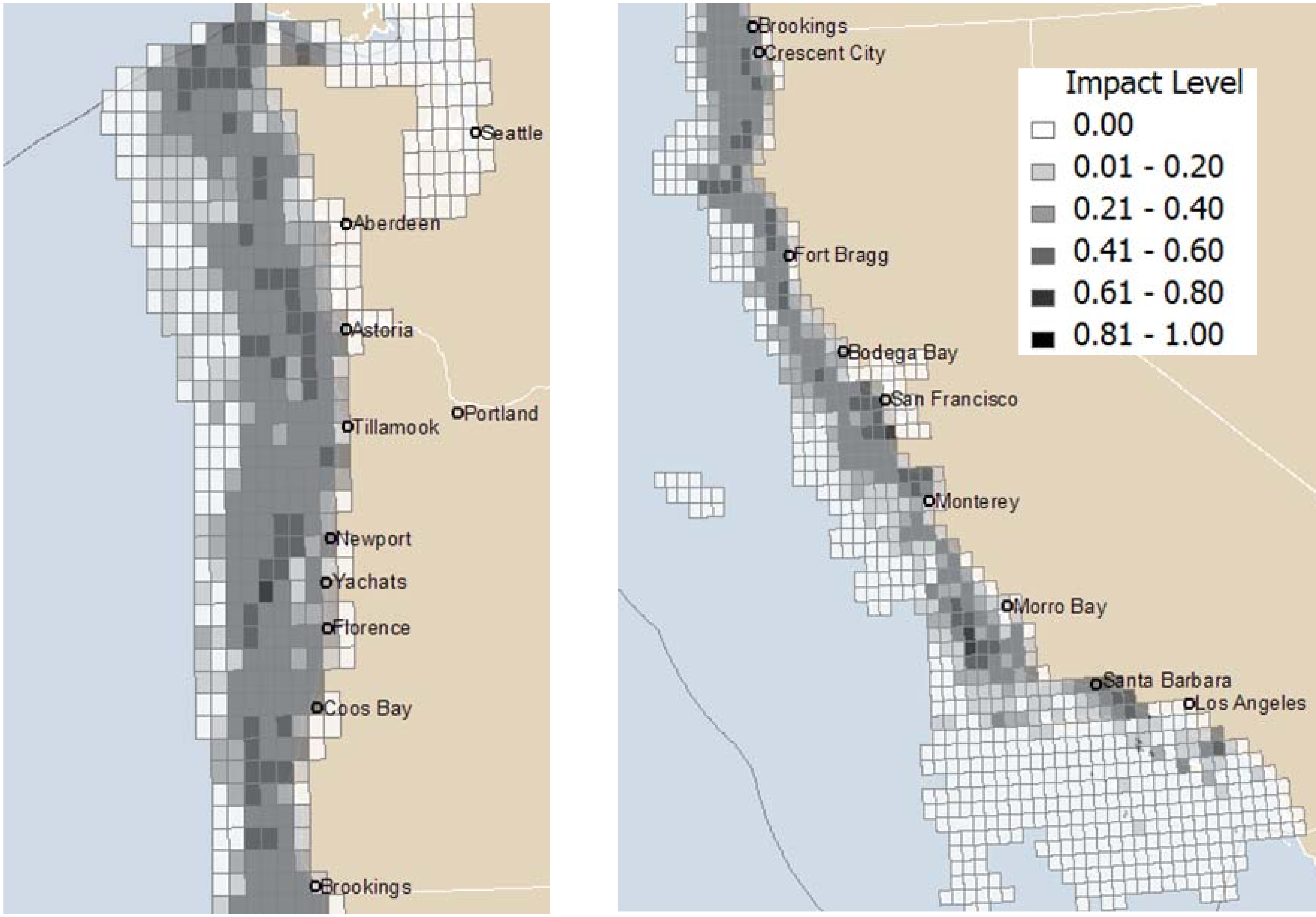

Figure 32 Example map depicting net cumulative impact from bottom trawls the west coast. Note: this diagram is not calibrated and is indicative of the type of output provided by the Impacts Model only.

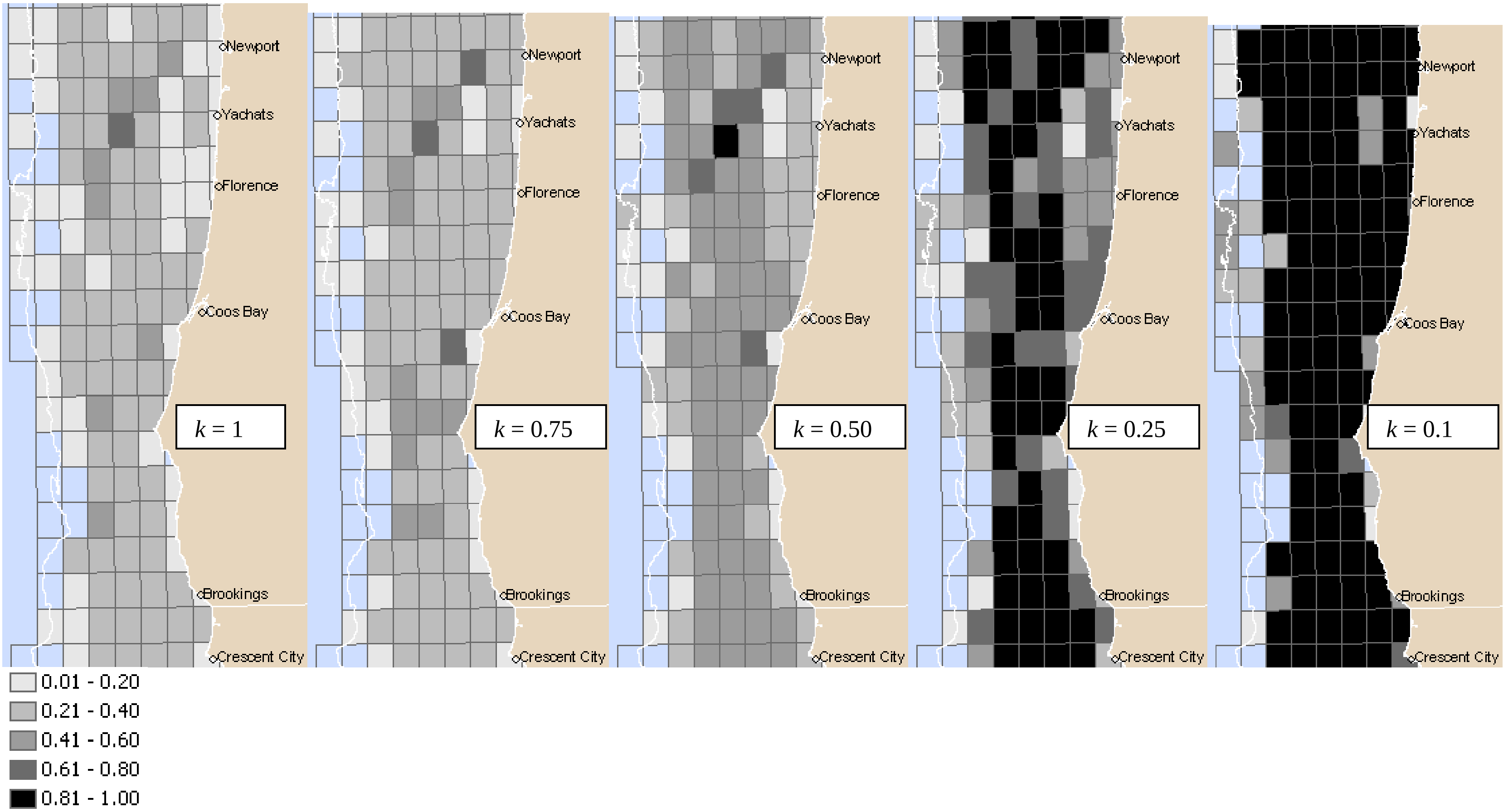

Figure 33 Example maps depicting net cumulative impact from bottom trawls for various levels of the tuning constant *k*

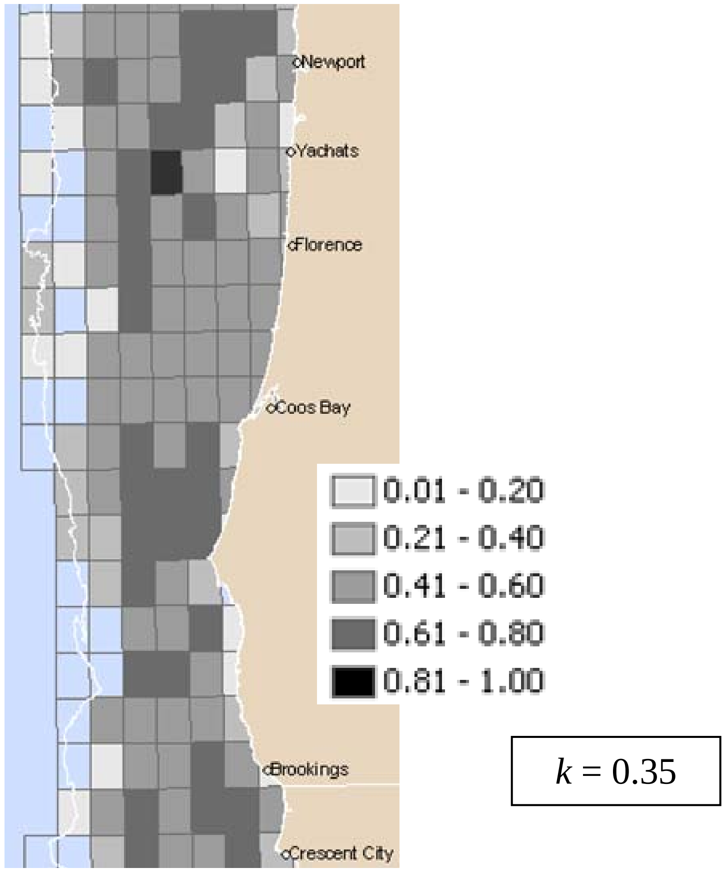

Figure 34 The result of tuning the Impacts Model according to the method described for calculating *k* for the area of the coast shown in Figure 33. This shows the maximum level of contrast in the impacts measure for the area shown, over the period modeled.

5.3 Data gaps analysis

Throughout this report, we have identified gaps in the information available for the comprehensive risk assessment. This is the first time a comprehensive, coast-wide assessment of EFH has been undertaken on the west coast. It has required the compilation of new datasets, the use of existing datasets for purposes other than those for which they were originally intended, and the innovation of novel assessment techniques. It is not surprising, therefore that this process has revealed many, and sometimes substantial gaps in our knowledge that it has not been possible to fill. Indeed, the identification and assessment of these gaps is perhaps one of the most important products of the research effort to date, and is one that should feed directly into the development of management alternatives.

The National Environmental Policy Act (NEPA) requires treatment of incomplete or unavailable information in an EIS. Under the CEQ regulations (1502.22), when information is incomplete or unavailable, it is to be obtained if costs are not exorbitant. If the information cannot be obtained, the EIS must:

- State that the information is incomplete or unavailable
- State the relevance of the information to the analysts' ability to evaluate reasonably foreseeable significant effects
- Summarize credible scientific evidence about likely impacts
- Use methods generally accepted by the scientific community for extrapolating, modeling, predicting and so forth

In the main document, we have provided information and undertaken analyses that address the last two bullet points in this list. In this section we provide a summary of the information that is incomplete or unavailable and discuss both the implication of the data gaps for the assessment and ways in which the information could be obtained. The presentation of this information in the following sections is firstly divided between the two major lines of enquiry in the assessment: the identification of EFH and the assessment of impacts, and secondly according to the five major data types shown in Figure 1.

The assessment itself has been designed, to the greatest extent possible, in a way that will allow updating as new information becomes available. We note, however, that some of the more fundamental types of missing information, should they become available, may warrant significant re-structuring of the approach, particularly in the case of the Impacts Model.

5.3.1 Data gaps for identifying EFH

5.3.1.1 Groundfish habitat

5.3.1.1.1 Geological substrate

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

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

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

- transition zones (e.g. between 2 substrate types, or areas where depth changes sharply); and
- genuine mixtures within a parcel of habitat identified as a single substrate type (e.g. gradual changes in depth or latitude).

No data quality information is currently available for California.

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

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

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

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

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

Summary of Data Gaps for Geological Substrate

Data Gap	Significance for the identification of EFH	Potential means of filling data gap
Data quality is highly variable across the existing substrate	HSP maps assume habitat type is recorded in the GIS without error	The most recent data on benthic substrate need to be processed and

Data Gap	Significance for the identification of EFH	Potential means of filling data gap
map; new data exist that have not yet been incorporated into the assessment, due to time constraints.	irrespective of the true level of uncertainty; identification of EFH may miss important areas of substrate, and/or areas may be mis-identified as EFH for some species and life stages.	incorporated into the EFH Model.
Data quality data do not currently reflect the full range of uncertainty in benthic substrate type and are not used in the EFH model	As above	Enhanced measures of data quality need to be developed and their use in the EFH model investigated further.
No data quality data are currently available for California (Section 2.2.5.1)	As above	Data quality information for California could be developed by Moss Landing Marine Lab
Detailed geological substrate data are missing for some areas of the EEZ	No EFH can be identified offshore of the area of the current benthic substrate map to the edge of the EEZ; some important features, such as seamounts may not be properly represented; estuaries are defined as a single substrate "type" irrespective of the actual substrate; there can be no subdivision of areas within estuaries based on substrate type.	Benthic substrate data for areas not covered by the substrate map should be collected, processed and incorporated into the assessment.
The classification system does not separate out some benthic features that may be important to groundfish.	The importance of some specific areas of seabed as EFH for groundfish may not be properly identified.	The classification system needs to be re-examined from a groundfish ecological perspective.
Off California, substrate type is divided only into hard and soft.	Habitat preferences are recorded in the HUD to a finer classification than just hard and soft substrates, but this information is lost when projecting these preferences onto the substrate map off California; the information is used in a risk averse way such that some areas may be mis-identified as EFH for some species/life stages	More detailed substrate type data should be compiled for California.
The shoreline is not set to a consistent standard and does not align with the estuary data.	Identification of EFH at the shoreline boundary may be inaccurate when projected onto some maps. It may appear that some small areas of land have been identified as EFH, or some small areas of the seashore may not be properly mapped as EFH.	The shoreline must be set to a common standard along the entire coast and must be aligned with all other relevant GIS datasets, such as estuaries.

5.3.1.1.2 Bathymetry

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

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

A small data gap exists between Oregon and Washington, approximately 100 to200 meters across. This was bridged by extending the contour lines to meet the shared boundary.

Summary of Data Gaps for Bathymetry

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

5.3.1.1.3 Biogenic habitat

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

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

Summary of Data Gaps for Biogenic Habitats

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

5.3.1.2 Use of habitat by groundfish

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

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

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

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

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

Summary of Data Gaps for habitat use data

Data Gap	Significance for the identification of EFH	Potential means of filling data gap
The analysis of NMFS survey data for distribution of fish by depth and latitude does not take into account relative densities as indicated by catch per unit effort. The limitations of presence/absence information to infer EFH should not be ignored (SSC Feb 2004).	The use of presence/absence data in the EFH Model treats the data in a risk averse way. A species may have a broad depth or geographic distribution, but may only reach high densities in a limited area. However, catch per unit effort data from surveys may provide an overly distorted picture of relative density depending on the statistical techniques used to analyze them.	GAMs and GLMs that can accommodate zero catches have been commonly used to obtain indices of abundance using West Coast trawl survey data for stock assessment and could be used in a re-examination of the data for the purposes of identifying EFH.
168 species/life stage combinations have no HSP profile developed for them. Only six species in the FMP have depth/latitude profiles developed for all life stages. All species in the groundfish FMP have at least one HSP profile developed (all adults are covered).	EFH cannot be identified for species/life stage combinations without an HSP profile. EFH identified for species with less than the full complement of four profiles may not represent the full extent of EFH. However, when all areas identified as EFH are added together for the FMP, the likelihood than an area for a particular species is missed will be reduced.	Conduct an extensive, worldwide literature review to investigate whether more data can be obtained for filling out the HUD, particularly for eggs and larvae; Undertake exploratory data analyses of ichthyoplankton survey data such as the CalCOFI and NMFS datasets for areas off California to investigate the utility of these type of data for identifying EFH;
Only 36 HSP profiles were developed from NMFS trawl survey data. A further 20 profiles could be developed with the help of expert opinion	EFH will likely be described less precisely from HUD-based HSP profiles than they would be from survey-based profiles for these species and life stages	Obtain information from specialists with expert knowledge of the distributions of the species involved, using the same technique as used during this study.

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

5.3.2 Data gaps for assessing impacts

5.3.2.1 Groundfish habitat

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

From the perspective of the identification of EFH, alternative to mitigate impacts will apply only to EFH. Hence if some areas that are important for groundfish are not identified as EFH due to inadequacies in the identification of habitat types, they will not receive whatever protection may be necessary from the impacts alternatives.

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

5.3.2.2 The effects of fishing on habitat

5.3.2.2.1 Sensitivity and recovery

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

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

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

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

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

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

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

5.3.2.2.2 Fishing effort data

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

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

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

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

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

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

5.3.2.3 Effects of non-fishing activities on habitat

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

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

5.3.2.4 Measuring cumulative impacts

The groundfish FMP, as with all others, must be amended, as necessary, to prevent, mitigate, or minimize to the extent practicable adverse effects from fishing on EFH (600.815(a)(2)(ii))[26]. 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.

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

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

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

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

5.3.2.5 Economics analysis: evaluating practicability

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

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

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

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

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

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

On the benefit side, this would involve consideration of economic gains arising from habitat restoration that results in, for example, improved productivity of fisheries, or perhaps eco-tourism. The benefits of fishery management measures would need to be evaluated in the context of impacts arising from non-fishing activities, which themselves may or may not be mitigated once identified[27]. However, the benefits of specific actions to protect or restore habitat are not all readily quantifiable in the same units as the costs. This is in part due to uncertainty in the direct effects of fishing gears and non-fishing impacts on habitat function and the lack of information on the relationships between habitat function and productivity. This uncertainty and lack of information is both a consequence of and exacerbated by the complexities of the ecological relationships and processes involved.

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

The EFH EIS for the Gulf of Mexico FMPs[28] used six specific practicability factors relevant to EFH Final rule requirements to evaluate the concepts discussed in the previous section (see table below). These factors were chosen to help identify the costs and benefits to EFH, the fisheries, and the nation. Factors 1 and 2 address burdens on fishers, and the remaining four address availability and effectiveness of technology.

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

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

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

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

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

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Appendix 1

Phased approach to the Assessment

1.1 Introduction

At the outset, the authors of the Risk Assessment recognized that new data had become available since the Council's initial EFH effort in 1998 that provided an opportunity to integrate a much broader range of information than was used before. For instance, the designation of groundfish EFH in 1998 was based primarily on catch records and a literature review of species' habitat associations. The method developed through the risk assessment process includes those elements as well as detailed analysis and interpretation of physical and biological substrate types that play key ecological roles in the functionality of habitat for groundfish. The risk assessment was developed in distinct phases with public workshops and opportunity for comment throughout. It should be noted, however, that the realities of budgeting and project management have caused some blurring of the lines between the phases, which are noted in the summary below. The phases are summarized as follows:

1.2 Phase I - Initial Scoping (April, 2001 through October, 2001)

This phase began upon publication of a Notice of Intent prepare an EIS that was published on April 10, 2001 (66 FR 18586) and went through the October, 2001 Council meeting. The result of this phase was the decision to prepare two EISs instead of the single EIS contemplated in the NOI. The decision was described and published in a Notice of Availability for the scoping report (67 FR 5962; February 8, 2002). One EIS was to focus on programmatic elements of the FMP and the second, this EIS, to focus on EFH. Public scoping meetings during this phase were held as follows:

- Newport, OR, Hatfield Marine Science Center; May 22, 2001.
- Astoria, OR, Oregon State University, Seafood Laboratory; May 23, 2001.
- Eureka, CA, Humboldt Bay Harbor, Woodley Marina; May 29, 2001.
- Los Alamitos, CA, California Department of Fish and Game; May 30, 2001.
- Seattle, WA, NOAA Sand Point Facilities; June 5, 2001.
- Burlingame, CA, Park Plaza International Hotel; June 12, 2001.

1.3 Phase II – Kick-off (October, 2001 through April, 2002)

This phase began after conclusion of initial scoping and resulted in Council adoption of the draft decisionmaking framework (most recent version shown in Figure 1 in the Risk Assessment) at their April meeting. Two important meetings were held during this phase as follows:

- Seattle, WA, NOAA Sand Point Facilities, March 24-25, 2002. Agency meeting of NMFS EFH experts that resulted in a draft of the decisionmaking framework and identification of key data sources.
- Portland, OR, DoubleTree Hotel - Columbia River, April 8-12, 2002. Council adopted decisionmaking framework.

1.4 Phase III - Data Consolidation and Infrastructure Development (April, 2002 through November, 2002)

This phase began after the April, 2002 Council meeting and established the technical infrastructure, databases, personell, and committee structure necessary to implement the decisionmaking framework. PSMFC used this time to develop appropriate contracts and consolidate necessary data and a preliminary risk assessment approach. It should be noted that data consolidation has in reality continued throughout implementation of the decisionmaking framework. One important public meeting was held during this phase:

- Foster City, CA, Crowne Plaza Hotel, October 28 – November 1, 2002. Council formed TRC to provide guidance to risk assessment authors.

1.5 Phase IV – Proof of Concept (November, 2002 through April, 2003)

This phase began upon formation of the TRC and resulted in guidance and endorsement of the preliminary assessment approach. Two important public meetings were held during this phase:

- Seattle, WA, NOAA Sand Point Facilities, February 19 – 20, 2002. The TRC reviewed the preliminary approach to the risk assessment and provided guidance and endorsement.
- Vancouver, WA, Red Lion Hotel; April 6 -11, 2003. The Council was presented with the results of the TRC meeting.

1.6 Phase V - Assessment Modeling and Review Phase (April, 2003 through June, 2004)

The technical work of developing the risk assessment and having it reviewed was completed during this phase, culminating in delivery of final products to the Council at their April and June meetings in 2004. The TRC provided in-stream guidance while the risk assessment was being developed. The SSC provided scientific review of the final products. Six important public meetings were held during this phase:

- Teleconference on August 4, 2002. Public listening posts in Seattle, WA; Gladstone, OR; Newport, OR; and, Santa Cruz, CA. The TRC reviewed progress and provided guidance to the risk assessment authors.
- Santa Cruz, NMFS, Southwest Fisheries Science Center Laboratory, November, 20-21. TRC reviewed progress and provided guidance to the risk assessment authors.
- Seattle, WA, NOAA Sand Point Facilities, February 23 24, 2004. SSC Groundfish Subcommittee reviewed and endorsed EFH component of the risk assessment.
- Sacramento, CA, Red Lion Hotel, April 4-9, 2004. Council adopted EFH component of the risk assessment as basis for alternative development in the EIS. Additionally, the Council tasked the Groundfish EIS Oversight Committee with holding public meeting(s) to develop alternatives for the EIS.
- Seattle, WA, NOAA Sand Point Facilities, May 24 - 25, 2004. SSC Groundfish Subcommittee reviewed and provided a qualified endorsement of the impacts component of the risk assessment.
- Foster City, CA, June 13 - 18, 2004. Council adopted impacts component of the risk assessment, with caveats described by the SSC, as the basis for alternative development in the EIS.

1.7 Phase VI – Validation and Policy Development (June, 2004 through May, 2006)

This phase is marked by separation from the risk assessment phases described above and is focused on development and analysis of alternatives through the EIS and if necessary promulgation of FMP amendment(s) and regulations. Important meetings for this phase include:

- Portland OR, Pacific Fishery Management Council, August 16-18, 2004. EIS Oversight Committee: develop preliminary alternatives for Council review.
- Place, September, 2004. Council adopts preliminary alternatives for analysis in the EIS.

- Place, Time. TRC reviews results of EFH component of risk assessment for validation develops preliminary research plan.
- Place, November, 2004. Council adopts preliminary preferred alternative for the EIS.

Appendix 2

Active Tectonics and Seafloor Mapping Laboratory Publication 02-01

Interim Seafloor Lithology Maps for Oregon and Washington
Version 1.0

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Project Description

As harvest levels for northeast Pacific groundfish fisheries continue to shrink, increasing attention is turning to conservation strategies and to the complex questions of the contribution of habitat to the productivity and long-term sustainability of fish stocks. The Sustainable Fisheries Act of 1996 (amending the Magnuson-Stevens Fishery Conservation and Management Act) requires regional fishery management councils to define and describe essential fish habitat. The Pacific Fishery Management Council amended its groundfish fishery management plan in October 1998 (Amendment 11) to meet this mandate. It further requires Councils to minimize adverse impacts on EFH due to fishing activities.

Those seeking solutions for the current groundfish crisis are considering controversial changes in fisheries management including gear modifications, time-area closures and areas that are closed to fishing along with more traditional approaches. However, little is known about the physiography, state, and role of marine habitats, the effects of annual and inter-decadal ocean variability, or how fishing and other human activity affect marine habitats or fisheries resource productivity on broad scales. Future management decisions to conserve and restore marine fisheries resources will depend on the availability of well-curated data sets of habitat and species distributions. These future decisions will also need to consider the impacts of fishing (and other human) activities in the context of natural changes in the environments through climatic and geologic processes.

The goal of this project is the creation and use of a comprehensive, helpful and easily accessible, multi-layer GIS database of the geologic and geophysical data for the Oregon and Washington continental margin. The project expands on one recently completed for the Oregon Department of Fish and Wildlife (ODFW) that was more limited in geographic scope (Goldfinger et al., 1998). Using similar methods and datasets, we are expanding this earlier database to include the Oregon and Washington continental shelves and margins, incorporating many important new datasets collected since the ODFW project was completed in 1998.

The Interim Seafloor Lithology Maps for Oregon and Washington are being supported by the National Marine Fisheries Service, The Cooperative Institute for Marine Resources Studies (CIMRS), Pacific States

Marine Fisheries Commission, Oregon Sea Grant, U. S. Geological Survey, the National Science Foundation, and Marine Conservation Biology Institute (MCBI).

Due to time constraints for release of the Interim Maps, complete references for data sources and investigations used in this report are not yet available. We apologize to all the original investigators who collected and interpreted geological and geophysical data used in these maps for this temporary omission, which will be rectified in the next release of the Interim Seafloor Lithology Maps for Oregon and Washington.

Oregon and Washington Groundfish Geological and Geophysical Database

Many types of geological and geophysical data (e.g., seafloor bathymetry, sidescan sonar images, sediment and rock types, active fault zones, observations and measurements from submersibles) have been collected on the U.S. West Coast continental margin. The goal of this project is to integrate these extensive datasets in a Geographical Information System (GIS) so that they can be utilized to characterize, classify and predict the distribution of geological features and associated biological entities. The Oregon-Washington GIS integrates the datasets described below into this database, designed for ease of use and interpretation. The interpretations are designed for use by both a lay audience and a scientific audience with no geologic background. The underlying data are maintained at full resolution (not included on this CD) so they may be used for quantitative studies of fisheries habitats of interest.

Sediment and Rock types

Coastal rivers supply sediments that are deposited on the continental shelf and slope off Oregon and Washington. These sediments record complex processes of dispersal, deposition, and subsequent seasonal re-suspension by surface waves on the shelf with eventual re-deposition on the slope (Harlett and Kulm, 1972; Kulm et al., 1975; Nittrouer et al., 1978; Carson et al., 1986). Superimposed upon this regime is the seasonal production of biological material (organic matter, diatoms, foraminifera, radiolarians) from the upwelling centers and their subsequent transport and deposition with the terrigenous materials at localities seaward of the upwelling centers. A large historical database of bottom sediment samples has been converted to an Arc/Info coverage to map their distribution on the Oregon and Washington shelf and margin. Individual samples have been attributed with lithologic data, biological components, organic carbon, texture, and mineralogy data. These data are from a combination of surface sampling, including surface grabs and box cores, dredge hauls, piston and gravity cores, and dart cores from a database of oil industry data donated to OSU, and submersible samples. Approximately 3500 sediment samples are included in the Oregon and Washington Interim maps.

Bathymetry/Topography

Bathymetry of the continental margin and abyssal plain off, Oregon and Washington is available in a variety of forms. Bathymetric data of the continental slope, between water depths of 600 and 3000 m, were collected during the Deep Water SeaBeam surveys of the EEZ Bathymetric Mapping Program (1984 - 1992) conducted by NOAA (National Oceanic and Atmospheric Administration) and NOS (National Ocean Service), (Lockwood and Hill, 1989). Hydrosweep and SeaBeam swath bathymetry of areas of the Washington margin was collected in 1993-1999 during NSF funded geologic investigations at OSU. Some areas of the outer continental shelf and upper slope (150-600m water depths) were surveyed with a shallow water 36 kHz multibeam system (BSSS; S. Mutula, NOAA, pers. comm. 1993). The BSSS data have been made available to the OSU group and have been incorporated in offshore geologic studies. The Monterey Bay Aquarium Research Institute (MBARI) has collected additional high-resolution bathymetry data at Heceta Bank, and Hydrate Ridge on the central Oregon shelf and slope. These data, collected using the Simrad EM-300 system and gridded at 10m resolution, present a remarkable view of the seafloor environment never before available to scientists and managers. Continental shelf bathymetry elsewhere consists of point soundings available in digital form from NGDC. New swath bathymetric data were also collected on the Oregon shelf in 1993-1995 using a deep-towed sidescan system as part of an OSU geologic investigation, funded by NOAA National Undersea Research Program. The data represent partial coverage of all of the submarine banks: Coquille, Siltcoos, Heceta, Stonewall, Daisy, and Nehalem banks.

These data have been combined and resampled to a smooth 100 m grid using a natural-neighbor gridding scheme, which produces excellent results with clumped or otherwise non-uniformly distributed data. The Washington data present several difficulties in that the data are patchier, with significant gaps. The holes are being filled by a hybrid technique of hand contouring available soundings constrained by GLORIA regional sidescan data. The contours honor the data points, and use the sonar data to extract the shapes of the features. Washington bathymetry presents a number of problems stemming from the lack of public domain uniform surveys. The NOAA EEZ surveys that were conducted are now restricted by the Navy, and the remaining data are assembled from academic surveys using a variety of multibeam systems (EEZ-SCAN 84 Scientific Staff, 1988).

Bathymetry data are used to distinguish physiographic provinces that are found in the maps (e.g. shelf, slope, canyon). The data are also used to interpret surficial lithology, mostly to distinguish rock outcrop from other types, where the data are of sufficient resolution to provide such information. Bathymetry data have also been used to predict the occurrence of rock outcrop in a regional sense based on bottom slope. Direct observations from submersibles suggests that there is a minimum slope value at which unconsolidated sediment will give way to outcrops of what lies beneath. The critical slope is determined using definitive areas of sidescan coverage and or submersible observations to determine the minimum value of slope at which underlying strata, be it rock or semi-consolidated material will be exposed (Goldfinger and McNeill, 1997; Goldfinger, 1999). This scheme is used on the continental slope, and does not work on the relatively flat abrasion platforms of the shelf, where slope and outcrop are not correlated in a regional sense due to the interference of the severe subaerial erosion that created the shelf.

Geologic Structure

Geologic maps and structure of both the coastal and nearshore region have been integrated as digital data. Structural geologic maps off shore Oregon and Washington have been completed at OSU as a part of other tectonic studies, and were used to guide interpretations of surficial geology (Goldfinger et al., 1997; McNeill et al, 1997).

Sidescan Sonar Imagery

Existing sidescan sonar imagery have been integrated in the GIS, including high-resolution AMS 150 kHz sidescan sonar imagery (Oregon shelf; Goldfinger et al., 1997); Klein 50 kHz sidescan sonar imagery (Oregon Shelf); GLORIA long-range sidescan collected as part of the EEZ project throughout the Cascadia continental slope (Oregon and Washington; EEZ-SCAN 84 Scientific Staff, 1988); deep-towed SeaMARC-1A 30 kHz sidescan (Oregon and Washington continental slope; Goldfinger et al., 1997); Simrad EM-300 backscatter data (Oregon shelf; MBARI 2001); and several other small studies conducted for either cable routes or habitat. In particular, a 1999 survey at 1m pixel resolution off central Oregon provides an anchoring high-resolution transect across the entire margin that can be used for future habitat analysis (Johnson and Goldfinger, in review). This extensive survey was funded by the National Science Foundation.

Seismic Reflection Data

Seismic reflection profiling produces sub-surface images of rock and sediment layers at and below the seafloor. While these images cannot distinguish between sediment types, they can offer a basic distinction between rock outcrops and sediments, and are used particularly where little other data exist. We have used all existing seismic reflection profiles on the Oregon and Washington margins to enhance our ability to map rock outcrops in this way. We cross check these interpretations with sidescan, core and observational data where available. Approximately 30,000 line km of reflection data have been used in this study. The sources of these data include USGS, Oregon State University, University of Washington, Western Geophysical GECO, Shell Oil Company, Arco Oil Company, Chevron Oil Company, Exxon Corporation, GEOMAR, and Scripps Institution of Oceanography

Miscellaneous
Submersible tracklines are separated and stored according to the year of fieldwork, allowing differentiation between individual study areas and the ability to cross-correlate with data stored outside the GIS database. Each submersible dive has an associated videotape and textual record of measurements and observations made by the observer as well as photographic data, and sediment and rock samples. The trackline vector layers are presently time coded to key sample sites to these external databases. Submersible observations have been integrated in a limited sense to provide ground truth for data layers used in this project.

Methodology

The datasets that have been used to produce the Interim Seafloor Lithology Maps for Oregon And Washington are by their nature patchy, and form an irregular quilt of variable data density and quality. Uniform sampling and imaging of continental margins does not yet exist, thus these maps are an attempt to glean as much information as possible from the framework of existing data. In any given area of the maps, the quantity and quality of data available varied considerably, and required a hybrid method of interpretation based on this availability. For a given area, the precedence of data types was assessed first to determine which dataset gave the most detailed information. An initial interpretation of that area was done based on this primary dataset. Other datasets were interpreted in conjunction with the primary data to modify the initial interpretation. This process was completed iteratively around the loop of available data until misfits between datasets were minimized. Each dataset adds information, and also helps calibrate the other data.

<u>Explanation of Assigned Lithologies and Sediment Types</u>

Lithologic Units in Core Database (primary dataset)

- mud
- clay
- silt
- sand
- gravel
- tuff
- mud/sand (mostly fine grained)
- rock

Lithologic Units in the Seafloor Lithology Maps

Oregon	**Washington**
-Mud*	-Mud
-Sand*	-Sand
-Sand/Mud*	-Clay
-Gravel	-Gravel
-Mixed Sand & Gravel	-Mixed Sand & Gravel
-Rock	-Rock/Sand
-Predicted Rock	-Rock
	-Tuff

*Indicates sediment facies (Kulm et. al., 1975)

The facies shown differ slightly for several reasons. In the case of the "tuff" lithology, this has been reported only in Washington. The predicted rock unit is not shown in Washington, pending permission to release this product at the request of the US Navy. The other differences are due to differences in reporting schemes used by different investigators. Subsequent versions of the Seafloor Lithology Maps for Oregon And Washington will resolve this issue.

Mud
This unit indicates that the seafloor is covered with fine-grained sediment, silts and clays (by definition, < 0.0625 mm diameter). Common on much of the continental slope, although rock may be present less than 1 m below the seafloor (thin sediment drape).

Sand
Indicates the seafloor is covered with coarser-grained sediments (by definition, > 0.0625 mm, and <2mm diameter), largely sand (rare gravel). Most commonly found on the inner continental shelf close to the modern coastline, but also on uplifted submarine banks on the continental shelf where bedrock is exposed.

Mud/Sand
This unit contains mixed mud and sand with predominantly fine-grained sand. Fairly common on the outer shelf and uppermost slope in transition with mud on the mid to lower slope. Also contains glauconite mixed with sand on the outer shelf ("greensand").

Gravel
This unit indicates areas covered with unconsolidated sediments of mean grain size larger than sand (by definition, >2mm diameter). Relatively uncommon in the maps due to sampling and identification techniques.

Mixed Sand & Gravel
Areas of the seafloor that have sample data and some additional supporting data verification (usually sidescan) indicating a mixed seafloor environment (e.g. sand waves. transition zones around weathering rock outcrops).

Tuff
Sediment samples and seafloor areas with high concentrations of volcanic ash.

Rock
This unit indicates rock outcrops, and includes areas of authigenic carbonate deposits. Bedrock outcrop and associated boulder fields would be present in these areas. In some cases, sidescan sonar data may penetrate through a thin sediment drape to image underlying bedrock. This may introduce error to some interpretations of rock outcrop.

Predicted Rock
This unit is predicted from multibeam bathymetric data to show consolidated or semi-consolidated harder substrate. The criteria used here is slopes greater than 10°, which have been found from submersible dives, camera tows, and sidescan sonar data to nearly always contain a high percentage of harder substrates.

Physiographic Units
A simplified list of descriptors of major physiographic and lithologic units is used in the Interim Maps to depict major provinces, and show the relationship of these provinces to the lithologic units described above. These units are called GeoHab units in the attribute tables of the map, and are described in detail the separate file "Lithologic Unit Descriptions" in the directory with this report. These descriptors are modified from Greene at al., 1999. Map polygons are drawn according to their GeoHab and Lithology. Any unique combinations of these two attributes define a polygon (Lithologic and GeoHab unit descriptions follow). Map compositions in this first release version are symbolized by GeoHab only. It is possible to edit map compositions contained on the CD to symbolize polygons according to both attributes.

Uncertainties and Error Bars

Dataset Distribution
Due to the uneven distribution and incomplete coverage of datasets, there are certain errors or uncertainties incorporated into the maps. Greater detail is provided in areas of sidescan sonar data (other than GLORIA) where swaths of 1 - 5 km provide a resolution of ~ 0.5 - 5 m. Some generalization is incorporated here, providing resolution of ~ 20 - 30 m. Where no sidescan sonar data is available, sediment type is derived from bathymetry, bottom samples, and seismic reflection data only. Resolution is reduced in these areas (50 - 100's m) and sediment type is more generalized.

Navigational Precision
The navigation systems used for collection of the geophysical data and samples varied widely, resulting in different levels of position error associates with each dataset. Bottom samples were mostly collected in the 1960's and 70's with LORAN A or LORAN C navigation, introducing errors typically on the order of hundreds of meters (most of this is in the east-west direction). Therefore interpretations from these datasets alone may have reduced resolution. However, when these data are used as ground truth for other

more precisely navigated data, the error only matters if the older data lies close to an interpreted boundary within the newer data. Sidescan sonar data, multibeam bathymetric data, and submersible dives were navigated using either civilian code, differential or P-code (military grade) GPS, with errors of ~50m, and ~10-15 m respectively.

Resolution

Resolution is the ability of a given instrument to distinguish two objects from each other (Johnson and Helferty, 1990). Multiple objects below that resolution appear as one object. The resolution of raster datasets such as multibeam bathymetry that are collected with ship mounted systems is dependant on water depth, as the individual sonar beans are defined by fixed angles in the sonar array, and these beams get larger with increasing water depth. Such datasets are usually gridded at a compromise cell size, chosen to cover the range of depths in a given survey. Thus the resolution at most given locations will be less than the instrument is capable of, and cell size differs from resolution, though the terms are often confused. Sidescan sonar imagery is usually collected by deep-towed platforms towed at a fixed height above the bottom, so their resolution does not vary as much. These data are more often gridded at a cell size that closely reflects the instrument resolution.

Extrapolation and Geological Interpretation

Sidescan sonar data interpretation has been ground-truthed during sample collection and submersible dives, and this information is then extrapolated to non-ground-truthed regions. There is uncertainty in these extrapolations, but geological knowledge of the continental margin and likely distribution of sediment and lithology types was used to reduce this uncertainty as much as possible.

Misinterpretation of sidescan sonar data (reflectance, topography, penetration)

The reflectance in the sidescan sonar image reflects both sediment grain size and rock type as well as topographic relief. On the continental shelf, minimal relief allows much of the reflectance changes to be interpreted changes in sediment type. This correlation between reflectance and sediment type or grain size has been ground-truthed in several locations. However, changes in reflectance are also introduced by changes in gain, and by location relative to the center sonar beam. In addition, differentiation between sand, mud/sand, and mud can be difficult in areas without samples or direct observations.

On the continental slope, topographic relief introduces another source of variation in reflectance. For example, both a facing slope and a region of calcium carbonate may produce high reflectivity in a sidescan image. The topographic factor must be removed by eye using bathymetric data or digitally in order to determine sediment type. The former was used throughout because model driven methods fail to account for gain changes and height changes inherent in sidescan data, and are generally inferior to a geologist’s interpretation.

Sidescan sonar may also penetrate the uppermost cm's to several meters of draped seafloor sediment to image the sub-surface depending on the frequency, radiated power, and pulse length of the sonar. This may lead to misinterpretation of seafloor character if the sediment drape is thin.

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Laboratories with whom we worked in parallel to complete this map series for the U.S. West Coast, and who developed a classification scheme, which is modified and used here. Many others contributed to the Interim Maps, including but not limited to Lisa McNeill (formerly at OSU) Suzanne Lovelady, Beth Myers, Jason Chaytor, Joel Johnson, and Britta Hinrichsen of Oregon State University, Marta Mas and Miquel Marin of the University of Barcelona, Mayte Pedrosa of the University of Granada, and Susane Schmid of the University of Liverpool. We thank the crews and officers of the Research Vessels R/V Revelle, R/V Thompson, R/V Melville, R/V Ronald Brown, F/V Auriga, and R/V New Horizon. We also thank Chevron Oil, Shell Oil, Exxon Corporation, the Washington Department of Natural Resources, the US Army Corps of Engineers, Ken Piper of the Mineral Management Service, and Western Geophysical for providing seismic reflection and or sidescan sonar data.

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Appendix A

Brief descriptions of datasets used in the Interim Seafloor Lithology Maps for Oregon And Washington

Sidescan Sonar

SeaMARC 1A deep-towed sidescan sonar system. 30 kHz. Images a 0.5-5 km swath width with spatial resolution of 0.5-2.5 m. May image 0-3 meters subsurface in soft sediment. Surveys conducted by Oregon State University.

AMS 150 kHz deep-towed sidescan sonar system. 150 kHz. Images swath widths of 0.5 - 1 km with spatial resolution of 0.2 - 0.5 m. May image 0-1 m subsurface in soft sediment. Surveys conducted by Oregon State University.

Klein 50 kHz deep-towed sidescan sonar system. Images swath widths of 0.5 - 1 km with spatial resolution of 0.2 - 0.5 m. May image 0-1 m subsurface in soft sediment. Surveys conducted by Oregon State University.

GLORIA shallow-towed sidescan sonar system. 6 kHz Images a swath width of 45 km, a positional error of < 200 m, and resolution of 50 - 100 m. May image 0-20 m subsurface in soft sediment. Surveys conducted by the US Geological Survey.

Edgetech DF-1000 deep-towed sonar system. 100/500 kHz. Surveys Conducted by the Oregon Department of Fish and Wildlife.

Edgetech DTSMS-3000 deep-towed sonar system. 75 & 410 KHz. Surveys conducted by Oregon State University and the Olympic Coast National Marine Sanctuary.

Multibeam Bathymetry
SeaBeam (now called "classic") 16 and 19 beam sonars. 16 or 19 beams, swath width ~ .75 x water depth. NOAA Exclusive Economic Zone (EEZ) surveys of the 1980's. Navigational error less than 50 m. The data cover all of the Oregon continental slope. Washington EEZ data are classified. Cell size 100 m.

SeaBeam 2000 and 2112. 151 beams. Backscatter data also available. These data were collected on academic cruises by Oregon State University. Navigational error less than 20 m. Cell size 100 m. Swath width ~ 3.4 x water depth.

Simrad EM-120. 191 beams. Backscatter data also available. These data were collected on academic cruises by Oregon State University. Navigational error less than 20 m. Cell size 100 m. Swath width ~ 3.4 x water depth.

Simrad EM-300. 135 beams. Backscatter data also available. These data were collected on joint cruises by Monterey Bay Aquarium Research Institute (MBARI) and NOAA . Navigational error less than 20 m. Cell size 10 m. Swath width ~ 3.4 x water depth.

AMS-150 Isophase bathymetry collected with AMS-150 deep-towed sidescan vehicle. Number of "beams" variable. Navigational error less than 50 m.

SeaBeam 10/50 (AKA Elac Bottomchart II). 50 kHz. 126 beams. Swath width ~ 3.4 x water depth. Data collected by Oregon State University and NOAA. Swath width ~ 3.4 x water depth.

Seismic Reflection Profiles
Oregon State University sparker profiles. Collected 1965-1970. 2 kJ "sparker" analog system.
Oregon State University/Digicon Multichannel survey. 1989. 144 channel multichannel survey.
Oregon State University 3.5 kHz profiles. 1985-2002
Oregon State University 4.5 kHz deep-towed sub-bottom profiles. 1992-1999.
USGS multichannel profiles. Various years and systems.
USGS single channel profiles. Various years and systems.
USGS/Geomar multichannel profiles.
Scripps/Silver single channel profiles. 1971.
Shell Oil Company. Analog single channel profiles. 1961-1963
Chevron Oil Company digital multichannel profiles. Mid 1980's.
Chevron Oil Company analog dynamite profiles. 1960's.
Exxon digital multichannel profiles. 1980's.
Western Geophysical digital multichannel profiles. 1980's
University of Washington. Analog single channel profiles. 1970's.

Bottom Samples
Oregon State University Core Repository samples and logs. Mostly Oregon State University and University of Washington samples. 1960 present.
Oregon State University Theses, 1960-present.
University of Washington Theses, 1960-present.
Shell Oil Company dart core samples, 1960-1962.
U.S. Geological Survey databases, 1960-present.
Geological Survey of Canada.

Appendix 3

Final Report

Essential Fish Habitat Characterization and Mapping of the California Continental Margin

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For:
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Job No. 574.02
(CFDA #11-454)

Under Supervision of:
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Seattle, WA

February 15, 2003

Introduction

This report briefly describes the procedures and methods that were used to characterize and map Essential Fish Habitats (EFH) for offshore California. The habitats characterized are an expanded version of those defined in the Magnuson-Stevens Act (16 USC 1801 *et seq.* 1996) because the original definition essentially encompassed two-thirds of the planet (Bax and Williams, 2001). As stated by these and other authors, vague or variable habitat definitions make if difficult to determine environmental effects of fishing and make management decisions problematic without further qualification. Our intent was to better define deep-water marine benthic habitats so that constructive management decisions can be made.

The National Marine Fisheries Service (NMFS) of NOAA approached the Center for Habitat Studies (CHS) of Moss Landing Marine Laboratories (MLML) in June 2001 to request assistance to characterize and map EFH in order to address legal concerns. A time frame of approximately 2 months (from June 20 to August 30, 2002) was initially established for the work, although the extent of the project was difficult to calculate at that time. It was agreed that this work would be coordinated with similar work being conducted for the Oregon and Washington offshore area so that a standardized habitat map would be produced for the west coast of the contiguous United States.

Statement of Work

The statement of work agreed upon for this project is as follows:

The Center for Habitat Studies (CHS) of Moss Landing Marine Laboratories (MLML) will synthesize all available analog and digital data to construct a marine benthic habitat map of the California Continental margin (to the 200 mile EEZ limit where data allows) that can be used to determine the areas and locations of interpreted seafloor habitat types. Seven 1:250,000-scale offshore geologic and marine benthic habitat maps that span the length of California, smaller scale industry and government data, bathymetric and side-scan sonar mosaics, and recently acquired multibeam bathymetric and backscatter images will be utilized to meet the above criteria and incorporated into an overall GIS. Habitat types will be interpreted by H. Gary Greene and attributed using a version of the deep-water marine benthic habitat scheme of Greene et al. (1999) that was modified to facilitate use in GIS programs. Area analyses of all delineated habitat types will be conducted and digital products will be produced as polygon shapefiles in ArcView® 3.2 or ArcGIS®. The project goals are to develop habitat maps in a GIS that can be queried to relate seafloor substrate type (hard, soft, mixed), approximate slope (or slope analyses where data allows), major geomorphic features such as submarine canyons, seamounts or prominent banks, and depth (bathymetry) for specific coordinates (represented in Latitude and Longitude or in UTM, as specified) or regions. The final products of this project are intended to provide biologists and resource managers with a starting point for habitat studies of commercially landed fishes and invertebrates and as a basis to determine future mapping efforts.

Procedures and Methods

Source materials for habitat interpretations in the region of interest (from the Oregon border to the Mexican border) consisted of digital multibeam, artificial sunshaded bathymetry and backscatter data, side-scan sonar, and hard copy geologic maps. This region was initially mapped for the California Department of Fish and Game (CDFG) under Contract #FG8293MR – "California nearshore marine habitats: Mapping and characterization" (2001). The habitat interpretation resulting from the CDFG project was used as the basemap for this work and was updated through the incorporation of new data sources. Habitat interpretations based on these sources were facilitated primarily through funding from the National Sea Grant Program (Grant #R/F-181A, 2002) and from supplemental funding provided by the Pacific States Marine Fisheries Commission.

Using digital imagery or hard copy maps as source materials, layouts were created in ArcView® and exported as georeferenced .tif files using the extension ArcPress. For digital data, this process was repeated at different scales until a final scale, most appropriate to the data quality, was chosen for habitat interpretations. Hard copy maps were scanned, resized to 36" x 42", and printed for interpretation. If multibeam imagery was used, backscatter data were printed at the same scale. Mylar sheets were affixed over the final printed layouts and coordinate tic marks were copied onto the Mylar sheets for later georeferencing. For this project, all files were projected in either Universal Transverse Mercator (UTM) Zone 10 (north of Point Conception) or Zone 11 (south of Point Conception) with a World Geodetic System (WGS) 84 datum and spheroid.

A coding system was established to standardize attributes used during habitat interpretations and to facilitate ease of use and queries in GIS and other database programs (Table I). This code was modified from the deep-water habitat characterization scheme developed by Greene et al. (1999) and based on interpretations of seafloor geology, morphology, and biology. A copy of the most recent habitat attribute code and a corresponding explanation are included as Appendices I and II and can also be found on the MLML Center for Habitat Studies web site: www.mlml.calstate.edu/groups/geooce/habcent.htm

Seafloor imagery was interpreted and habitat types were outlined (mapped), based on knowledge of the geology and seafloor processes in a particular study area, as the first steps in map production. Interpretations were made on a light table by drawing polygons on a Mylar overlay of the source image around distinct habitat features based on geological processes, structure and morphology. Geologic and sediment maps were modified and reclassified into habitat types. Multibeam and backscatter data provided a general picture of the location of bedrock and unconsolidated sediment. Resolution of the interpretations varied with the quality and scale of the images. However, on most images, we could easily identify such seafloor features as bedrock types (e.g., sedimentary rocks, crystalline rocks, and carbonate mounds), structures (e.g., faults, folds, and landslides), and bedforms of unconsolidated sediment such as sand waves.

Once interpretations were finalized, Mylar overlays were scanned using the WideImage® program, with the scan preset on Mylar, georeferenced to 0.5m (when possible), and processed in GIS programs (TNT Mips® and ArcView®). Scanned Mylars were then printed and used to attribute habitats. Individual polygons were color-coded on printed Mylar copies. This served to check the habitat interpretations and to assist in final editing. Processed files (rasters) were edited in the Spatial Data Editor within TNT Mips®. Unwanted features such as speckles, attribute numbers and text from within the interpreted polygons, and tick marks were erased during this process. Dashed lines were connected and missing lines were re-drawn using a drawing tool. The final raster file was then converted to a vector file using the Auto Trace method in TNT Mips®. Several tests were run before the final conversion in order to check the results of the line editing and tracing.

After raster to vector conversion, the vector file was edited to either delete or add nodes and lines and to correct the shape of polygons. During vector editing the original georeferenced .tif files were used for reference. These files were imported into TNT Mips® and then projected as layers beneath the vector file in the Spatial Data Editor. The edited vector was then warped to create an implied georeference with the output projection set, as appropriate. If necessary, smoothing of the warped vector file was performed with the Vector Filtering tool. If the lines were too angular, the smoothing process was used to better round the curves. Several tests were run before the final smoothing to ensure that no features were omitted during processing.

If more than one interpreted Mylar sheet existed for an area, the warped (and filtered) vector files were merged. Final cleaning was done with the Spatial Data Editor. The original georeferenced .tifs were once again projected as layers beneath the vector file and used as references. Special attention was paid to the overlapping areas to make sure that all of the lines met and all polygons closed. Once final cleaning changes were made, the file was exported as a shapefile (.shp). Shapefiles were opened in ArcView® where a legend (explanation) file was added and any additional attribute fields were included in the attribute table. The file was checked for proper georeferencing and for overlapping polygons, and area analysis was performed on each habitat type using the feature geometry calculator extension in ArcView®.

Due to the breadth of this project, the offshore region of California was subdivided into three regions (Northern, Central, and Southern California) for data compilation and interpretation. From one to three CHC graduate students and staff members worked to locate and assimilate all available data from each region into a GIS. All data for each region were then synthesized and plotted for interpretation as described above. Transitions between regions were edited to insure continuity and three final habitat maps were submitted to TerraLogic GIS, Inc. as final products. After troubleshooting, these maps were then merged to form one contiguous habitat map of offshore California.

The senior author of this report, who performed the original interpretations, was available during all stages and consulted when questions arose. In this way, we were able to provide consistency within and among the various areas and regions. As additional data becomes available, this habitat interpretation of the region of interest can be further refined and updated in the same manner outlined above.

Data Sources and Quality

Extensive public and private holdings of offshore geologic and deep-water marine benthic habitat data sets were compiled and incorporated into this work. These data sets can be subdivided into two main types: 1) those that were incorporated into a general basemap for this work and were therefore created from data sources that extended throughout the California offshore region, 2) those that were derived from smaller areas and based on imagery collected and interpreted at higher resolution. These higher resolution habitat maps were integrated into the lower resolution basemap to improve and update it, where possible.

Footprint maps depicting data type and quality for all interpreted geophysical datasets are included as Appendix III.

Basemap

The California Marine Benthic Habitat Map Series (CMBHMS) was used as the basemap for the Southern and Central regions (Kvitek et al., 2001). These interpretive maps were based on the seafloor geology depicted in the California Continental Margin Geologic Map Series (CCMGMS, 1:250,000) jointly published by the California Department of Mines and Geology (CDMG) and USGS (Greene and Kennedy, 1986, 1987a,b, 1989a,b, 1990). The CMBHMS consists of probabilistic maps in the sense that they delineate areas where various geologic or substrate types likely crop out on the seafloor. Although seven adjacent regions encompassing all of offshore California were mapped in this series, contiguous geologic maps were created only for Areas 1-5, corresponding to the region from the Mexican border to Tomales Bay. Therefore, the basemap available for the Northern region, created solely from the limited geologic map of Area 7, was far less detailed and devoid of data in most regions. Each habitat type depicted in the CMBHMS was modified to one of the 46 available habitat types developed for this project (Table I). Habitat attributes were determined from seafloor geology, bathymetry, and previously interpreted habitat. These attributes characterize habitat types that range from soft, unconsolidated mud to hard granite basement rock exposures.

Construction of the CCMGMS was based primarily on seismic-reflection profile and seafloor sediment and rock sample data. These data provided a general picture of where bedrock and unconsolidated sediment are located with lithologic contacts being interpretive. Although more advanced imaging techniques are now available, no other extensive data sets exist in the offshore California margin to provide a regional outline of the various lithologic units that may crop out on the seafloor. Most all lithologic units depicted in the CCMGMS, with the exception of Quaternary sedimentary units, are either exposed on the seafloor or lie no more than three meters beneath the seafloor. This detail was taken into consideration during the interpretive process that led to the construction of both the CMBHMS and the EFH products. However, it should be noted that not all of the more than 70 habitat types defined in the CMBHMS easily converted to the more restrictive code established for this project.

After the CMBHMS was converted to EFH attributes, it was separated into Southern, Central, and Northern regions as previously described and augmented in each region with newly interpreted, higher resolution data sources. The project "Fisheries habitat characterization of the California Continental Margin: Identification, quantification, and synthesis of existing information.", developed for the National Sea Grant College System was being completed within the duration of this project (Greene et al. 2002). Maps developed for Sea Grant were modified to fit EFH attributes in the manner described above and integrated into the CMBHMS basemap for each region. Many additional data sources were also located and interpreted specifically for this project. In addition, two digital bathymetry files of offshore California were used during interpretations and were helpful in distinguishing physiographic provinces and large-scale seafloor features. Bathymetry was also contoured and used whenever possible from region-specific multiebeam grids. A list of these and all geophysical data sources interpreted for this project is included (Table II).

How to Use these Maps

The habitat maps produced under this contract reflect the most probable locations for the various habitat types depicted. However, in many cases basement and bedrock outcrops are probably locally or extensively covered with thin (<1m) Quaternary sediment and soft sedimentary habitats may contain some rocky outcrops. This is largely a result of the scale of the map interpretations and the sampling methods. In general, the accuracy and detail of the map interpretations is directly related to the resolution of the source data.

These maps are excellent formulative tools and can be used to effectively plan for scientific investigations that require knowledge about potential seafloor conditions. They are useful for determining bottom relief, physiography, geomorphology and other parameters important for classifying EFH or as a basis for habitat affinity studies that can lead to effective conservation and management.

Results

Like all interpretive seafloor maps, this map series is in flux and will need to be periodically updated once significant new data are available. For example, new geologic and bathymetric data recently published for the Monterey Bay, Santa Barbara Channel and Southern California Borderland regions are not included in this series and should be incorporated in the near future. Extensive seafloor observations, video data, and rock samples have also recently been collected in southern California by Mary Yoklavich and others during six-weeks of manned submersible dives. Some of these data are being used to groundtruth and update interpretations a small portion of that region part of a separate project. We are also aware of several other new data sets that are becoming available and are poised to utilize these data to update and modify the EFH maps once the need is recognized and supported.

Due to the extensive distillation of complex previously interpreted habitat types to the more limited EFH habitat types, confusing, and sometimes misleading, habitat characteristics have been designated in some instances. This is often the case where habitats were previously determined to be a mixture of both hard and soft substrate. Under the EFH attribute code, no mixed category was available. This has no doubt resulted in the misdesignation of some habitats as soft when they may be either mixed or primarily hard (and vice-versa).

From simple map observations one can determine the resolution and sophistication of the data sets used in the compilation along with the confidence of the interpretations. Boundaries that delineate habitat types (polygons) can be used as the determining feature. For example, boundaries that are comprised of general sweeping curves at large scales represent poorly defined and mapped habitat. Conversely, boundaries that are more crenellated and complex represent smaller scale, higher resolution data sets and a greater degree of confidence in the interpretations. For more specific data inquiries, a table containing mapping scales, data types, and data sources are included (Table II).

Conclusions

The California Marine Benthic Habitat Map Series and the EFH maps represent the most comprehensive habitat maps of the seafloor found anywhere in the world. Although these maps are probabilistic, they represent the most advanced knowledge available with regard to the interpretation of seafloor habitat types in the offshore region of California. However, they can be considerably improved over time and with the addition of technologically advanced data sets such as digital multibeam bathymetric and backscatter images, the accuracy and resolution can be enhanced. It must be considered that the final EFH map of California was constructed over a very short time frame (less than 4 months) from a multitude of disparate bathymetric and geophysical data sets that individually required intensive interpretation. This process allowed for the production of only preliminary EFH maps, maps that are in need of groundtruthing and critical editing. Nevertheless, these maps will provide indications of: 1) where various habitat types are located, 2) what the mapping accuracy is, and 3) where data voids are located and future mapping efforts should be concentrated.

Literature Cited:

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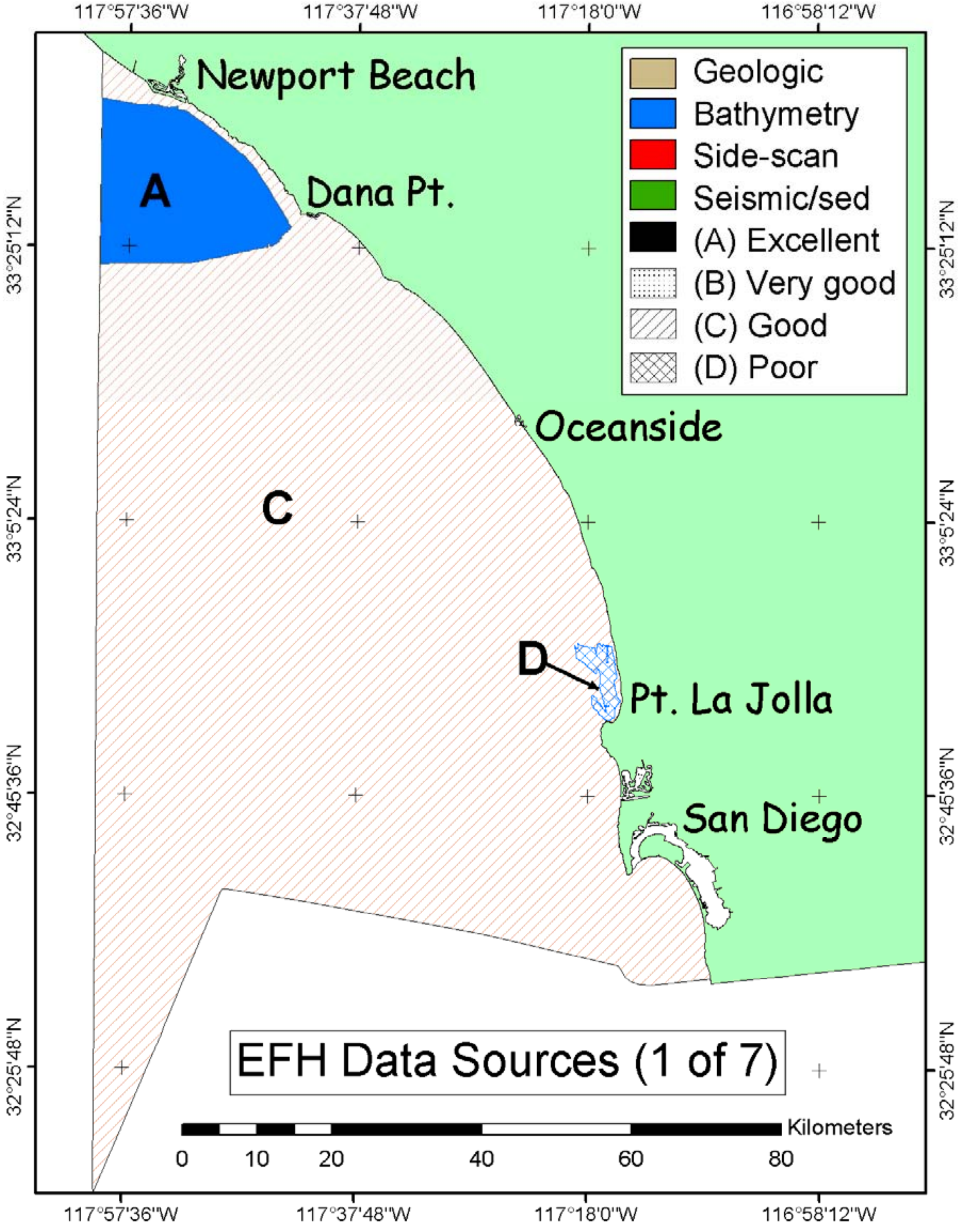
Kvitek, R., Greene, H.G., Iampietro, P., Bretz, C., Sandoval, E., and Bizzarro, J.J. 2001. "California nearshore marine habitats: Mapping and characterization." California Department of Fish and Game Contract #FG8293MR. Vol. 1-7.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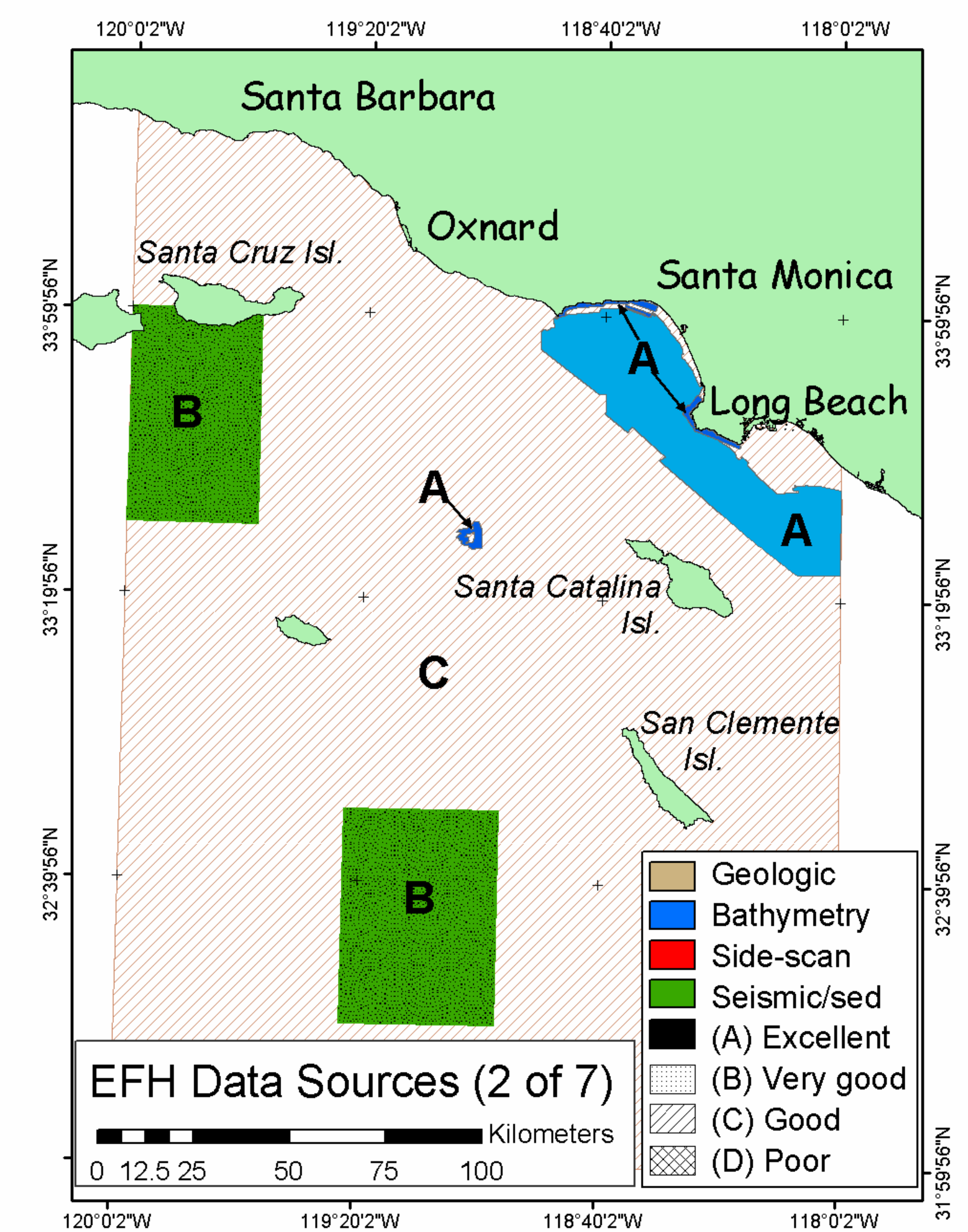
117°18'0"W
116°58'12"W
33°25'12"N
33°5'24"N
32°45'36"N
32°25'48"N
Newport Beach
Dana Pt.
Oceanside
Pt. La Jolla
San Diego
A
C
D
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
EFH Data Sources (1 of 7)
Kilometers
0
10
20
40
60
80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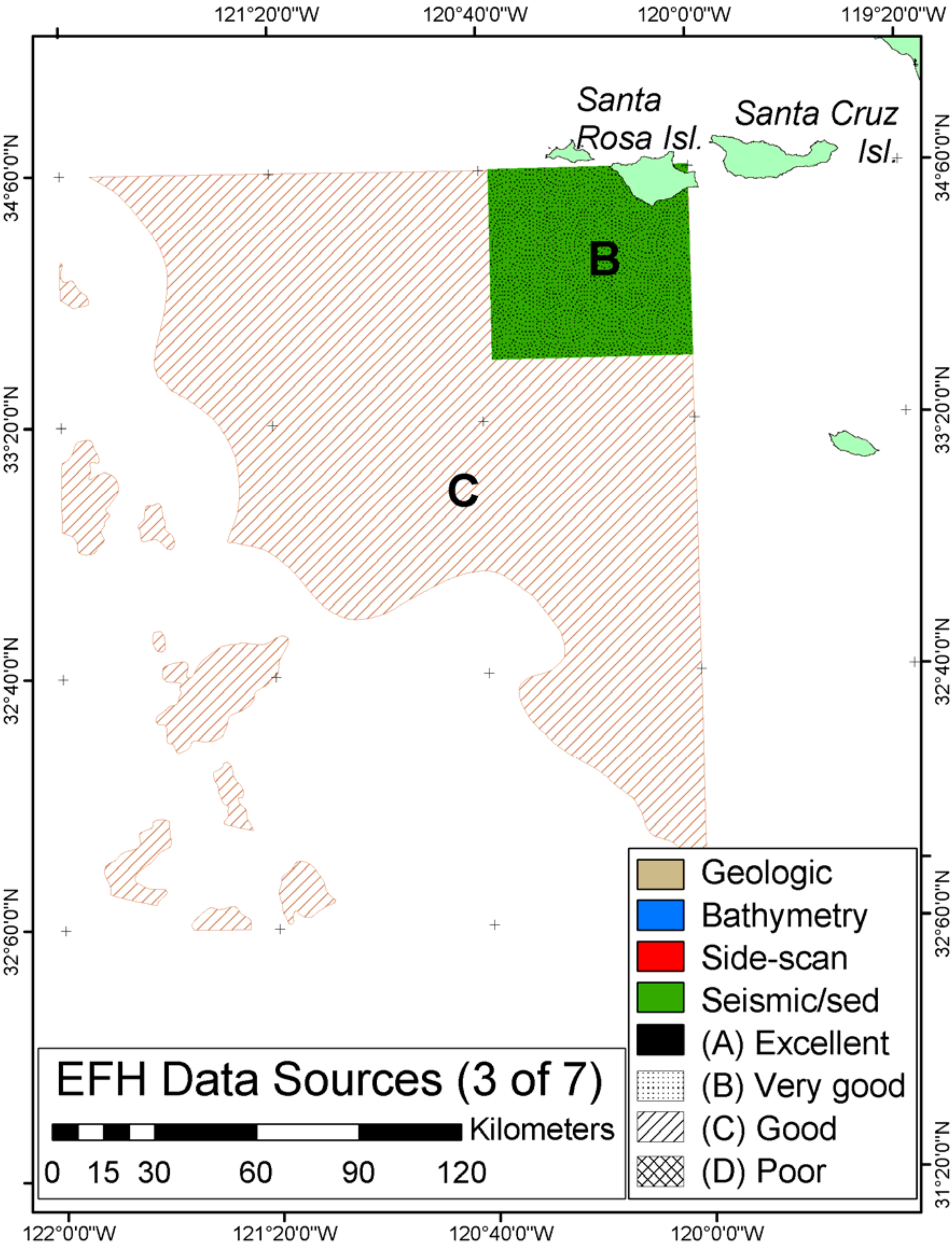
119°20'2"W
118°40'2"W
118°0'2"W
33°59'56"N
33°19'56"N
32°39'56"N
31°59'56"N
Santa Barbara
Oxnard
Santa Monica
Long Beach
Santa Cruz Isl.
Santa Catalina Isl.
San Clemente Isl.
A
A
A
A
B
B
C
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
EFH Data Sources (2 of 7)
Kilometers
0 12.5 25 50 75 100


121°20'0"W
120°40'0"W
120°0'0"W
119°20'0"W
Santa Rosa Isl.
Santa Cruz Isl.
34°60'0"N
33°20'0"N
32°40'0"N
32°60'0"N
31°20'0"N
B
C
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
EFH Data Sources (3 of 7)
Kilometers
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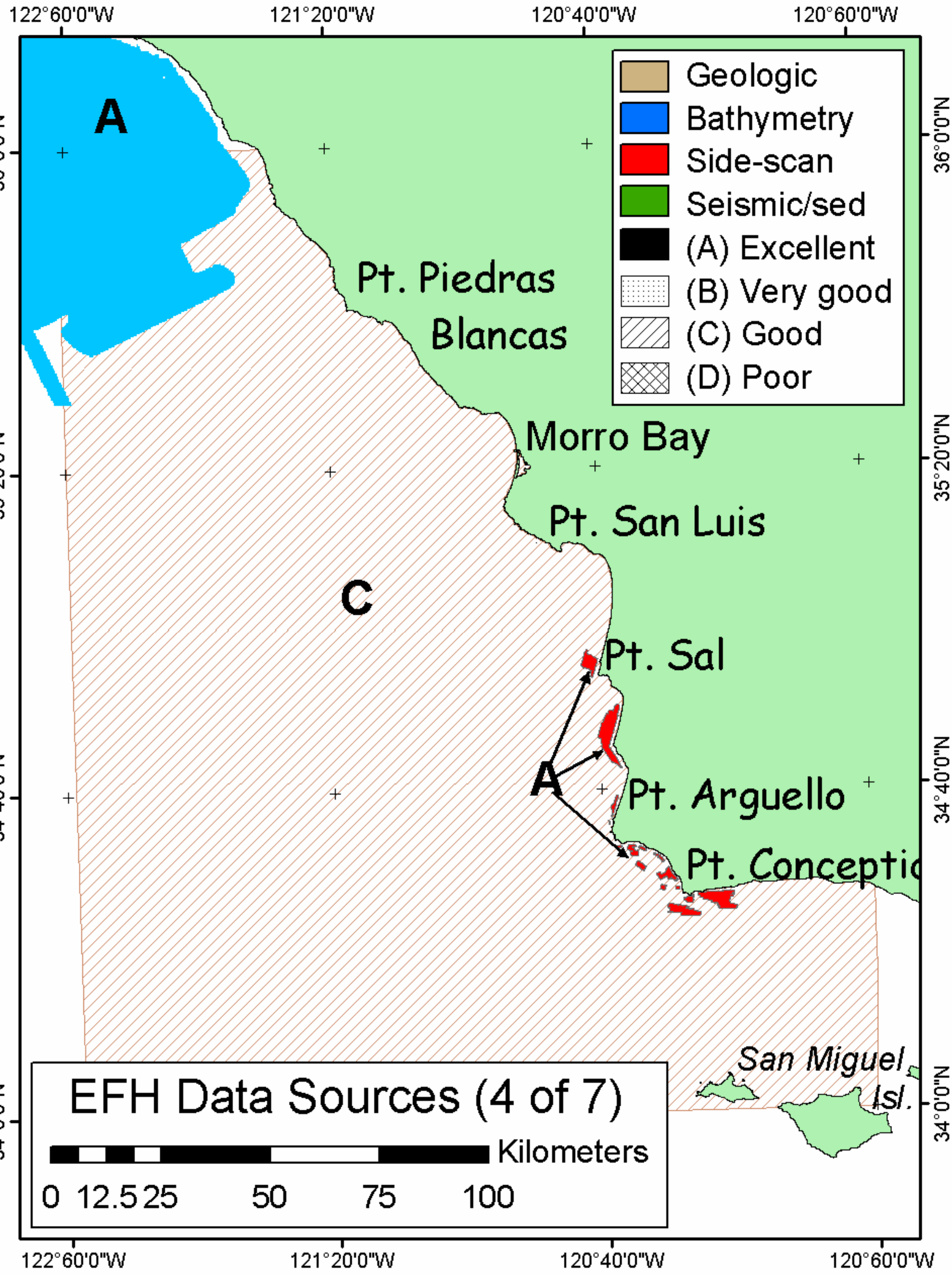
122°0'0"W
121°20'0"W
120°40'0"W
120°0'0"W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120°40'0"W
120°60'0"W
36°0'0"N
35°20'0"N
34°40'0"N
34°0'0"N
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
A
C
Pt. Piedras
Blancas
Morro Bay
Pt. San Luis
Pt. Sal
Pt. Arguello
Pt. Conceptio
San Miguel
Isl.
EFH Data Sources (4 of 7)
Kilometers
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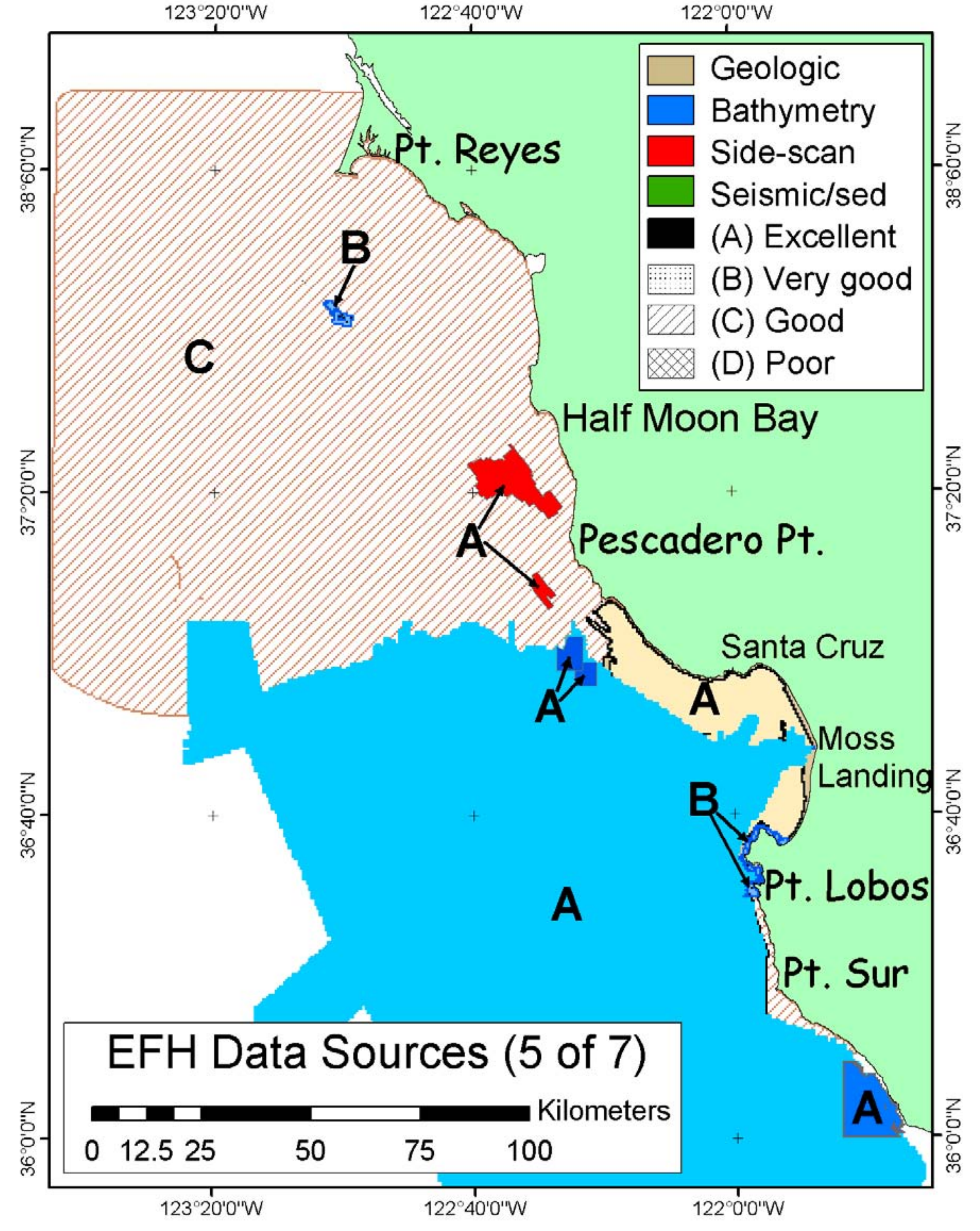
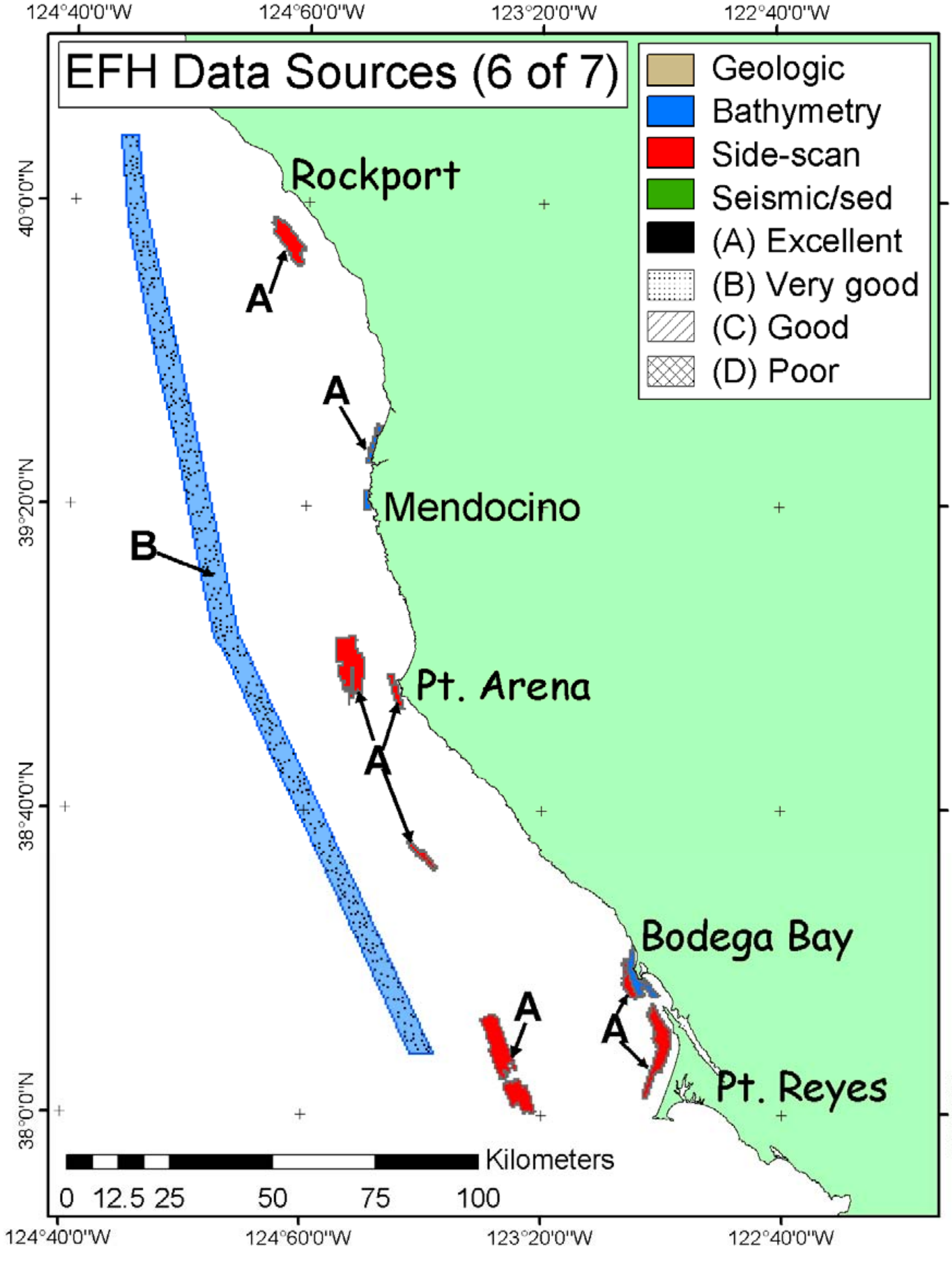


123°20'0"W
122°40'0"W
122°0'0"W
38°60'0"N
37°20'0"N
36°40'0"N
36°0'0"N
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
Pt. Reyes
B
C
Half Moon Bay
A
Pescadero Pt.
Santa Cruz
A
A
Moss
Landing
B
Pt. Lobos
A
Pt. Sur
EFH Data Sources (5 of 7)
Kilometers
0 12.5 25 50 75 100
A


EFH Data Sources (6 of 7)
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
Rockport
Mendocino
Pt. Arena
Bodega Bay
Pt. Reyes
A
B
Kilometers
0 12.5 25 50 75 100
124°40'0"W
124°60'0"W
123°20'0"W
122°40'0"W
40°0'0"N
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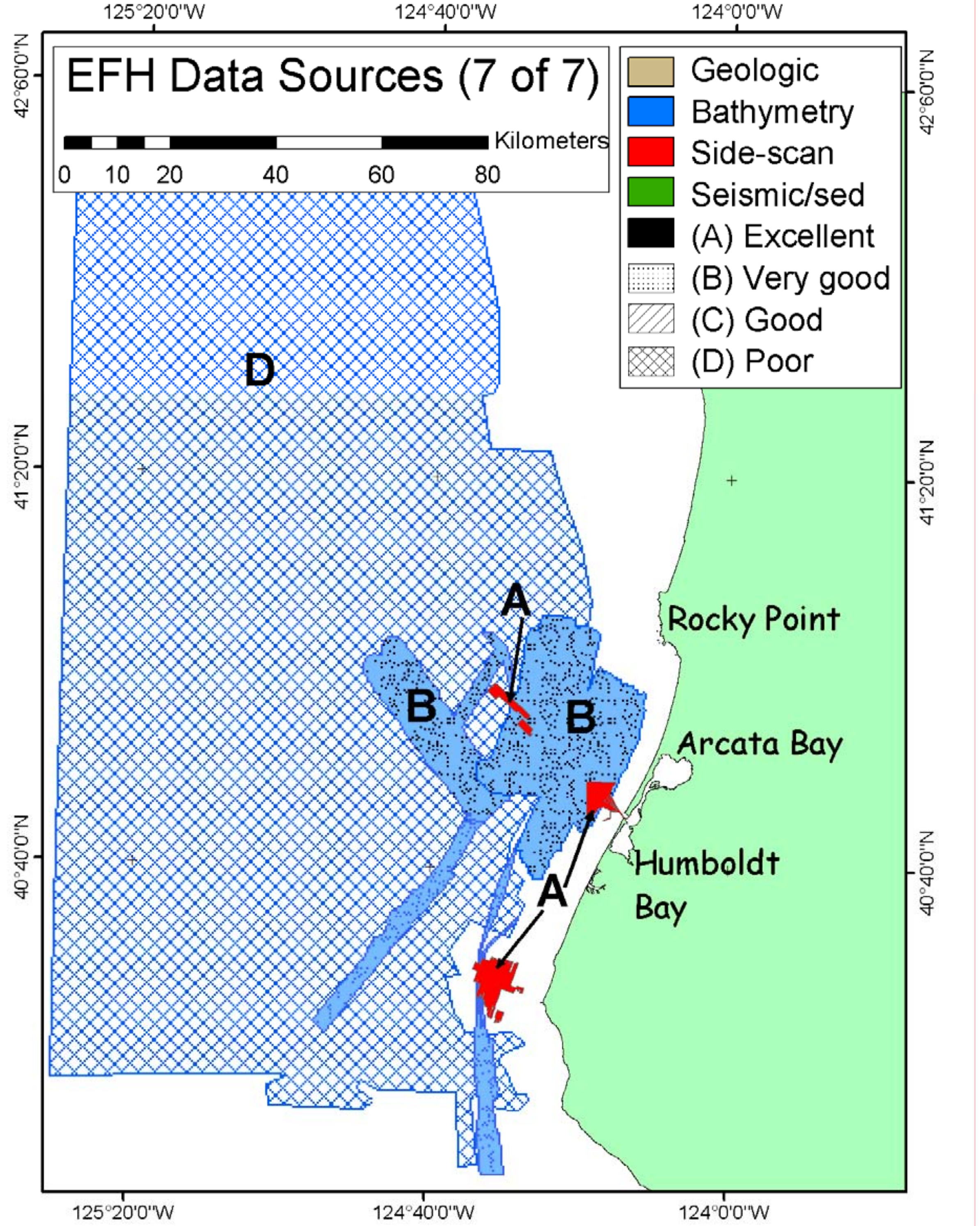
38°0'0"N


EFH Data Sources (7 of 7)
Kilometers
0 10 20 40 60 80
Geologic
Bathymetry
Side-scan
Seismic/sed
(A) Excellent
(B) Very good
(C) Good
(D) Poor
125°20'0"W
124°40'0"W
124°0'0"W
42°60'0"N
41°20'0"N
40°40'0"N
D
A
B
B
A
Rocky Point
Arcata Bay
Humboldt Bay

ANNEX 1 to APPENDIX 3

Deep-Water Marine Benthic Habitat Classification Scheme

Key to Habitat Classification Code for Mapping and use with GIS programs

(modified after Greene et al., 1999)

Interpreted from remote sensing imagery for mapping purposes

Megahabitat – Use capital letters (based on depth and general physiographic boundaries; depth
ranges approximate and specific to study area).

A = Aprons, continental rise, deep fans and bajadas (3000-5000 m)
B = Basin floors, Borderland types (floors at 1000-2500 m)
F = Flanks, continental slope, basin/island-atoll flanks (200-3000 m)
I = Inland seas, fiords (0-200 m)
P = Plains, abyssal (>5000 m)
R = Ridges, banks and seamounts (crests at 200-2500 m)
S = Shelf, continental and island shelves (0-200 m)

Seafloor Induration - Use lower-case letters (based on substrate hardness).

h = hard substrate, rock outcrop, relic beach rock or sediment pavement
m = mixed (hard & soft substrate)
s = soft substrate, sediment covered

Sediment types (for above indurations) - Use parentheses.
(b) = boulder
(c) = cobble
(g) = gravel
(h) = halimeda sediment, carbonate
(m) = mud, silt, clay
(p) = pebble
(s) = sand

Meso/Macrohabitat - Use lower-case letters (based on scale).

a = atoll
b = beach, relic
c = canyon
d = deformed, tilted and folded bedrock
e = exposure, bedrock
f = flats, floors
g = gully, channel
i = ice-formed feature or deposit, moraine, drop-stone depression
k = karst, solution pit, sink
l = landslide
m = mound, depression
n = enclosed waters, lagoon
o = overbank deposit (levee)

p = pinnacle (Note: Pinnacles are often difficult to distinguish from boulders. Therefore, these features may be used in conjunction [as (b)/p] to designate a meso/macrohabitat.

r = rill
s = scarp, cliff, fault or slump
t = terrace
w = sediment waves
y = delta, fan
$z_{\#}$ = zooxanthellae hosting structure, carbonate reef
1 = barrier reef
2 = fringing reef
3 = head, bommie
4 = patch reef

Modifier - Use lower-case subscript letters or underscore for GIS programs (textural and lithologic relationship).
$_a$ = anthropogenic (artificial reef/breakwall/shipwreck)
$_b$ = bimodal (conglomeratic, mixed [includes gravel, cobbles and pebbles])
$_c$ = consolidated sediment (includes claystone, mudstone, siltstone, sandstone, breccia, or conglomerate)
$_d$ = differentially eroded
$_f$ = fracture, joints-faulted
$_g$ = granite
$_h$ = hummocky, irregular relief
$_i$ = interface, lithologic contact
$_k$ = kelp
$_l$ = limestone or carbonate
$_m$ = massive sedimentary bedrock
$_o$ = outwash
$_p$ = pavement
$_r$ = ripples
$_s$ = scour (current or ice, direction noted)
$_u$ = unconsolidated sediment
$_v$ = volcanic rock

Seafloor Slope - Use category numbers. Typically calculated for survey area from x-y-z multibeam data.

1	Flat (0-1º)
2	Sloping (1-30º)
3	Steeply Sloping (30-60º)
4	Vertical (60-90º)
5	Overhang (> 90º)

Seafloor Complexity - Use category letters (in caps). Typically alculated for survey area from
x-y-z multibeam slope data using neighborhood statistics and reported in standard deviation units.

A	Very Low Complexity (-1 to 0)
B	Low Complexity (0 to 1)
C	Moderate Complexity (1 to 2)
D	High Complexity (2 to 3)
E	Very High Complexity (3+)

Geologic Unit – When possible, the associated geologic unit is identified for each habitat type and follows the habitat designation in parentheses.

Examples: Shp_d1D(Q/R) - Continental shelf megahabitat; flat, highly complex hard seafloor

with pinnacles differentially eroded. Geologic unit = Quartenary/Recent.

Fhd_d2C (Tmm) - Continental slope megahabitat; sloping hard seafloor of deformed (tilted, faulted, folded), differentially eroded bedrock exposure forming

overhangs and caves. Geologic unit = Tertiary Miocene Monterey Formation.

<u>Determined from video, still photos, or direct observation.</u>

Macro/Microhabitat – Preceeded by an asterik. Use parentheses for geologic attributes, brackets for biologic attributes. Based on observed small-scale seafloor features.

<u>Geologic attributes (note percent grain sizes when possible)</u>
(b) = boulder
(c) = cobble
(d) = deformed, faulted, or folded
(e) = exposure, bedrock (sedimentary, igneous, or metamorphic)
(f) = fans
(g) = gravel
(h) = halimeda sediment, carbonate slates or mounds
(i) = interface
(j) = joints, cracks, and crevices
(m) = mud, silt, or clay
(p) = pebble
(q) = coquina (shell hash)
(r) = rubble
(s) = sand
(t) = terrace-like seafloor including sedimentary pavements
(w) = wall, scarp, or cliff

<u>Biologic attributes</u>
[a] = algae
[b] = bryozoans
[c] = corals
[d] = detritus, drift algae
[g] = gorgonians
[n] = anemones
[o] = other sessile organisms
[s] = sponges
[t] = tracks, trails, or trace fossils
[u] = unusual organisms, or chemosynthetic communities
[w] = worm tubes

Seafloor Slope - Use category numbers. Estimated from video, still photos, or direct observation.

1 Flat (0-1º)
2 Sloping (1-30º)
3 Steeply Sloping (30-60º)
4 Vertical (60 - 90°)
5 Overhang (90°+)

Seafloor Complexity - Use category numbers. Estimated from video, still photos, or direct observation. Numbers represent seafloor rugosity values calculated as the ratio of surface area to linear area along a measured transect or patch.

A Very Low Complexity (1 to 1.25)
B Low Complexity (1.25 to 1.50)
C Moderate Complexity (1.50 to 1.75)
D High Complexity (1.75 to 2.00)
E Very High Complexity (2+)

Examples: *(m)[w]1C - Flat or nearly flat mud (100%) bottom with worm tubes; moderate complexity.

*(s/c)1A - Sand bottom (>50%) with cobbles. Flat or nearly flat with very low complexity.

*(h)[c]1E - Coral reef on flat bottom with halimeda sediment. Very high complexity.

Shp_d1D(Q/R)*(m)[w]1C - *Large-scale habitat type:* Continental shelf megahabitat; flat, highly complex hard seafloor with pinnacles differentially eroded. Geologic unit = Quartenary/Recent. *Small-scale habitat type:* Flat or nearly flat mud (100%) bottom with worm tubes; moderate complexity.

ANNEX II to APPENDIX 3

Deep-Water Marine Benthic Habitat Classification Scheme

Explanation for Habitat Classification Code

(modified after Greene et al., 1999)

Habitat Classification Code

A habitat classification code, based on the deep-water habitat characterization scheme developed by Greene et al. (1999), was created to easily distinguish marine benthic habitats and to facilitate ease of use and queries within GIS (e.g., ArcView®, TNT Mips®, and ArcGIS®) and database (e.g., Microsoft Access® or Excel®) programs. The code is derived from several categories and can be subdivided based on the spatial scale of the data. The following categories apply directly to habitat interpretations determined from remote sensing imagery collected at the scale of 10s of kilometers to 1 meter: Megahabitat, Seafloor Induration, Meso/Macrohabitat, Modifier, Seafloor Slope, Seafloor Complexity, and Geologic Unit. Additional categories of Macro/Microhabitat, Seafloor Slope, and Seafloor Complexity apply to areas at the scale of 10 meters to centimeters and are determined from video, still photos, or direct observations. These two components can be used in conjunction to define a habitat across spatial scales or separately for comparisons between large and small-scale habitat types. Categories are explained in detail below. Not all categories may be required or possible given the study objectives, data availability, or data quality. In these cases the categories used may be selected to best accommodate the needs of the user.

Explanation of Attribute Categories and their Use

Determined from Remote Sensing Imagery (for creation of large-scale habitat maps)

<u>1) Megahabitat</u> **–** This category is based on depth and general physiographic boundaries and is used to distinguish regions and features on a scale of 10s of kilometers to kilometers. Depth ranges listed for category attributes in the key are given as generalized examples. This category is listed first in the code and denoted with a capital letter.

<u>2) Seafloor Induration</u> – Seafloor induration refers to substrate hardness and is depicted by the second letter (a lower-case letter) in the code. Designations of hard, mixed, and soft substrate may be further subdivided into distinct sediment types, which are then listed

immediately afterwards in parentheses either in alphabetical order or in order of relative abundance.

3) Meso/Macrohabitat – This distinction is related to the scale of the habitat and consists of seafloor features ranging from 1 kilometer to 1 meter in size. Meso/Macrohabitats are noted as the third letter (a lower-case letter) in the code. If necessary, several Meso/Macrohabitats can be included either alphabetically or in order of relative abundance and separated by a backslash.

4) Modifier **–** The fourth letter in the code, a modifier, is noted with a lower-case subscript letter or separated by an underline in some GIS programs (e.g., ArcView®). Modifiers describe the texture or lithology of the seafloor. If necessary, several modifiers can be included alphabetically or in order of relative abundance and separated by a backslash.

5) Seafloor Slope – The fifth category, represented by a number following the modifier subscript, denotes slope. Slope is typically calculated for a survey area from x-y-z multibeam data and category values can be modified based on characteristics of the study region.

6) Seafloor Complexity – Complexity is denoted by the sixth letter and listed in caps. Complexity is typically calculated from slope data using neighborhood statistics and reported in standard deviation units. As with slope, category values can be modified based on characteristics of the study region.

7) Geologic Unit – When possible, the geologic unit is determined and listed subsequent to the habitat classification code in parentheses.

Determined from video, still photos, or direct observation (for designation of small-scale habitat types)

8) Macro/Microhabitat –Macro/Microhabitats are noted by the eighth letter in the code (or first letter, if used separately) and preceded by an asterisk. This category is subdivided between geologic (surrounded by parentheses) and biologic (surrounded by brackets) attributes. Dynamic segmentation can be used to plot macroscale habitat patches on Mega/Mesoscale habitat interpretations (Nasby 2000).

9) Seafloor Slope – The ninth category (or second category, if used separately), listed by a number denotes slope. Unlike the previous slope designation (#5), the clarity of this estimate can be made at smaller scales and groundtruthed or compared with category #5. Category values can be modified based on characteristics of the study region.

10) Seafloor Complexity – The designations in this category, unlike those in category #6, are based on seafloor rugosity values calculated as the ratio of surface area to linear area along a measured transect or patch. Category letters are listed in caps and category values can be modified based on characteristics of the study region.

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Appendix 4

Shadow Maps of Data Density & Quality for the Seafloor Habitat and Lithology Maps of Oregon & Washington

April, 2003

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Background:

It is often difficult to examine a map and visually assess the density and quality of the underlying data used to produce the map. Maps produced with Geographic Information System (GIS) often contain metadata or documentation that details the origin, extent, accuracy, scale, resolution, and creation date. Metadata provides a means to assess the utility of the spatial information for a specific purpose. However, this type of information can be difficult to translate in terms of a visual and spatial description of data density and quality. Additionally, it is not in a form that readily applies to spatial models, which require quantitative spatial inputs.

We have created supplemental maps of weighted data density to address the data quality issue for the Seafloor Habitat & Lithology Maps. The map set displays continuous density surfaces, weighted according to the unique qualities of each principle dataset and for the strict purpose of interpreting the physiographic and lithologic character of mapped habitats. The composite weighted density surface or “shadow map” serves as a visual guide among data rich and data poor regions and as a model input. Its raster data format permits the researcher or modeler to make spatial queries and recieve quantitative assessment of quality within each grid cell. We specifically designed these maps for incorporation into the Essential Fish Habitat modeling exercise of the Pacific Fisheries Management Council.

In total there are five individual shadow maps of data density and quality, the first four maps are each unique to a particular data type or survey technique (bathymetric, samples, seismic reflection, and sidescan datatypes). The fifth map is an additive composite of the principle four. We also provide the data distribution maps used to create the weighted density surfaces. In this format, the deliverable product is not a dead-end product. It remains possible to view, reorder, or re-render any map according to the needs of the research question at hand.

Methods:

The quality mapping method evaluates the spatial coverage (or density) of each data type, first independently on a scale of one to ten, then in aggregate (final composite map) on a scale of one to forty. Quality ranks are determined according to the nature and shape of density distributions and to our interpretation as to their utility. That is, each data type is standardized to a qualitative assessment of their value for habitat mapping. This standard ranking procedure allows us to combine disparate data types in the final assessment of their additive "quality".

Bathymetric Density and Quality:
The number of depth soundings per unit area is highly variable over the continental margins of Oregon and Washington. Soundings are typically most abundant over the continental slope. This is especially true off Oregon where naval restrictions on seafloor mapping do not apply, and soundings are densest. The continental shelves remain less well covered and in some areas rely heavily on historic point soundings. Nearshore waters where bathymetric surveys become difficult and expensive are typically areas of lowest bathymetric sounding density.

The mapping scheme used in the Seafloor Habitat & Lithology Maps depicts local physiographic habitats and their associated lithology. An uneven distribution of soundings will undoubtedly have an effect on both our perception of what the actual bathymetric surface looks like and how to map it. This effect is what is of immediate importance when evaluating the quality of the habitat map. Logically, areas of dense soundings are of the highest quality.

The density of available depth or bathymetric soundings is determined within a 100m grid cell area by using an extension within *MB SYSTEM* (Caress, 2003), a swath bathymetric mapping tool. All available data for the survey area is input to the gridding operation. The extents of the survey area were set at -127 W, -123.5 W, 48.5 N, and 42.0 N (the final composite map also shares these same coordinates). Density of soundings per 100m grid cell (10,000m^2) ranged from 0 to 101871.

The density distribution is negatively skewed and long tailed (mean = 51.10 or 0.511 soundings per m^2, sd = 264.02). This highly skewed and long tailed density distribution was reclassified to emphasize the lower portion of the range. We create 5 bins to accent where large increases in habitat map quality are gained by seemingly small increases in data density. This assumption may or may not be valid in other types of seafloor investigations, however, is well suited to our interpretations of local physiography.

Table 1. Bathymetric Weighting Scheme

Density of soundings per 100m grid cell	Quality/Rank
0*	1
1	2
2–5	3
5–60	5
>60	10

Layers Provided:	UTM/WGS1984
(1) Unclassified sounding density grid	orwa_100m_density_num.img
(1) Classified sounding density grid	orwa_den_utmf.grd

Sidescan Survey Density and Quality:

This map describes the distribution and quality of sidescan sonar surveys available and used while making the habitat map. Several extensive high resolution surveys, which cover large areas of the continental shelf and slope of Washington and Oregon, are available from earlier geophysical investigations. The surveys were originally collected to map faults, scarps, and authigenic carbonate rock, but are used here for habitat. Additionally we include interpretations from a nearshore survey (Siletz Reef Area) collected for habitat by the Oregon Department of Fish and Wildlife. Subsequent versions of the habitat map will include sidescan data provided by ODFW (at Perpetua and Orford Reefs) and the Olympic Coast National Marine Sanctuary (for areas of the northern Washington Shelf and Slope).

High-resolution sidescan sonar systems provide detailed information within the swath that allows us to infer the hardness of the seafloor. This type of data becomes more useful when referenced to a nearby core sample or other form of ground truth, suggesting support for the final additive composite map. When mapping habitat, sidescan sonar data is extremely valuable and no quality differentiation among high-resolution survey systems is needed. However, a regional low-frequency survey (Gloria EEZ) exists and is used where other data are unavailable, within its known limitiations.

The Gloria survey system differs from the other systems in that it is acquired using a surface-towed, high-energy, low-frequency technique. An unfavorable characteristic of the GLORIA system when used to map habitat is its penetration of the surface sediment, imaging extensive areas of underlying rock. This characteristic may yield an overestimation of hard substrate at the sediment water interface. GLORIA imagery also has a very large pixel size (50m) limiting its ability to resolve fine detail in the seafloor surface structures and sediments.

To create a continuous raster surface of sidescan density and quality we applied the weighting scheme below (Table 2) to the imagery used during the habitat mapping process. An additive combination of sidescan images was made using Arc Map Raster Calculator. The final raster is reclassified (or scaled) so that areas of overlapping data do not exceed the maximum quality ranking of 10. It is not an intention to suggest that overlapping sidescan imagery has an additive effect on the quality of the habitat map, but simply that areas of high-resolution sidescan correspond to high quality interpretations.

Table 2. Sidescan Sonar Weighting Scheme

Sidescan Sonar Weighting Scheme	**Quality/Rank**
Gloria EEZ Survey	1
High Resolution Deep-Tow Surveys	10
High Resolution Nearshore Surveys	10

Layers Provided:	UTM/WGS1984
(1) Unweighted high resolution sidescan	highres_ss.grd
(1) Unweighted GLORIA EEZ sidescan (geographic)	gloria.grd
(1) Weighted sidescan density grid	ss_density.grd

Substrate Sample Data:

The habitat maps provide a description of lithology within each habitat polygon, accomplished by constructing and using a comprehensive sediment samples database for the survey area. The database consists of over 4000 individual samples collected over the continental shelves and slopes of Washington and Oregon. Densest sampling occurs over the shallow shelves. Seaward of the continental shelfbreak sample density generally becomes localized and sparse with increasing depth.

In 1975 Dr. Laverne Kulm published a map of sediment facies of the Oregon continental shelf in a paper which summarizes over a decade of work by himself and his graduate students (Kulm, 1975). We use this map a starting point for our descriptions of lithology and make appropriate changes where additional data suggest such. We also adopt Fulm's sediment classification scheme (Kulm, 1975) An analog map, based on a similar sampling pattern, does not exist at this time for Washington. However, it remains our objective to interpret the sediments of the Washington margin in a manner consistent with the Oregon lithology descriptions.

There are two principle problems associated with mapping the quality of habitats interpreted while using the sample database. The first being that the sample data was collected over several decades during which time navigational techniques evolved significantly. Also and perhaps more importantly, mapping several decades of samples implies that sediment patterns have remained fixed, however sediment distribution, particularly on the inner shelf is most likely not fixed. The second, that it's difficult to understand or quantify how surficial sediment properties, which were sampled at irregularly spaced points (in both time and space), may vary between the points. Sidescan sonar imagery often reveals complex surfical sediment paterns not described or missed in a contoured point surface. For these reasons we adopt a rule to constrain the quality ranking to a single value of 10 within a 500m radius of the sample point.

An alternative to this method may have been to assign a decreasing level of quality away from the sample position, potentially as concentric rings. This type of assignment is less favorable due to potential positional error associated with each sample. The current method implies a certainty that the actual sample position is contained within the buffered area and a reasonable assumption is that the sample describes that area.

The density tool of the Spatial Analyst Extension in Arc Map is used to create the raster density surface of samples. The analysis layer was the map of all sediment samples. A search radius is specified at 500m and the output grid cell size set at 100m. The final processing step is to reclassify the grid such that all cells within 500m of a sample received a quality ranking of 10

Table 3. Sediment Sample Data Weighting Scheme	Quality/Rank
All Sediment Samples	10
Grids Provided:	UTM/WGS1984
(1) Unweighted sample density grid	samples_den.grd
(1) Weighted sample density grid	samples_final.grd

2-D Seismic Reflection Data:

Seismic reflection profiles are aids to locating rock outcrops as well as areas overlain by soft sediment deposits. They are a two-dimensional acoustical technique developed to image changes in subsurface lithology. The primary limitation of this technique applied to habitat mapping is that it does not directly image the character of the sediment water interface. Seismic reflection profiles are instructive when used to identify areas of potential rock outcropping as they are implied by noting eroded, faulted, or scarp surfaces. The technique also confirms the presence of depositional environments where hard rock outcrops are less likely to exist. Additionally, they may provide clues for locating authigenic carbonate rock formations by revealing sites of fluid venting.

Collectively, the Active Tectonics Lab personnel have extensive experience and knowledge of the specific seismic surveys used for the habitat maps and we make several distinctions in their quality for habitat mapping purposes (Table 4). These distinctions are based on knowledge of the survey techniques, their specifications and objectives. Unlike sidescan imagery, it is not appropriate to generalize that all seismic reflection data are created equal for mapping habitat. Unique systems and surveys show significantly different abilities to image habitat features.

A weighted vector layer of all seismic survey distributions is created during the first step in the quality mapping proceedure. Again the density tool within the Spatial Analyst extension of Arc Map is used to create a density raster. The search radius is set at 500m and the output grid cell size specified at 100m. The final grid is reclassified by quantiles to yield 10 ranked classes (Table 5).

Table 4. Seismic Reflection Data Weighting Scheme	Quality/Rank
USGS, Corliss Cruise (Twichell, 1998)	10
MCAR(McCrory, 1998)	10
OSU (Goldfinger, 1997)	10
*Industry Dataset 1	10
*Industry Dataset 2	5
*Industry Dataset 3 (unpublished)	5
**USGS, Boomer	5
UW (Palmer, 1998)	5
Dgicon (Goldfinger, 1992)	5
Sonne (Flueh, 1996)	5
*Industry Dataset 4	1

Table 4. (cont.) Seismic Reflection Data Weighting Scheme	**Quality/Rank**
Silver (Silver, 1972)	1
**UW TT79	1
USGS Open File Report 87-607 (Snavely, 87-607)	1

*Reference information for the industry datasets used in these maps exists, but remains confidential by agreement.
**No reference available.

Table 5. Reclassification Scheme using Quantile Breakpoints

Weighted density score (per 100m grid cell)	Quality/Rank
0	excluded
0.00069455	1
0.001041832	2
0.003820052	3
0.005209162	4
0.005903717	5
0.006945550	6
0.010071047	7
0.012154712	8
0.015280210	9
0.088903040	10

Layers Provided:	UTM/WGS1984
(1) Unclassified density grid	seis_den.grd
(1) Weighted density grid	seis_den_fin.grd
(1) Weighted vector track lines	final_wt_seis.shp

Composite Shadow Map

The composite map or final shadow map is assembled by simply adding each of the four principle weighted rasters together in a method common to suitability modeling. This operation is performed using the raster calculator tool of the spatial analyst extension in Arc Map. Each quality map is overlain in an editable environment and the additive sum value at for each cell is calculated. The composite raster has cell values that range from 1 (lowest density and quality) to 40 (highest density or quality) and a cell size of 100m.

Layers Provided:	UTM/WGS1084
(1) Final composite quality grid	orwa_quality.grd

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Appendix 5

List of Groundfish Species in Life Histories Appendix

LEOPARD SHARK (Triakis semifasciata)
SOUPFIN SHARK (Galeorhinus zyopterus)
SPINY DOGFISH (Squalus acanthias)
BIG SKATE (Raja binoculata)
CALIFORNIA SKATE (Raja inornata)
LONGNOSE SKATE (*Raja rhina*)
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)
ARROWTOOTH FLOUNDER (*Atheresthes stomias*)
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 6

Pacific Coast Groundfish FMP Habitat use Database User Manual for Version 15B (Draft)

Table of Contents

1 DATABASE PURPOSE

The Pacific Habitat Use Relational Database has been developed to provide a flexible, logical structure within which information on the uses of habitats by species and life stages in the west coast groundfish species complex can be stored, summarized and analyzed as necessary. This will form an important component of the information base for developing the EIS for the Essential Fish Habitat amendment to the Pacific coast groundfish fishery management plan.

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 document compiled by NMFS. This document 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 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.

Appendix 8A contains an extract from the Updated Life History Descriptions document for canary rockfish (*Sebastes pinniger*). Parts of the text in this extract have been highlighted as an example of the types of information that need to be entered into the database.

Appendix 8B contains a list of tables and forms used in the database.

2 DATA STRUCTURE

It is essential for users to grasp the principle of data structuring and how it is used in a system like this to both enforce data quality and form the basis for developing interrelated lines of analysis. It is a different concept from a simple file storage system that can only receive, store and regurgitate data for use elsewhere. This system can of course be used in that way as well but that is only utilizing a fraction of its capabilities. Appendix 8C explains in detail these essential basic principles that underlie the design and construction of this Habitat Use Database.

Figure 10 is the 'Entity Attribute Relationship' analysis diagram for the database. It shows the data tables, their fields and which of these form the 'primary keys' (in bold) and the foreign keys which link the tables together via a network of one-to-many relationships. The tables contain all the data in the database. Some contain primary data (e.g. SpeciesLifeStage and PlaceTime) and others contain reference information such as Species, which is simply a list of all the species in the FMP. All data entry forms, data checking procedures, and queries are based around this table structure.

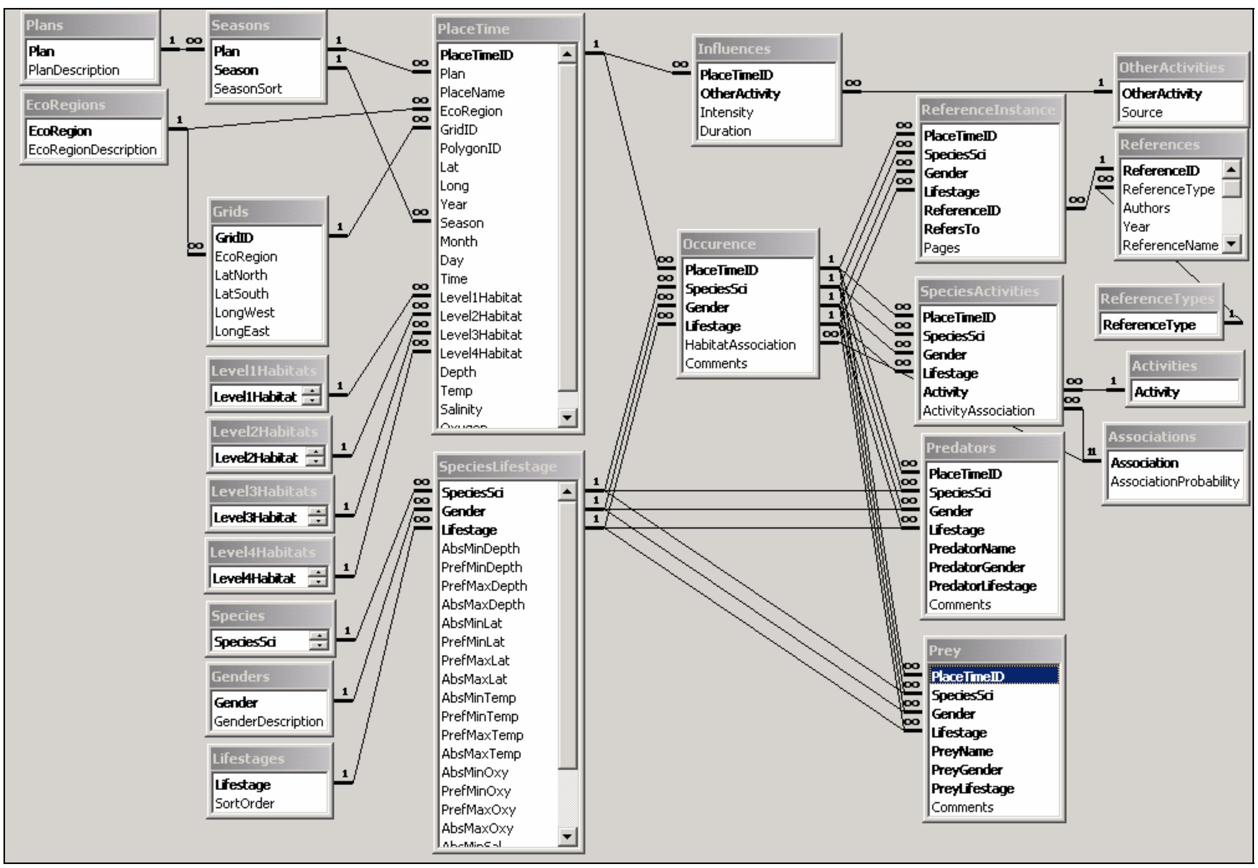


Figure 1: The structure of the data tables, their constituent fields and relationships between them.

2.1 Spatial and Temporal Data: The PlaceTime Table

The core of the database is the ‘PlaceTime’ table. This records where and when particular observations of species-habitat associations were recorded. Records in this table represent the place (or area) and time (or period) of the recorded occurrence of the species and life stage data and the habitat and physical conditions that prevailed at that time and place.

The principle is that the data being recorded are associated with some sort of time and space framework, whether this is in the most general sense such as the whole West Coast region for all time down to very fine scale data where exact times and places are known and might be used to stratify analyses. The system is therefore not dependant on exact spatial and temporal information about a particular species-habitat association. It can be used even where there are no spatial or temporal elements in the data. The information in the PlaceTime table simply allows the breakdown of analysis of species-habitat associations on a finer spatial and / or time scale than the entire range of the species/life stage should the information be available at that resolution. More detailed explanation of the implications of the different grades of spatial and temporal data are given in the following sections.

To allow such flexibility in the type of time and place data that can be recorded and to allow the combination of different types in the same table and analyses, it is necessary to uniquely identify each record in the PlaceTime table, refered to as ‘PlaceTime’ record in the preceding, with a unique number ‘PlaceTimeID.’ This forms the primary key in the table and cannot be repeated. **This means that either data should only be entered in one place or if there are multiple data entry sites then they should either co-ordinate with one another to ensure they use unique sets of numbers or access a centralized database via a network (local or wide area) or via the internet using active server pages. The other possibility is for the database to be ‘replicated’ and later ‘synchronized.’**

The remainder of the fields in this table can either by typed in directly or selected from the combo boxes provided at either table or form levels. There are also range limits on temp, salinity, depth, oxygen, latitude and longitude when their values are not null.

Frequently there is no temporal or spatial information and there may be just a series of observations of species occurring on different habitat types. We don’t know when or where these observations were taken, only that they are accurate in their recording of the types of habitat on which the species were seen. In such cases the record has an arbitrary but unique identifier in its PlaceTimeID field which has nothing to do with place or time but simply allows the habitat data to be linked to the occurrences of species and their activities (tables ‘Occurrences’ and ‘SpeciesActivities’).

Obviously for any of the given ‘PlaceTime’ records (even if it had very detailed location and date-time data) there can be multiple occurrences of different species and different life stages of the same species. These can also have multiple species and life stages of both predators and prey. The database is structured in such a way to allow the correct representation of such natural one-to-many relationships between entities.

In the PlaceTime table, the column PlaceName allows the use of place names where these are used to identify a known area or location at which observations have been made of species/habitat associations. Provided these names are used consistently (a reference set could be defined in a 'look-up' table) then they could also be used in a stratified analysis. This can be used independently, or in conjunction with grids and "EcoRegions." EcoRegions are used as a simple large scale subdivision of the area covered by the FMP so that analysis of habitat use can be broken down at a finer scale than the entire Pacific coast. Seven EcoRegions (numbered 1 to 7) have been proposed, as illustrated in Figure 11. EcoRegions are defined by their member GridIDs. In this implementation of the database no GridIDs have been identified, so EcoRegion and GridID are the same (i.e. there is only one grid per EcoRegion). Arranging it in this way means that if in the future Grids are defined, there will be no need to alter any code in queried that use the Grid/EcoRegion structure. These will run without modification both with the present scheme and when the grids are reassigned.

As shown in the data model, the allocation of results to Eco-Regions should, preferably, always be done via the Grids table. This allows the flexible re-definition of eco-regions and the grid squares they contain should this ever be necessary. There is also an EcoRegion field in the PlaceTime table into which the user can enter the value of the eco-region directly and simply analyze via this field when ignoring the Grid system. There is also a PolygonID field available in the 'PlaceTime' table for recording finer scale spatial allocations, should these be required.

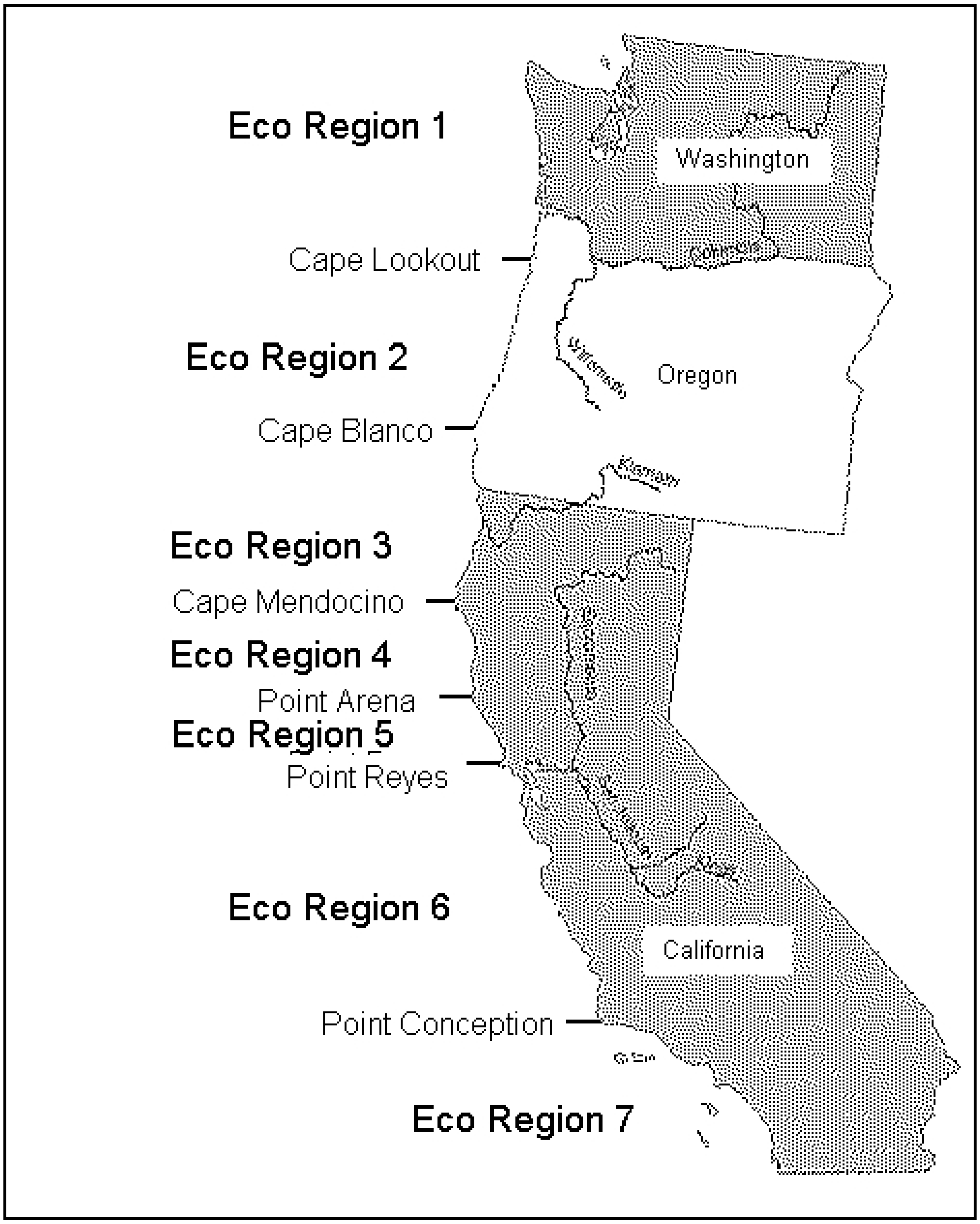


Figure 2: The Eco-Regions

The Grids table has four fields LatNorth, LatSouth, LongWest and LongEast which can be used to define a grid square in terms of its binding latitudes and longitudes. It is assumed these will be entered in a decimal as opposed to sexagesimal notation and that the upper bound for one limit will not run into / overlap with the lower bound of the adjoining limit. The GIS conventions will define the appropriate usage. As with the PlaceTime position fields, there are range limits on what can be entered based on the latitudes and longitudes that enclose the whole west Coast region.

Temporal data in the PlaceTime table include years, seasons, months, days and exact times. Data on these attributes can be entered as and when they are available and deemed to be relevant. The fields can be ignored when the data are unavailable or deemed to be irrelevant. The availability of the fields within the system and the way they are defined allows flexibility in this respect.

2.2 Scaling of spatial and temporal data

The hierarchy of detail available in the PlaceTime table allows data of different temporal and spatial scales to be combined in the analyses. It is important to bear in mind that a few basic assumptions must be adhered to in order to make informed use of this flexibility.

1. Data should be unique. Where data are collected on the basis of one of the finer temporal and/or spatial scales and are also available as a summary of this on one of the higher scales then the data should be entered into the database according to only one of these scales and preferably the finest scale available.
2. Where there are data of mixed temporal and/or spatial scales then care must be taken in framing analyses on two counts:
   a) when such data are combined in an analysis then the results can be stratified spatially or temporally down only to the level of the data with the broadest spatial and temporal scales, and
   b) when a stratification of results is intended on a fine scale, then 1) either all the data should have values entered for those fine scales or 2) careful conditions need to be set to exclude records that do not have values for those finer scales. Note, however, that in this latter case the analysis would not be using all of the available data.

2.2.1.1 Seasons

Seasons are defined within the management plan though it is not obligatory to utilize either of these features where they are not required or are irrelevant. It allows several concurrent seasonal regimes to be defined where management plans are based around a major species and the recognized seasonal patterns of these are different even though they occupy the same areas and times. Equally the defined seasonal regimes for different plans can also be matching, which is the simpler and more likely scenario. Where there is either no defined management plan or a single management plan, the structure allows the simple definition of a single seasonal regime. Where there is no information on seasons, or seasonal attributes are not applicable or irrelevant then the user can enter an appropriate single ‘seasonal’ value in the look up table such as ‘All Year’ or ‘Unknown’ or ‘Not Applicable’ or whatever the user chooses.

Should it ever be required in the future to extract or ‘manufacture’ the spatial and temporal data from the descriptive information in source documents then an example methodology is provided in Appendix 8D.

2.2.1.2 Fishery Management Plan

The system is designed to be able to represent several Fishery Management Plans by specifying the FMP in the filed “Plan” in the PlaceTime database table. The facility thus offers the opportunity to stratify analyses according to FMPs where this is required. The present implementation does not require such a facility (there is only one FMP) but it has been left in the database structure in case data from another FMP are entered into the same database at some future time. Its functionality can be ignored by always entering one single value for the 'plan' field. **As with all such 'look-up' data values (e.g. species names etc), if the names are altered the alterations are automatically 'propagated' throughout the entire database doing away with the need to manually update all the associated data with any such name changes.**

2.2.1.3 Habitats

Habitat is currently defined in the PlaceTime table under four tiers of classification. The four levels of habitat classification are currently independent and are not structured as sub sets within one another. For ease of data entry and comparison all three levels are displayed within the same form (Figure 12). As with all of this kind of 'look-up' data the user is free to add or alter the values under these classification schemes.

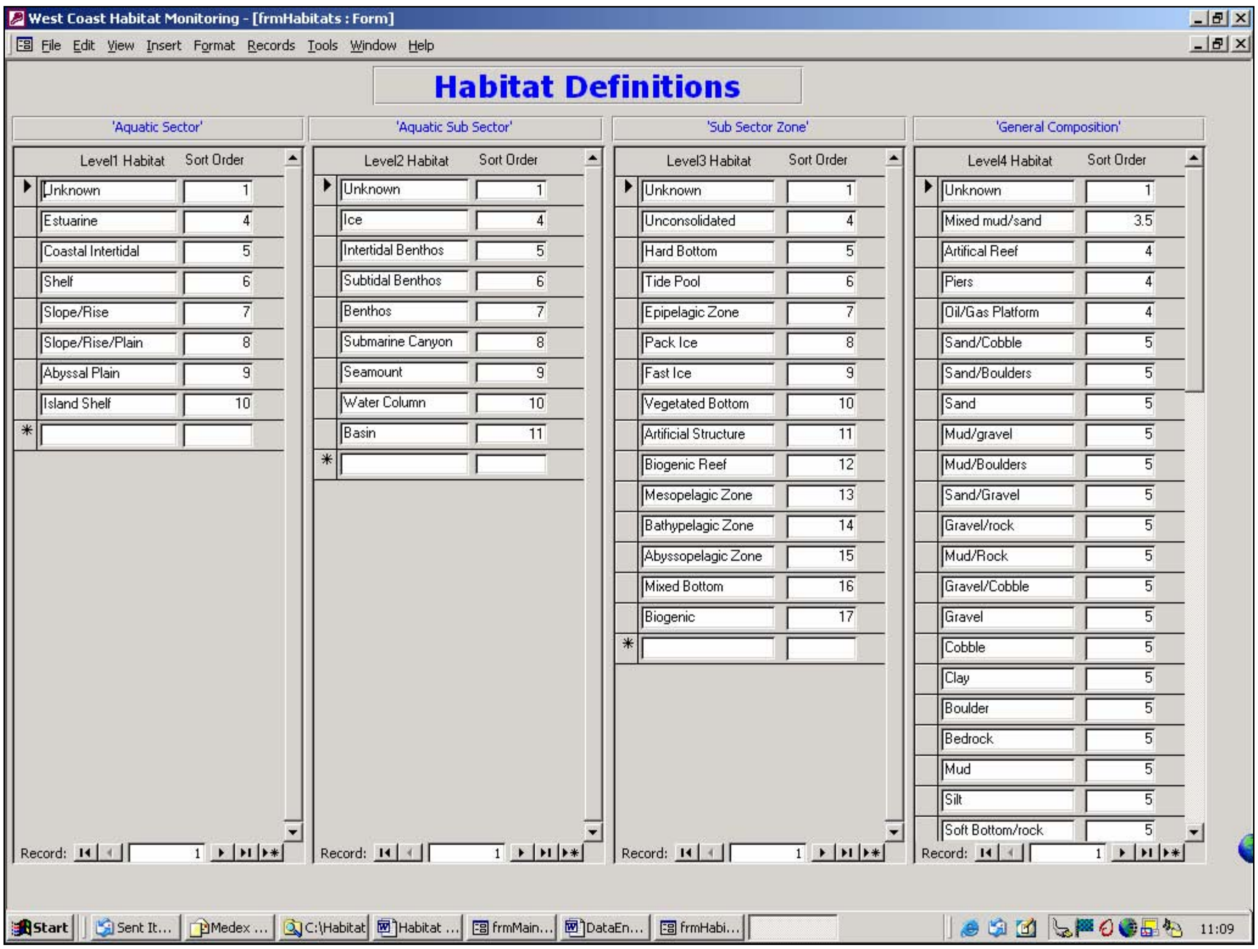


Figure 3: Habitat definitions

2.3 The Species, Genders and Life Stages Tables

These data each reside in a separate table and also in a combined SpeciesLifestage table, although the forms that serve these tables have been conveniently combined. There is also a button to call up the life stages form so that the life stages available in the Lifestages table can be added to or amended. The same is the case for genders. The design of the system also assumes that all predator and prey species and life stages are also entered in these tables. Where no life stage info is available or is deemed irrelevant then a value such as ‘Unknown’ or ‘All’ must first be entered via the Lifestages form. This will then appear as a life stage option when entering the value of the life stage for that species under the SpeciesLifestage form. The same principle applies for genders. Care must be taken to bear both data entry and later analyses in mind when deciding on values for life stages and genders at the data entry stage and on what values to filter these on during analyses, e.g., if a combination of ‘Both’ and ‘Unknown’ are used as values for gender then one or the other must be used alone with reference to a particular life stage and not both of them. If you used both of the two values it could conceivably distort results. Equally where ‘Both’ and ‘Unknown’ have been correctly applied as genders to different life stages then the two values must be used in any filter that is being applied across genders and life stages for a given species.

2.4 The Occurrence Table

The ‘Occurrence’ table records which species and life stages occurred in the recorded place and time frame on the recorded habitat, etc. The relational structure allows the recording of several of the life stages of the same species that may occur simultaneously and of course as many species as there were present. As explained earlier if no spatial or temporal data are available then the so-called PlaceTimeID simply refers to the habitat type only, as defined.

There is also a ‘HabitatAssociation’ field in the Occurrence table which records a measure of the relative strength association of that species-life stage with the habitat recorded (as strong, medium, or weak) with matching probabilities. The number and names of values and the probability figures can be changed by editing the Associations table via its form or directly in the table. All the values are the same as those presented for the degree of association of a particular ‘Activity’ as well.

2.5 The SpeciesActivities table

The SpeciesActivities table records the activities of the fish (spawning, breeding, feeding, or growth to maturity) on a particular habitat in a particular time and place. There may be multiple activities for any given species-life stage in a Place/Time frame. As with the habitat associations, the degree of association of that activity performed by the fish in that habitat can be recorded as strong, medium or weak.

Associations between species can be derived via a query that groups which species-life stage-activities were occurring in a given Time and Place frame for the various habitats. This is providing all data have been comprehensively entered.

2.6 The Predators and Prey Tables

The predator and prey tables have a many to one relationship with the Occurrences table. i.e. any one given species at a particular life stage can have many predators and can also itself prey on several other species. These predators and prey will themselves also be at a particular life stage. The predators and prey recorded must also be represented in the three tables 'Species', 'Lifestages' and 'SpeciesLifestage' even if they are not in the FMP species list. For convenience and simplicity of design the main predator and prey groupings have been denoted as either a member of a predator (pred) or prey grouping in the comments field. That field is then sorted in the menu choice so that these groupings appear together.

2.7 The Influences and OtherActivities Tables

The database also accommodates the recording of other activities or occurrences (impacts) that might have influenced species and their activities in a particular time and place. This is done through a sub-section 'Influences' on the bottom of the 'Place-Time Centric' by allocating these "OtherActivities" in the "Influences" table the same PlaceTimeID as in the PlaceTime table. The extent to which this facility will be used is not clear at present, but this structure will allow comparative analyses to include such influences or 'impacts' as well as habitats and the other attributes on patterns of occurrence and species activities at their various life stages.

Such things as Pelagic Fishing or Acoustic Surveying can be recorded but also natural events such as an el-Nino event or a turbidity current. The OtherActivities table also has a field 'Source' that allows the user to group these other activities according to their source. This can be employed flexibly as required. E.g. it could take only two values such as 'Human' and 'Natural' or these could be subdivided further as required according to the kind of analysis being undertaken. As with the occurrences table the value of the PlaceTimeID is automatically inherited from the parent PlaceTime table in the form used to enter data.

2.8 References

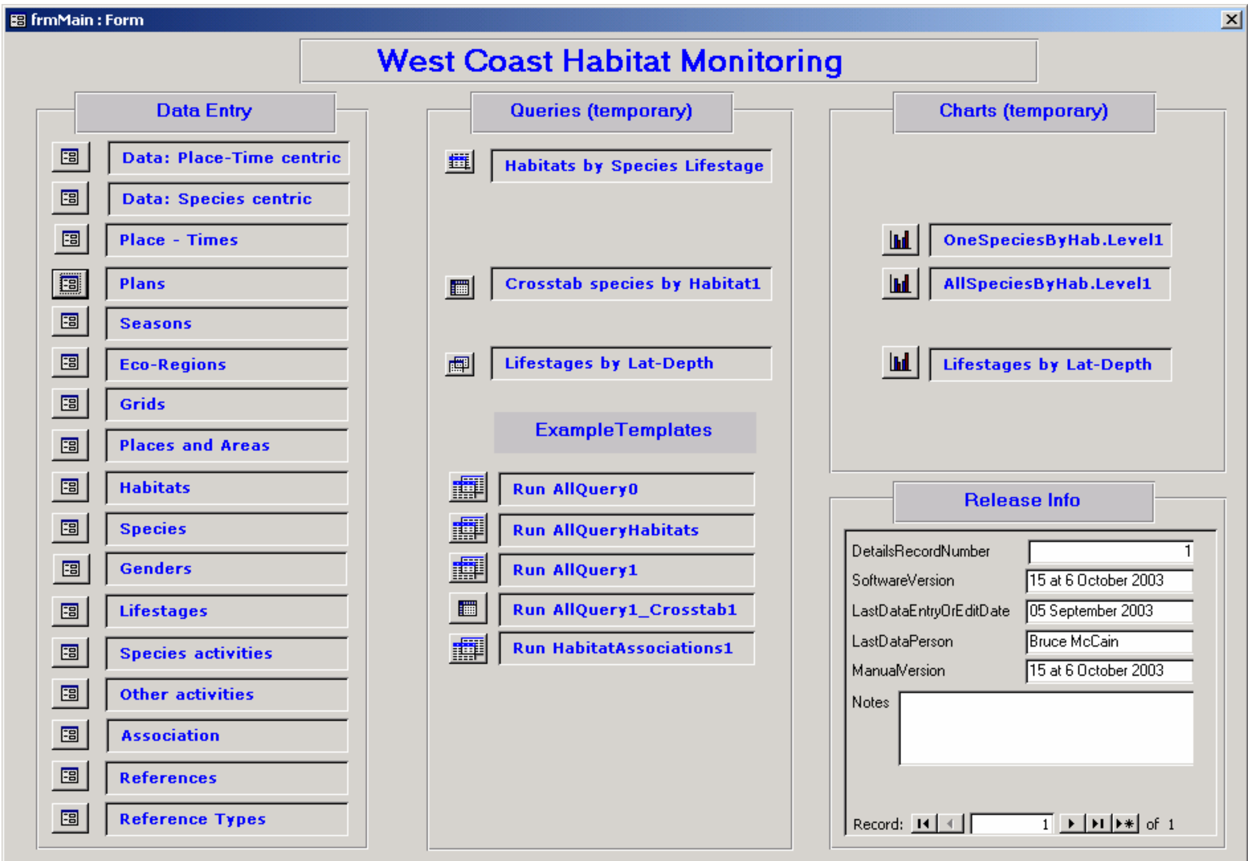
All reference materials are recorded in a single table "References." Each work should be recorded only once with a unique identifier 'ReferenceID'. The 'ReferenceInstance' table records the occurrences of that reference as and when it is referred to in relation to a given occurrence of a species-life stage for a specific time-place frame with its associated habitat and physical conditions. Thus a given reference can appear as many times as necessary in the 'ReferenceInstance' table even for the identical PlaceTime, Species and Lifestage providing it refers to different aspects as recorded in the remaining key field 'RefersTo.' For example, the same work can be recorded as a relevant reference for both Habitat and Predators.

A total of 557 references have been entered so far (October 2003). These are then also referred to from the database, thus explicitly describing the network of references and the context in which they are referred to.

3 WORKING WITH THE DATABASE

The database is designed to be as intuitive as possible with information naturally arranged in a hierarchy of ‘Parent’ – ‘Child’ tables. These tables are automatically linked in their data entry and viewing forms. For those unfamiliar with Access databases a period of practice on a dummy copy of the system will help familiarize the user with navigational controls. Liberal use of the ‘Help’ button should also be made.

The opening form appears as:



This form lists all the current options for data entry and data analysis. Additional queries and charts can be developed as required.

The ‘Release Info’ section presents a summary of which version of the software is under use and which data set it incorporates. This aims to reduce the danger of any copies getting out of synchrony with one another where data entry and analysis is ongoing at a number of sites. It also helps ensure the users have the correct set of documentation to go with the product.