Exhibit C.4.b
Attachment 1
June 2004

Version for Pacific Council June 2004 Meeting Briefing Book

Pacific Coast Groundfish EFH

EFH Impacts Assessment for the Pacific Groundfish FMP

Prepared for

Pacific States Marine Fisheries Commission

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

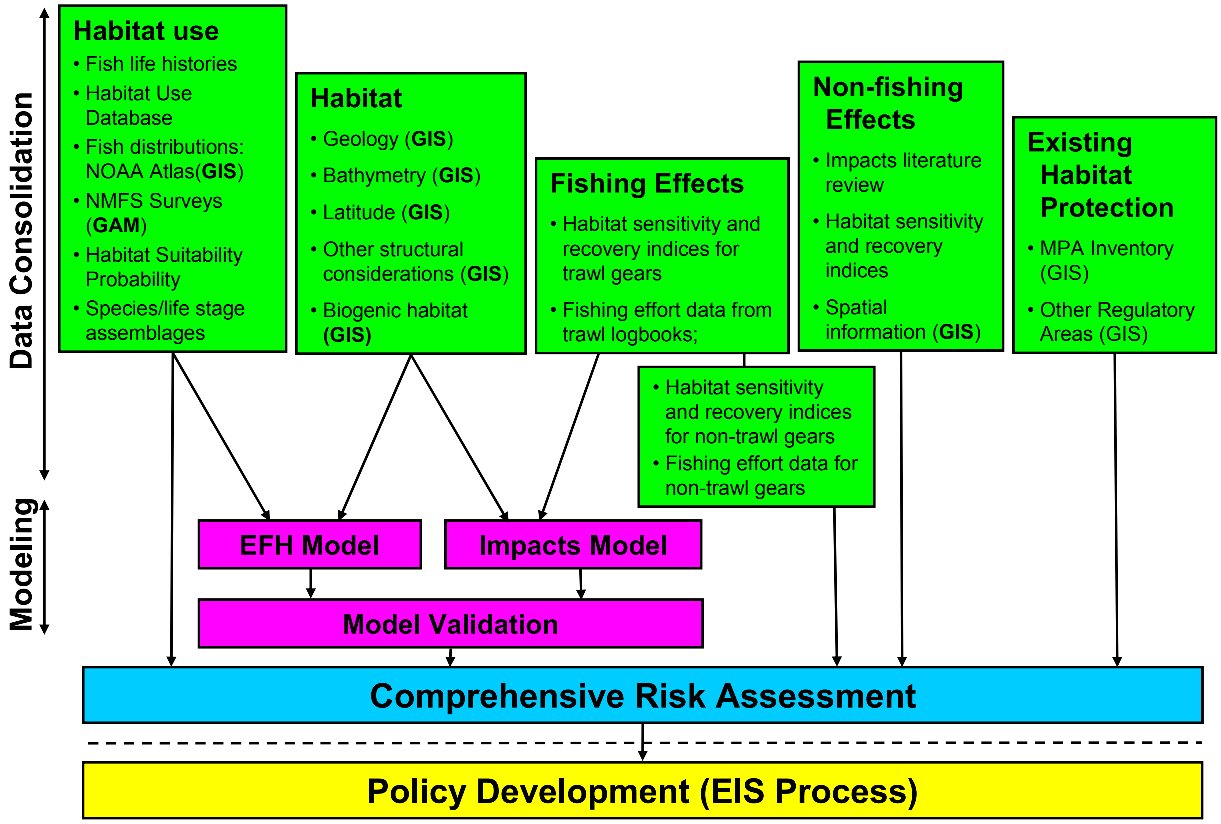

Figure 1. Revised decision-making framework for the assessment stage of the Pacific Coast Groundfish EFH EIS showing data inputs and separation of the assessment and policy components

Two models are depicted in Figure 1: the EFH Model and the Impacts Model. Together these represent the analytical framework that is being developed to support preparation of the EIS and, more specifically, the development of management alternatives by the Council and NMFS. While these components are clearly integrated, it is both pragmatic and practical, in terms of the Council's schedule of meetings, to address them initially one at a time, due to the complex and wide ranging scope of the issues they address. The first step in the process is the identification and description of EFH. A document and presentation providing the details of the analysis that will lead to the development of alternatives for EFH for the Groundfish FMP was given to the Council at its April 2004 meeting.

The second step, presented in this report, 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. We note that 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 primary purpose of this document is to present the first completed version of the Impacts Model. But in view of the need to develop a comprehensive risk assessment that incorporates all available relevant information, it also provides details of the other data elements in Figure 1. The "comprehensive risk assessment" will, of necessity, be a part quantitative and part qualitative procedure that will feed 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, a possibility that is discussed further in Section 4.2.

The results of the data consolidation phase for the Impacts Model are discussed in Chapter 2. The Impacts Model and the comprehensive risk assessment are described in Chapters 3 and 4.

2 MAJOR DATA SOURCES

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 2 (the decisionmaking framework), we have organized the various GIS and other databases that have been compiled for this project into five major categories:

- West Coast fish habitat
- Use of habitat by groundfish
- Effects of fishing on groundfish habitat
- Non-fishing activities that affect groundfish habitat
- Existing habitat protection measures

Within all of these categories, GIS is a pivotal tool in compiling, analyzing and presenting data. The first two also form the backbone of the EFH Model and were described in the report of that model presented to the Council. In this report we provide a brief summary of the data collection and processing procedures in the first two categories, and a more detailed presentation of the last three. For more detail on the first two, the reader is referred to the Council's April 2004 Briefing Book[1].

2.1 GIS deployment in the EFH process

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

[1] Identification of Essential Fish Habitat for the Pacific Groundfish FMP, Exhibit C6 in the April 2004 Briefing Book, available at www.pcouncil.org.

2.1.1 Challenges Encountered While Compiling EFH GIS

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

- Locating Quality Data
  Every GIS undertaking of this magnitude faces longstanding challenges to data sharing and integration. Compiling a GIS for a 822,000 square km study area requires navigating a complex web of federal, state and local agencies in an effort to locate the best available data. Ideally, data sets sought out for inclusion were comprehensive for the west coast where possible, already in GIS format, free, readily available, and redistributable. However, more often than not, meeting all these criteria proved impossible. Balancing cost and time requirements to meet the EIS schedule, it is important to note the data incorporated does not always represent the best data, but the best data available to the project in the timeframe dictated.

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

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

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

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

2.1.2 GIS, Modeling, and Management

The scale, scope, and complexity of this project have repeatedly pushed the limits of standard GIS technologies and existing spatial data, requiring the team to utilize innovative tools and multiple programming languages to develop the best possible GIS on which to base the EFH 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

2.2.1 Benthic habitat

Benthic habitat is characterized primarily on the basis of the 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. 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.

2.2.2 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.

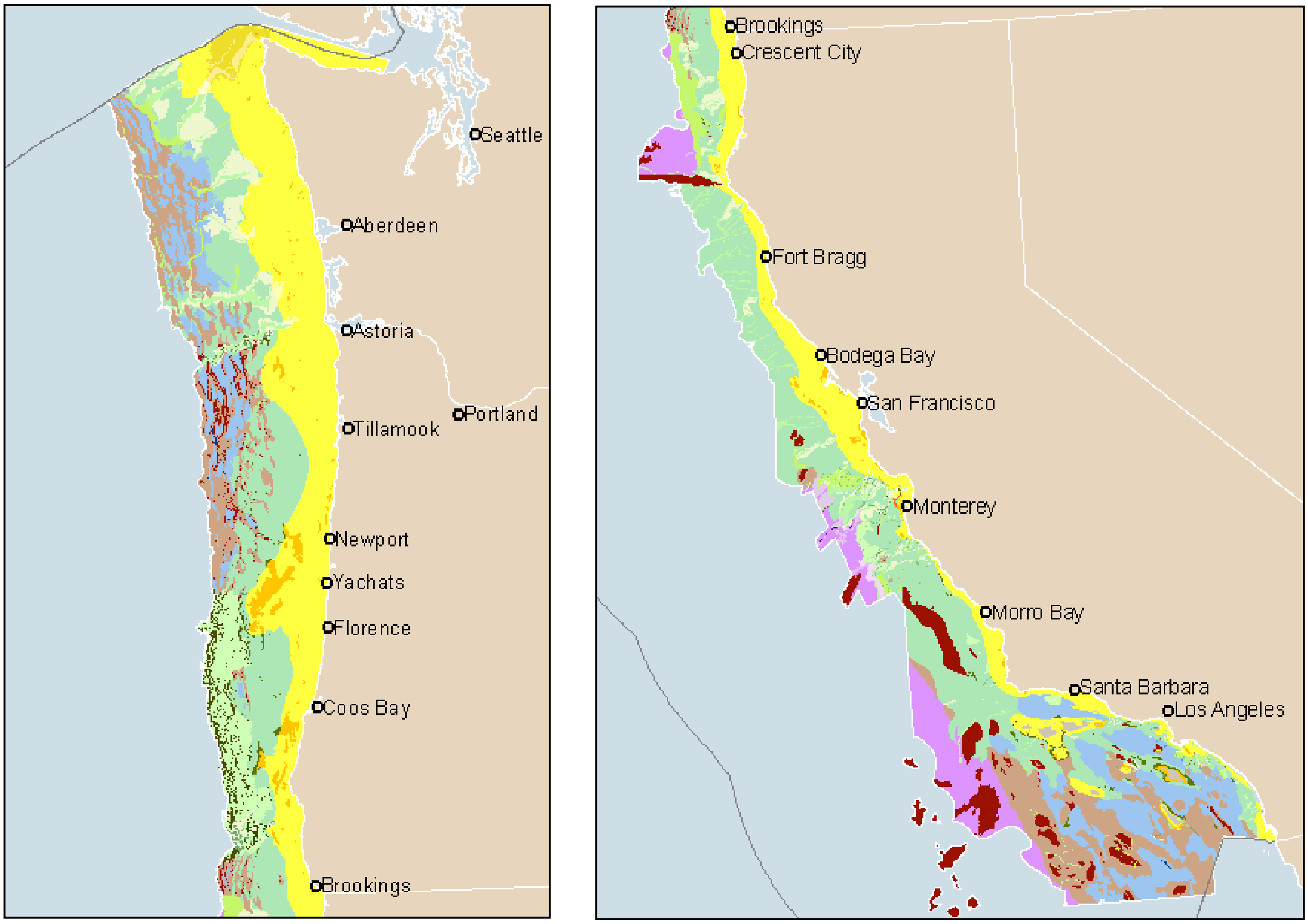

Figure 2. Thirty five (35) unique benthic types off the coasts of Washington, Oregon and California. Graphics created by TerraLogic GIS Inc. from data provided by MLML (CA) and OSU (OR, WA).

2.3 Effects of Fishing on Groundfish Habitat

2.3.1 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 1). 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 1 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[2]. A copy of this list is provided in Appendix 2 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[3]:

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

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

Table 1. Gear Types Used in the West Coast Groundfish Fisheries[4] [5].

	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)

[4] Adapted from Goen and Hastie, 2002.

[5] 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 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.

2.3.2 Fishing gear impacts: habitat sensitivity and recovery

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 an index of fishing gear impacts by gear type that will serve as an input into the overall risk assessment. The Committee suggested that, while several literature review and indices exist that may be utilized for this project, there is no clear direction on how that information should be applied to the west coast. As justification for the recommendation, the committee cited the general lack of west coast specific studies and the need to determine specifically how to make inferences from studies that occurred in other parts of the world. Appendix 3 presents the results of this analysis.

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, adverse effects of fishing gear were defined consistent with NOAA Fisheries EFH Final Rule and include "direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH" (50 CFR part 600.810).

The evaluation of impacts is made on the basis of notional indices of sensitivity of habitats to the action of fishing gears and time taken for the habitat to recover to a pre-impacted state: the Sensitivity Index and the Recovery Index. 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. Information on the effects on pelagic habitats has not been pursued to date. Appendix 3 presents the indices and provides background to 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 identification of the habitat types and gear types to be used in the analysis, and defining levels of sensitivity and recovery.

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 2.3.3) 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 3 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 to its pre-impacted function, at some assumed rate, if it is not subjected to a further impact.

Phase 2 was a detailed review of the global literature (using major recent reviews), culminating in construction of tables that summarize on a study-by-study basis the sensitivity levels and recovery times by gear type and habitat type. Phase 3 was the construction of the sensitivity and recovery matrices themselves.

Approximately 47 different habitat types were used in this analysis. Approximately 30 gear types are used in west coast fisheries but studies sufficient to develop meaningful sensitivity and recovery indices have been done on only five major categories: dredges, bottom trawls, nets, pots & traps, and hook & line. Hence, the final sensitivity and recovery matrices consisted of five columns and 47 rows. Because there is a wide range of sensitivity metrics in the literature, all studies were standardized to a scale of 0 (no impacts) to 3 (major impacts), and all recoveries were reported as time in years taken directly from the literature.

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 present analysis corroborated previous assessments of the relative impacts of major gear types, arranged from most damaging to least: dredges, trawls, nets, pots & traps, hook & line, as well as the following ranking from most sensitive to least for major habitat types: biogenic, hard bottom, soft bottom. Recovery times ranged mainly from 0 to 5 years, and the overall trends by gear and habitat types were similar to the trends for sensitivity levels.

2.3.3 Fishing effort

2.3.3.1 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 3), 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 Section 3.2.2. 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, only a small subset of the PACFIN gear types are included in the logbook data – these gear types are: groundfish trawl, midwater trawl, roller trawl, flatfish trawl, and other trawl. The breakdown of gear types in the PACFIN database is shown in Table 2.

Table 2. 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%)

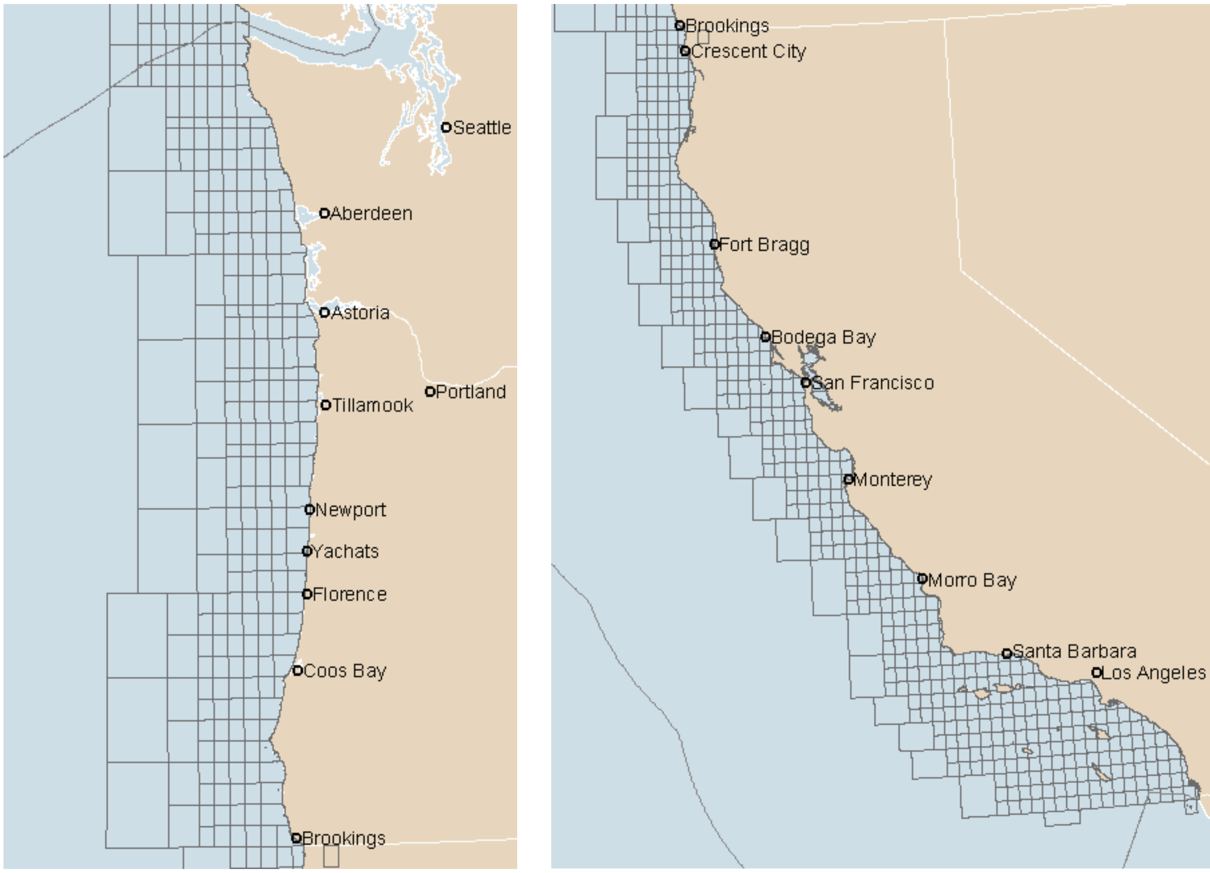

Figure 3 Trawl logbook blocks in the PACFIN database.

2.3.3.2 Non-trawl commercial effort data in PACFIN

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[6], Ecotrust, Inc. has developed a predictive model to further resolve this information to levels consistent with the commercial trawl data (Ecotrust 2003). Using this predictive model, catch in pounds and revenue in dollars are assigned to a specific 9 km block. The catch and revenue are also 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.

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

2.3.3.3 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 data collected covered current and historical fishing areas that they defined and fishing intensity for groundfish trawl and fixed gear fisheries within those areas. Due to funding constraints it was not possible to take the project beyond the pilot phase, the results of which are presented in Appendix 4. 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 the intensity information they provided. After the focus group sessions, the data were converted to GIS format using a 'heads-up' digitizing approach.

2.3.3.4 Using the 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[7]). 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 5 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[8] . In addition, the SSC review endorsed the use of the focus group approach for collecting

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

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.

2.3.3.5 Recreational fishery

The recreational fishery sector comprises the commercial passenger fishing vessel (CPFV) fleet (charters), private fishing vessels, and other miscellaneous fishing activities.

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.

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.

2.4 Effects of Non-Fishing activities on Groundfish Habitat

2.4.1 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 6). 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.

2.4.2 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 3). 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 3)

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 3. West coast non-fishing impact data located to date

	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			
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

	Data Collected	Geographic Extent	Limitations
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			
Persistent Organic Pollutants			

3 MODELING THE STATUS OF FISH HABITAT

3.1 Introduction

3.1.1 The purpose of the model

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

The guidelines advocate using information in a risk-averse fashion to ensure adequate protection of habitat for all species in the management units.

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

Bayesian Belief Networks were chosen as a suitable analytical tool [9]. The models have been designed to take advantage of the GIS data and literature reviews developed by NOAA Fisheries. It is recognized that this assessment is occurring in a data-poor environment and therefore must be expressed in terms of probabilities rather than hard numbers. In these situations, the models have been structured to express limitations on each component of the assessment in conjunction with a best estimate in answer to fundamental questions of habitat function. Presentations of the methodology were made to the TRC of the Pacific Fishery Management Council. Proper adjustments to the methodology were made based on input of the TRC.

The methodology was implemented with the goal of answering the questions listed below 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.

Hence, further work will involve developing an initial suite of alternatives for EFH designation and management measures in consultation with NOAA Fisheries as well as an analysis of the projected effects of alternatives on groundfish habitat.

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

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[9] The background to this decision and a basic introduction to Bayesian Belief Networks is described in the document Identification of Essential Fish Habitat for the Pacific Groundfish FMP, Exhibit C6 in the April 2004 Briefing Book, available at www.pcouncil.org.

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 results of the analysis to identify EFH that culminated in the development and implementation of the EFH Model is described in the document Identification of Essential Fish Habitat for the Pacific Groundfish FMP, Exhibit C6 in the April 2004 Briefing Book, available at www.pcouncil.org. The remainder of this report describes the development and implementation of the Impacts Model.

3.1.2 Guidelines for thresholds

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

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

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

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

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

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

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

3.2 Effects of data on model specification

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 (Section 2.3.2 and Appendix 3) and the fishing effort data (Section 2.3.3).

3.2.1 Sensitivity and Recovery Indices

The sensitivity index provides a relative measure of the effects of fishing gears on habitats. There is no quantitative link to habitat utility for managed species. For example if a habitat/gear combination is allocated sensitivity level 2, to what extent is its utility reduced by a single contact, and/or subsequent contacts and how long will it take for that piece of habitat to recover from a single and/or multiple contacts? In addition, in a spatial sense, is it possible for some fraction of a habitat area to be impacted and to remain in an impacted state without significantly affecting the utility of the whole area as habitat for managed species?

Additional work needs to be undertaken to investigate in detail how the sensitivity index 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. If these types of questions could be addressed, the utility of the impacts model for the management process would be substantially enhanced.

3.2.2 Fishing effort data

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 habitat. 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. In the case of the fixed gears, this uncertainty is so great that it has not been possible to develop an Impacts Model that would, with any reliability, predict even relative impacts between different locations. The trawl logbook data provide set points on a haul by haul basis, but not end points, and certainly not actual trawl tracks. While this is still far from ideal, we have been able to develop a quantitative model for bottom trawls that will assist the Council in making decisions about possible management alternatives to prevent, mitigate, or minimize to the extent practicable the adverse effects of fishing on EFH. The remainder of this section therefore refers to the Impacts Model developed for bottom trawl gear.

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. Due to the uncertainty created by these factors and the large variability in the size of the habitat polygons, it was decided that rather than allocating fishing effort to habitat polygons, a regular grid of fishing effort would be a more robust way to deal with the positional uncertainty of the fishing effort data.

The grid size needed to be a balance between being large enough to essentially ignore the effects of tans-boundary tows[10], but small enough to give output at a scale appropriate for informing management decisions that might include area based measures. The grid size was initially chosen to be two times the length of an average tow. 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 8). 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[11]. 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 3), 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 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

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[10] 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.

[11] Cell sizes increase in size as you go from north to south in the study area.

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.

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.

3.2.3 Non-fishing impacts

There is information available on non fishing impacts, but the spatial and temporal resolution of these data presently preclude their quantitative incorporation into the Impacts Model in any meaningful way. 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 at this time.

3.3 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 $0 < s < 1$ [12]. This function is a version of the generalized logistic function and can be written

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

[12] This is a simple conversion from the four point scale described in Section 2.3.2.

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

It has the following properties, which make it suitable as a basis for modelling 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.

3.3.1 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 3.2.2).

The distribution of total duration (Figure 4) suggests that a log-scale may result in greater discriminating power. To allow for zero effort, log (*duration* + 1) was used.

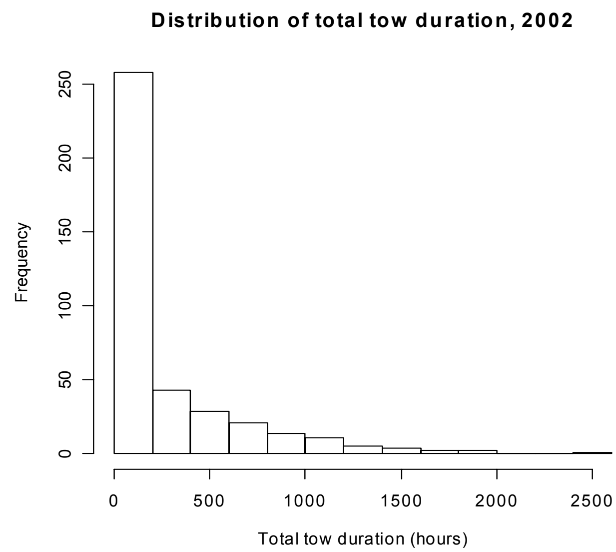

Figure 4. Distribution of total tow duration, 2002

3.3.2 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. **Error! Reference source not found.** shows a family of impact functions for various sensitivity levels with the tuning constant fixed at $k = 0.25$. Figure 6 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

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

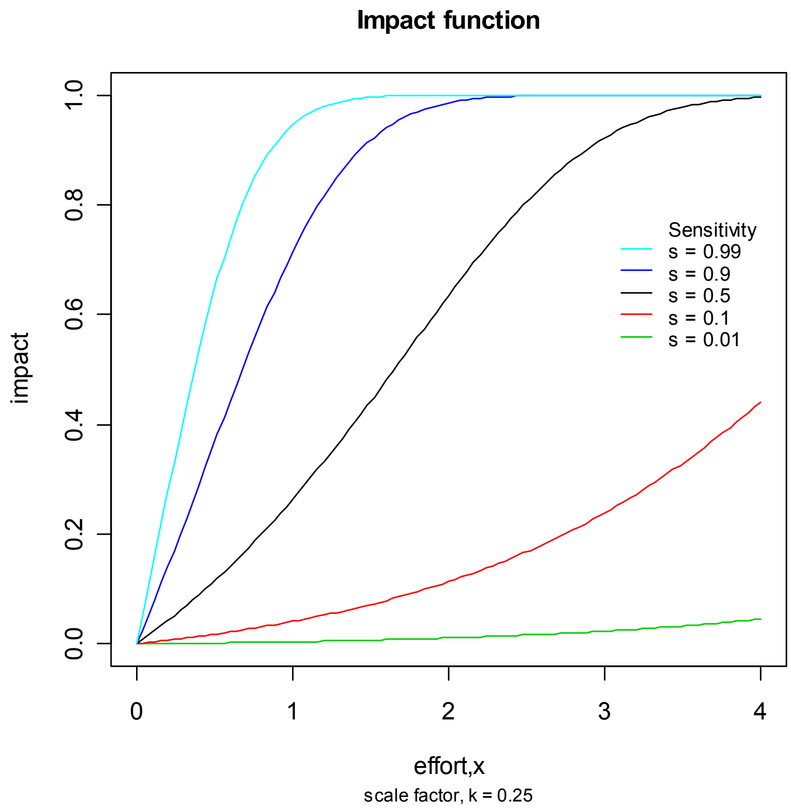

Figure 5. A family of impact functions for various sensitivity levels with the tuning constant fixed at $k = 0.25$

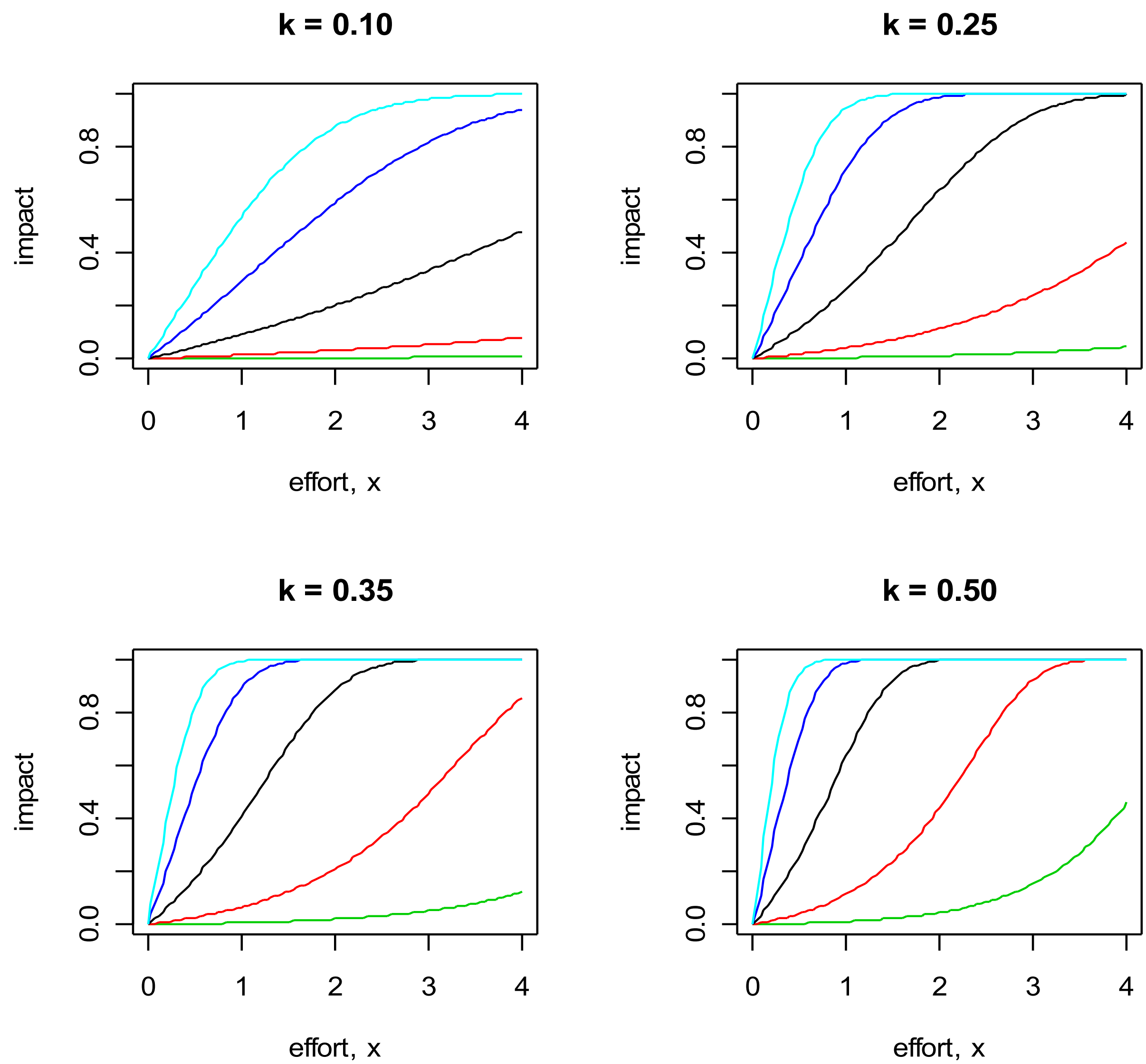

Figure 6. Figure 5 plotted for various levels of the tuning constant *k*.

3.3.3 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 $f(x) = \frac{1-(1-s)^x}{1+(1-s)^x}$, 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 $\to \infty$. 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: $f(x_{\max}) = I^*$. Inverting the impact function,

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

When CEE is *x* = 0, the impact is zero, i.e. $f(0) = 0$. 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 $f(x) = \frac{1-(1-s)^x}{1+(1-s)^x}$.

3.4 The Bayesian Network Model for Impacts (Version 1)

A diagram of the Bayesian Network is given in Figure 7. 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.

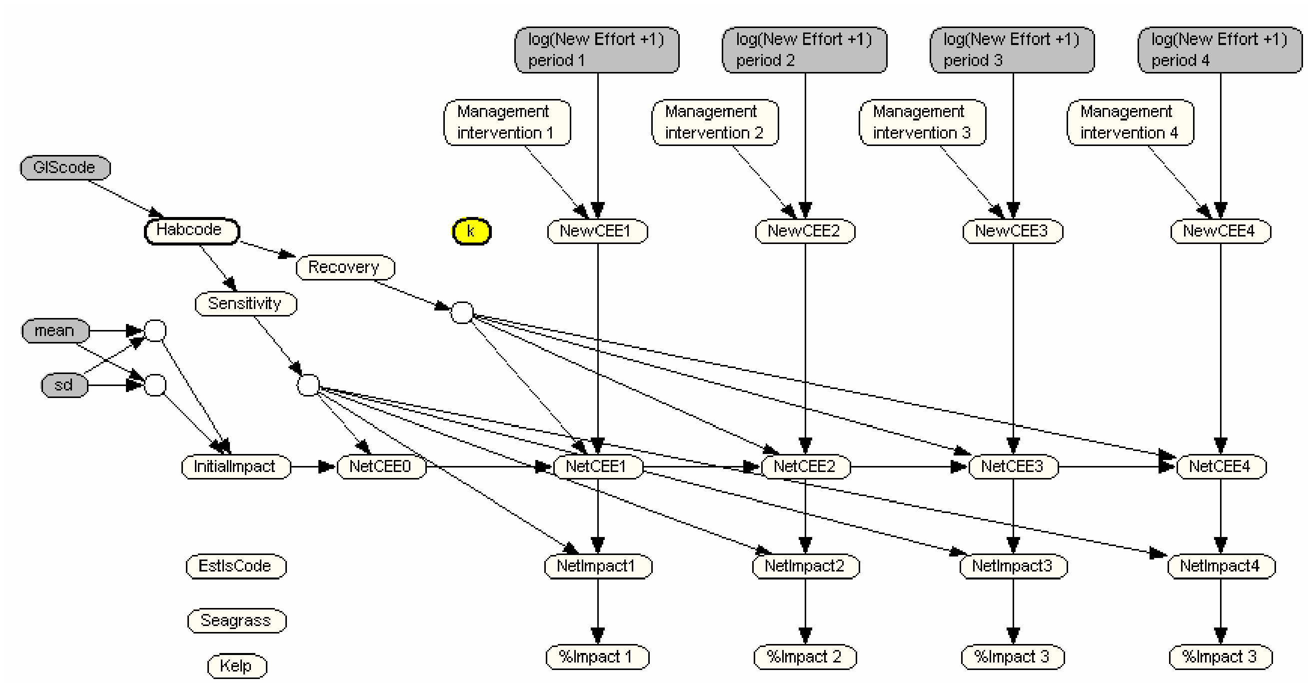

Figure 7. Bayesian Network to estimate impact of fishing gear - bottom trawls version

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 3, 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.

4 RESULTS

4.1 Comprehensive risk assessment

As described in Section 1, the Impacts Model forms only part of the input into the decision-making process. Other elements of the data consolidation work that has been undertaken as part of this project can be used as part of a comprehensive risk assessment, so that impacts alternatives can be developed that are not specifically tied to or informed by the Impacts Model.

For example, although the model itself uses only effort data from the trawl logbook, 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. The Council could, if it desired, consider management actions for these gears based solely on the information presented in Appendix 3. Some gear/habitat interactions may be identified as sufficiently undesirable, based solely on this information, that the Council does not need a detailed quantitative risk analysis to consider taking 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 model to develop management alternatives.

Given the major constraint to the incorporation of non-trawl gears into the model is effort data, one possible alternative approach would be to run the model using assumed distributions of fishing effort for these gears to illustrate potential effects of time and area measures. This option has not been explored to date.

In a similar vein, there are habitat types in the sensitivity and recovery matrices that are not mapped in the GIS. In particular, there are certain types of highly vulnerable biogenic habitats that are mapped either incompletely (e.g. seagrasses and kelp) or not at all (e.g. corals and sponges). Because the model has an explicit spatial component, it is not possible to use it to explore the consequences of alternatives relating to habitat types that are not mapped in the GIS. Indeed, it may not even be possible to develop the alternatives themselves, 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 information becomes available on the distribution of those habitats and they can be mapped, such alternatives would come into effect.

Perhaps one of the most important outputs of the research effort to date has been to identify clearly where data are lacking for the development of a comprehensive risk assessment. In this regard, mapping of vulnerable biogenic habitats is clearly one research activity that should be given a high priority.

Although only some of the available data sets have been integrated into the Impacts Model, 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), 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.

4.2 Using the Impacts Model

4.2.1 What the Impacts Model (Version 1) can do

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 status of 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 impacts and the current relative status of EFH, or they are alternative strategies for future management, in which case the model is used to investigate the potential change to habitat status resulting from management interventions.

4.2.1.1 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?

  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 6). It is, however, possible to develop some objective criteria for setting k (Section 3.3.2)

- 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 (see for example Section 4.2.3). 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 4.2.2.

4.2.1.2 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 3.2.2. 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 1, page 13). However, the impacts literature review presented in Appendix 3 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 2, nor do the trawl logbook data currently distinguish between these different types of bottom trawl.

4.2.2 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.[13] 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.

4.2.3 Maps and graphs produced by the Impacts Model

See following page

4.2.4 Validation of model results

See report of the SSC Groundfish Sub-committee meeting

[13] 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.

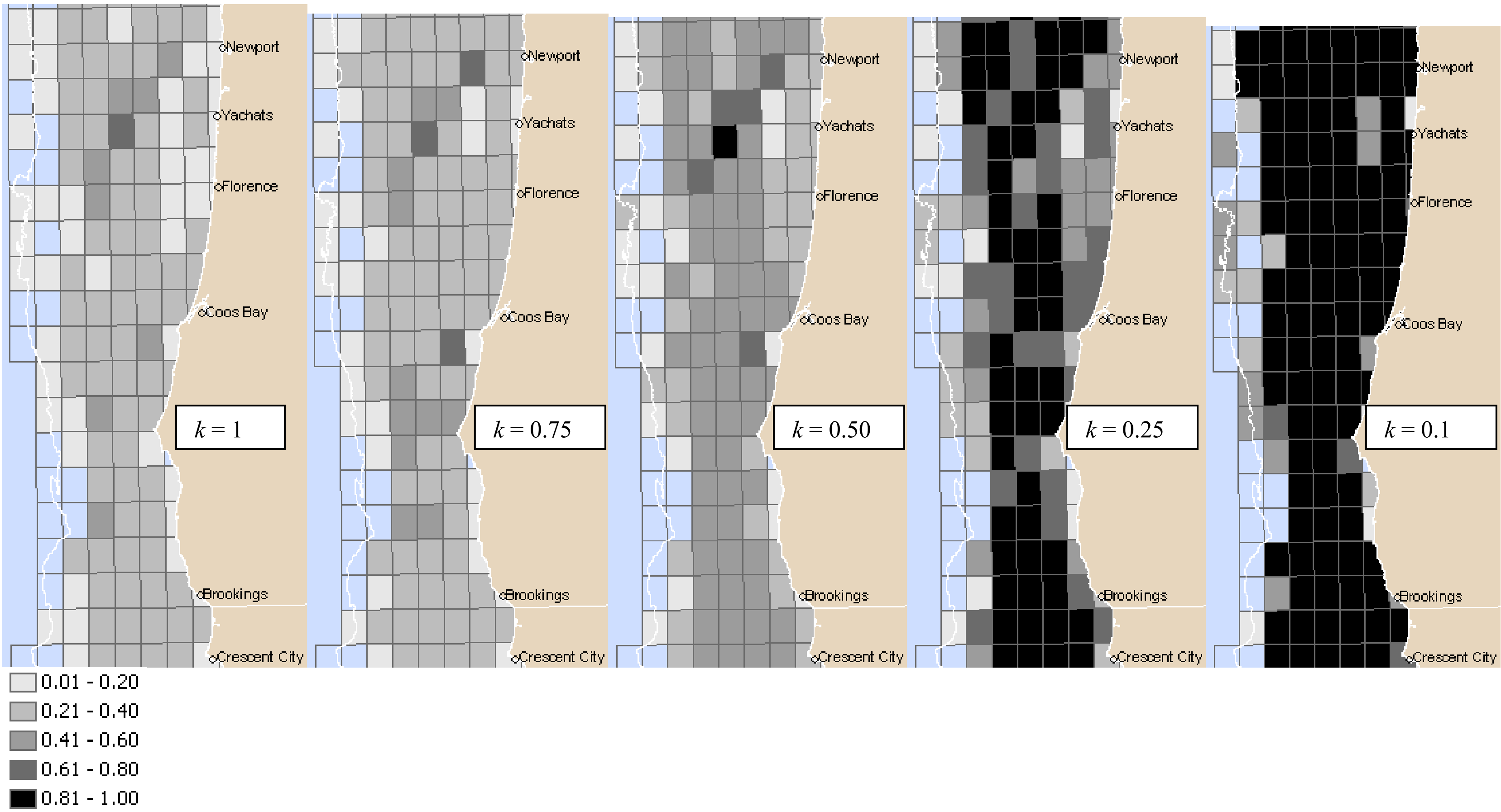

Figure 8 Example maps depicting net cumulative impact from bottom trawls for various levels of the tuning constant *k*

5 POTENTIAL FISHING IMPACTS ALTERNATIVES

5.1 Previous Council actions

When the Council is considering the development of management alternatives for fishing impacts, it should explore in detail any previous and existing measures that have been considered and/or implemented that may have actually or potentially served to prevent, mitigate, or minimize the adverse effects of fishing on EFH, whether by design or not. The EIS should include a section that describes these previous actions in detail.

5.2 Existing spatial habitat protection measures

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 [14]. 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 9). 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 9.

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[15]. 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,

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

Yelloweye Rockfish Conservation Area, Cowcod Conservation Area, and Darkblotched Rockfish Conservation Area from 2001 to the present time have been developed (Figure 10). 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 alternatives. Specific descriptions of the fishing regulations in these areas is provided in Appendix 10

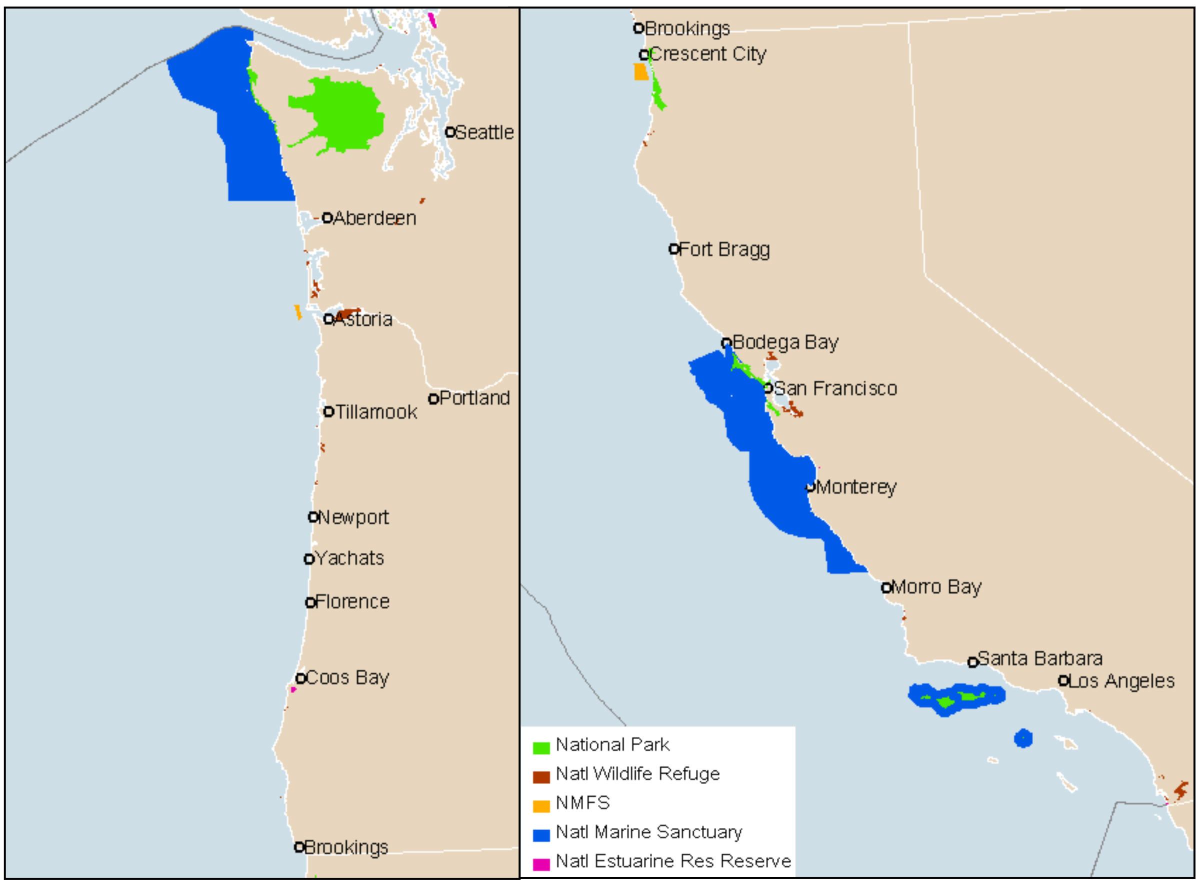

Figure 9. Federally managed areas on the west coast of the U.S.

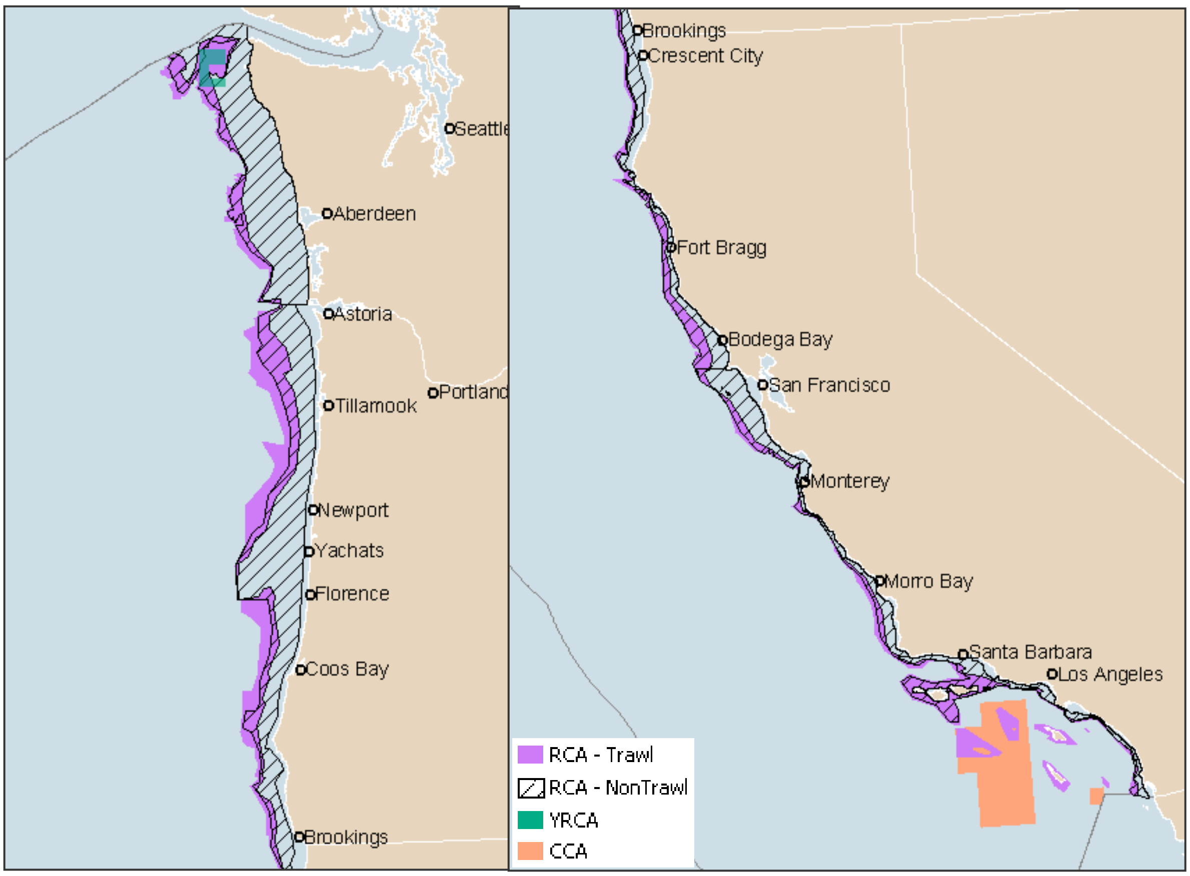

Figure 10. Polygons delineating Sample Rockfish Conservation Areas (RCA trawl and non-trawl), the Yelloweye Rockfish Conservation Area (YRCA), and the Cowcod Conservation Area (CCA).

5.3 Potential further Council actions

This section describes the types of actions that were considered when developing the range of fishing impacts alternatives to prevent, mitigate, or minimize potential adverse impacts by a gear on a habitat. Many different actions are possible for each gear, and the actions considered in developing the alternatives fell generally under five concepts: no action, gear modifications, time/area management, reduce fishing effort and full prohibition of the activity causing the impact. These concepts are described in more detail in Table 4 .

Table 4. 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.
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.

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