Applying Marine Habitat Data to Fishery Management on the US West Coast: Initiating a Policy-Science Feedback Loop

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Copps, S.L., Yoklavich, M.M., Parkes, G., Wakefield, W.W., Bailey, A., Greene, H.G., Goldfinger, C., and Burns, R.W., 2007, Applying marine habitat data to fishery management on the US west coast: Initiating a policy-science feedback loop, in *Todd, B.J., and Greene, H.G., eds., Mapping the Seafloor for Habitat Characterization: Geological Association of Canada, Special Paper 47, p. ??-??.*

Abstract

Recent experience in implementing legal requirements to designate and protect Essential Fish Habitat for groundfish off the US west coast is providing an opportunity to develop a feedback loop between science and policy for habitat- and *ecosystem-based management that mirrors the traditional stock assessment/harvest management paradigm. The stock assessment/harvest management feedback loop dates back to the 1940s and has strongly influenced the development of the marine fishery management infrastructure and associated research programs. Assessment of marine habitat and the related establishment of regulatory policies by west coast fishery managers offer the potential for a similar feedback loop and the tailoring of research and infrastructure to improve the information available for decision-making.*

Résumé

Text

INTRODUCTION

The Magnuson Stevens Fishery Conservation and Management Act (MSA) establishes the framework for managing fisheries in the US Exclusive Economic Zone (EEZ). Broadly, the provisions of the MSA were developed to promote the sustainable use of fishery resources, resulting in increased long-term economic and social benefits to the nation. This requires maintaining healthy fish stocks and, in some cases, rebuilding overfished ones. Recent amendments to the MSA also require that Fishery Management Plans (FMPs) "describe and identify Essential Fish Habitat (EFH), minimize to the extent practicable adverse affects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat" (16 U.S.C. 1853(a)(7)). The MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (16 U.S.C. 1802 sec. 3(10)). Regulatory guidelines elaborate 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 (50 CFR 600 subpart J)."

The amendments have provided regional fishery management councils with an opportunity to explicitly incorporate fish habitat requirements, and, to some extent ecosystem requirements, into the management process. Due to its relative newness and complexity, consideration of fish habitat and the broader ecosystem within the fishery-management process presents many technical and policy challenges. Many of these challenges are caused by the lack of existing infrastructure to support spatially explicit, habitat-based fishery management.

The starting point for both management and conservation is to assess the status of the resource. Assessments are generally used to characterize the status of a population, relative to an idealized (either unfished or sustainably fished) population size, and to predict the response of a population to anthropogenic impact. Policy makers, in turn, use the assessments to set harvest quotas that are predicted to be sustainable. In the US, stock assessments for fish and mammal species are routinely developed using a body of scientific literature and systematic data collection from both fishery-dependent and fishery-independent surveys. These assessments form the scientific foundation of most marine resource management decisions under federal jurisdiction.

Statistical methods for the assessment of fish stocks, in particular, were in place by the 1940s (Ricker 1975), and have been continually improved upon since that time. The National Marine Fisheries Service (NMFS) and the resource management agencies of coastal states, along with their academic partners, maintain diverse data sampling programs that supply information to the stock-assessment process in the form of fishery dependent catch information from observers, logbooks, fish tickets, and angler interviews, as well as fish density, abundance, and life-history information from fishery-independent surveys. In traditional, single-species stock assessment-based fisheries management, catch, abundance, and life-history data are interpreted through models of population dynamics, the results of which flow into a management process to establish allowable harvest quotas (Figure 1). Additional ecosystem information on habitats, trophic dynamics, ocean and climate conditions, and human impacts other than direct harvest is not typically considered explicitly in these assessments.

Assessment of risks to the function of marine habitats (both in terms of fishery production and within the broader ecosystem) at the broad geographic scale that fisheries are prosecuted is comparatively new. Until the EFH requirements were amended to the MSA in 1996, there was no mandate to consider habitat function for a wide variety of species (over 80 species in the west coast groundfish fishery FMP) over the range of their distribution within US waters. Prior to the 1996 EFH amendments to the MSA, habitat protection focused on unique habitat types or on the requirements of single species in limited locations, rather than consideration of all federally managed species as required by the EFH amendments.

The intent of this paper is to highlight the parallel structure of the traditional stock assessment/harvest quota process and that of EFH or ecosystem management and draw conclusions related to the

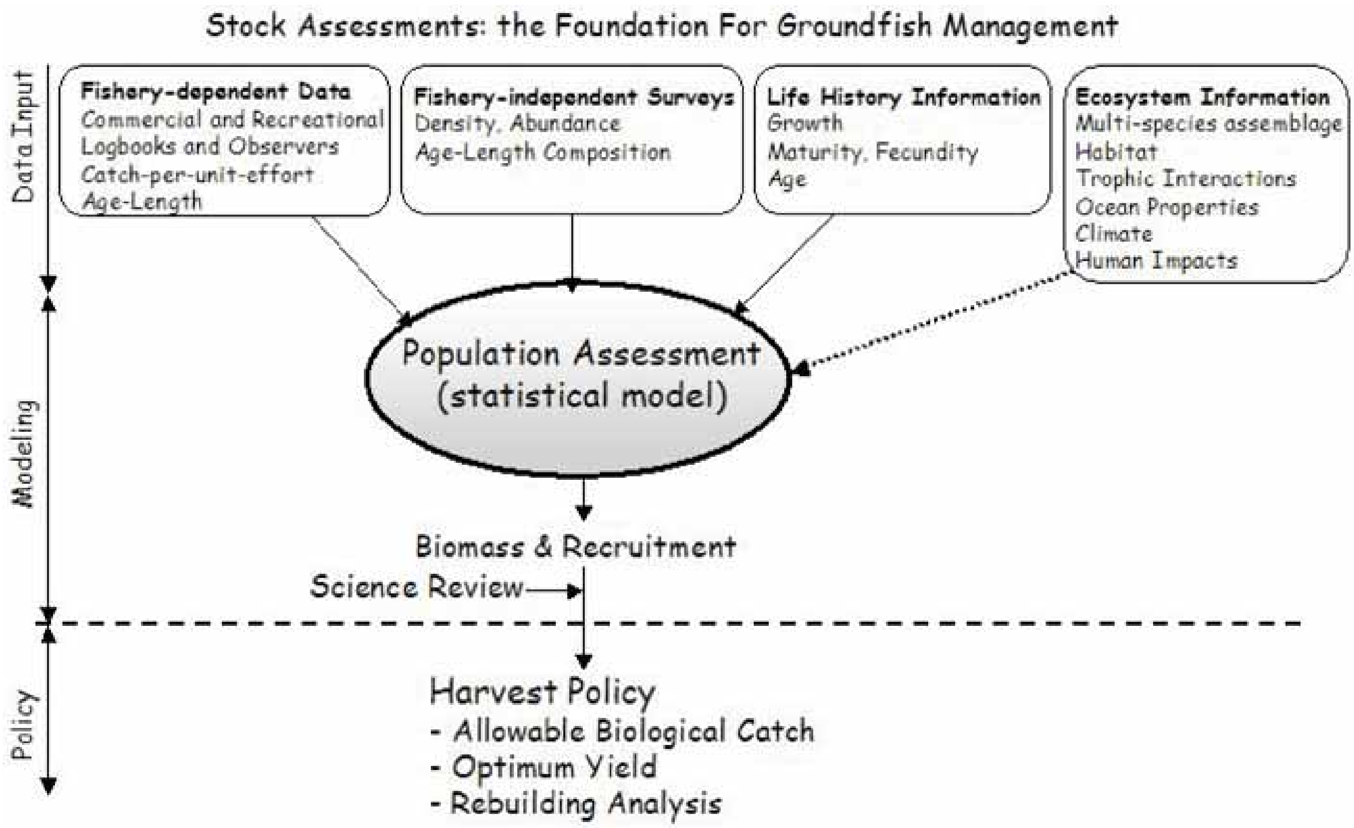

Figure 1. *The stock assessment process for US west coast groundfish includes three distinct components: data consolidation, modelling, and policy. Solid arrows indicate data flow into traditional single-species population assessments and resultant application to harvest policy. Dotted arrow indicates supplemental information that can be used to move toward ecosystem-based management (this figure has been modified from http://www.st.nmfs.gov/StockAssessment/StockAssessment.html and S. Ralston; NMFS Santa Cruz Laboratory).*

research and infrastructure necessary to support each. Heretofore, there have been limited or no opportunities to develop a feedback loop between assessment scientists and policy makers for EFH and the ecosystem. Recent experience from the west coast is summarized as a case study; in concept, such a feedback loop may be developed that would be used to structure decisions for building the necessary infrastructure and research programs to support habitat and ecosystem policy.

WEST COAST GROUNDFISH CASE STUDY: THE SCIENCE FRAMEWORK

The Pacific Fishery Management Council (the Council) developed a decision-making framework to guide a risk assessment and policy development process for groundfish EFH along the Pacific coast of the United States (Figure 2). The risk assessment shares two components that are common to stock assessments: data consolidation and modelling. Three models were developed for the risk assessment: EFH, Habitat Areas of Particular Concern (HAPC), and Impacts to EFH (both natural and anthropogenic). There is an important division between the scientific components of decision-making (*i.e.*, data consolidation and modelling) and the policy component, such that scientific advice is formulated in the absence of political influence. Additionally, as with stock assessments, social and economic decisions are considered in the policy component of the process. The risk assessment is designed to inform the policy process, with a clear articulation of the status of habitats (even if such status is unknown) and, if appropriate, a problem statement relevant to groundfish habitats. In this paper, the EFH model as it was applied to groundfish management decisions is summarized to compare new experience with the traditional stock assessment/harvest policy process.

Available Data for the EFH Model

In the data consolidation component of the risk assessment for west coast groundfish EFH, the best available ecological, environmental, and fisheries information was reviewed and incorporated into appropriate databases, in consultation with scientific advisory committees and agency scientists. Specific information was assembled into a Geographical Information System (GIS) and applied to the identification and description of EFH alternatives. This information includes:

- fish distributions;
- distribution of benthic substratum types (including maps on data quality in some areas);
- size and location of estuaries;
- distribution of canopy kelp;
- seagrass distribution;
- bathymetry;

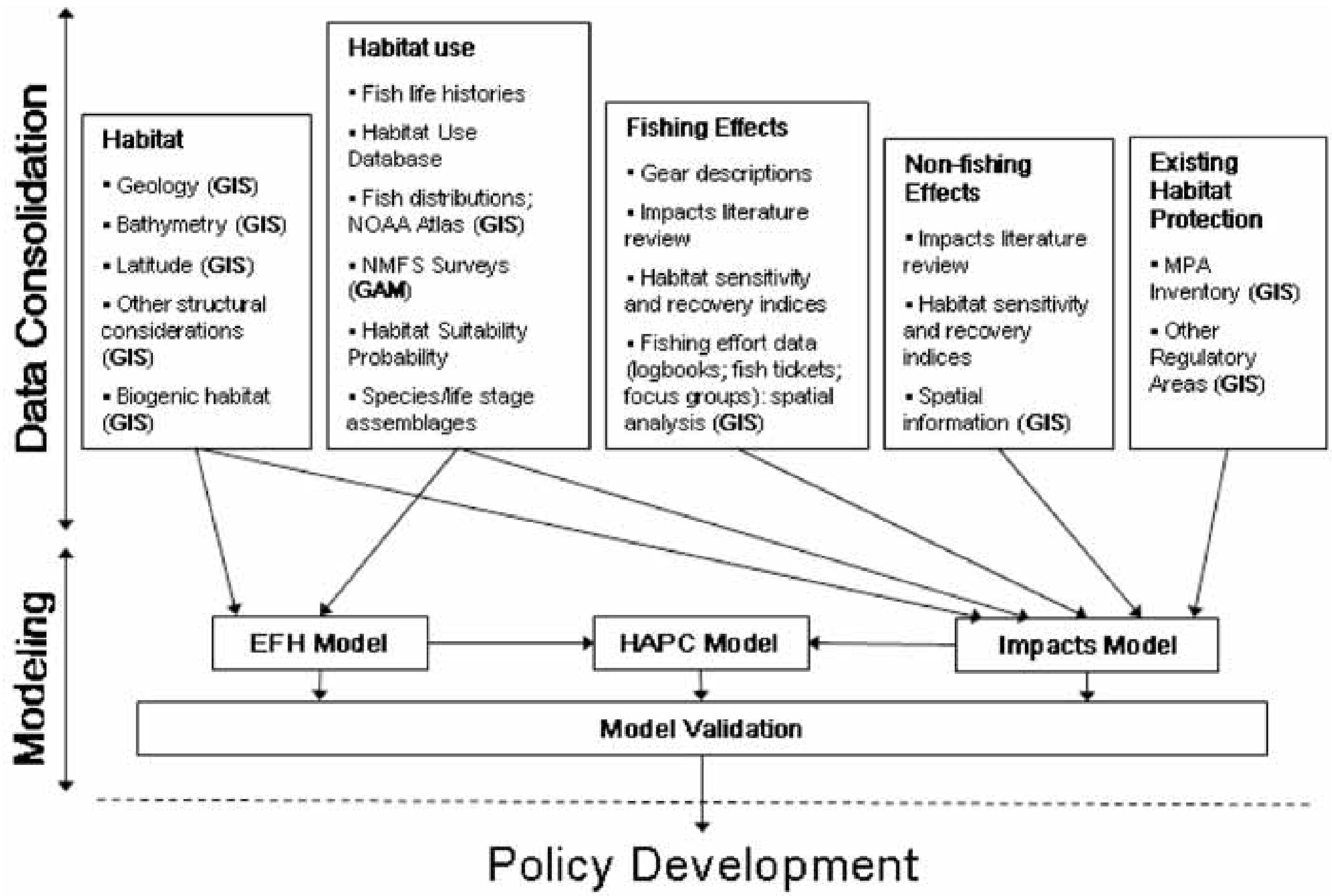

Figure 2. *Decision-making framework to guide the risk assessment and policy development for Essential Fish Habitat for groundfish on the US west coast (MRAG Americas* et al.*, 2004).*

! latitude; and
! distribution of some structure-forming invertebrates.

Also considered in identifying and describing EFH alternatives were data on:

! associations among groundfish species and benthic substratum types;
! life histories of groundfish species; and,
! a general description of pelagic habitats.

The ultimate goal was to delineate EFH in terms of its contribution to rates of growth, reproduction, survival, and production for the diverse group of groundfishes on the west coast. Currently, the present understanding of EFH for many of these groundfish species is based on limited presence/absence data for late-juvenile and adult stages of the fishes and their associated habitats. Data on habitat-specific densities are available for only a few species in a few locations, and there are even less data to evaluate habitat-specific productivity. Until the 1970s, surveys of benthic marine habitats and associated groundfishes were limited mostly to relatively shallow subtidal (<30 m water depth) observations, while most of the 82 west coast groundfish species and fisheries studied here occur in deeper water. Assessing attributes and functions of EFH remains especially difficult in deep-water marine environments because of increased expense and restricted access to this habitat.

Preliminary Habitat Suitability Models

To designate EFH for west coast groundfish, managers had to be provided with spatially explicit estimates of some metric that would enable them to make a choice about which portions of a species range might be designated as EFH. This was needed for a large number of species and their associated life-history stages (>300 when combined) occurring in a large geographic area (>80 million hectares). Virtually no information exists that quantifies the function of habitat for Pacific Coast groundfish. Therefore, a Bayesian Belief Network model was developed to characterize the probability that particular habitats were suitable for groundfish species (an introduction to Bayesian Belief Networks can be found in Jensen (1996); a more complete treatment can be found in Colwell *et al.* (1999)). This approach uses habitat suitability modelling based on the occurrence of fish in trawl survey catches, and published and unpublished habitat associations of groundfish. The model output, termed Habitat Suitability Probability (HSP), is based on associations of species and life stages with various habitat variables. The HSP is mapped via GIS to provide managers with a visual, quantitative framework for decision making.

Three main habitat attributes or variables are used in the EFH model to describe habitat conditions for groundfish off the west coast: depth, latitude (generally a proxy for water temperature at the seafloor), and substratum type. HSP is calculated from separate probabilities for each of these three variables, and also taking into account data quality as well as the interactions that might exist among the variables (*e.g.*, depth range of a species can vary with latitude). Together, these three variables provide a basis for predicting the HSP. The habitat polygon data are passed to the EFH model, which calculates the HSP values and returns them to the GIS data file to be mapped in the form of coastwide contour plots for each individual species life-history stage, where sufficient data exist to make credible estimates (Figure 3).

HSP is a measure of the likelihood that a habitat with given characteristics is suitable for a single fish species/life stage or for a species/lifestage assemblage. The measure of suitability is used in a predictive, probabilistic sense to infer that a species is more or less likely to occur in an area with known habitat characteristics, even though direct evidence of its occurrence from *in situ* observations is not available. In all areas, where the measure is greater than zero there is a finite probability that the fish will occur and therefore contain fish habitat. Whether or not this is Essential Fish Habitat, depends on management decisions about the threshold level of suitability, above which the habitat should be afforded the protection inferred by its identification as such.

The HSP maps (see Figure 4) provide the necessary contrast for managers to make informed decisions about the identification of EFH across all habitats where species occur. From a manager's perspective, the HSP is designed to be user-friendly and, with relatively minor technical support, is easily manipulated to investigate alternative policies. For example, it is possible to select those areas having HSP 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. The decision to adopt a particular definition of EFH could then 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 too broadly. Adopting a relatively narrow EFH definition may make it easier to develop effective precautionary mitigation alternatives.

Ongoing Research to Improve Quality and Quantity of EFH Data

There is a critical need for comprehensive, detailed, and accurate information on benthic habitats and associated groundfish assemblages on spatial scales relevant to fishery management and habitat protection. Development of more efficient and effective visual and acoustic methods to survey deepwater benthic habitats and fishes is ongoing, especially in complex, diverse habitats that are difficult to assess with conventional survey tools. Additionally, core nursery

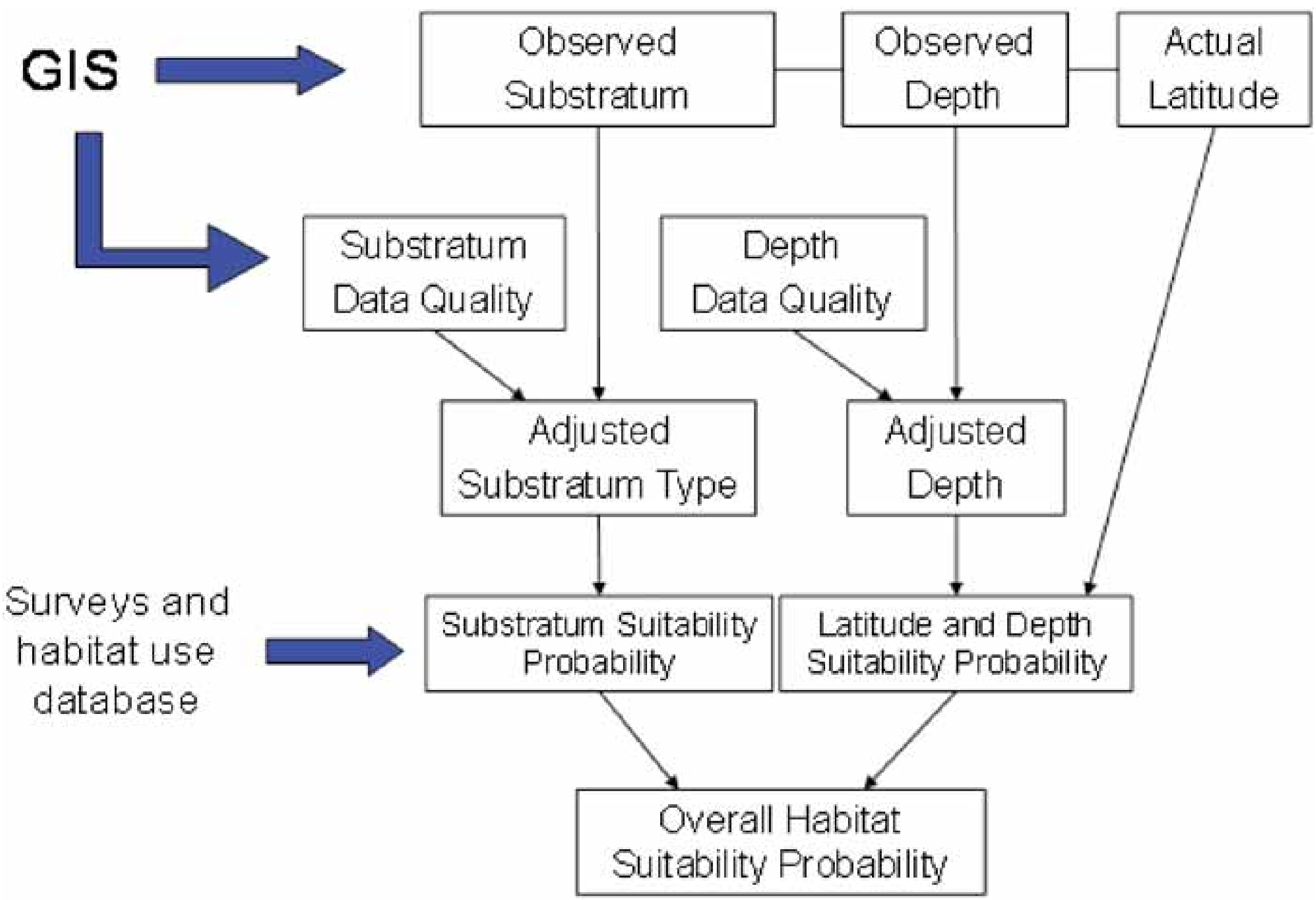

Figure 3. *Basic relationships among data components in the EFH Model.*

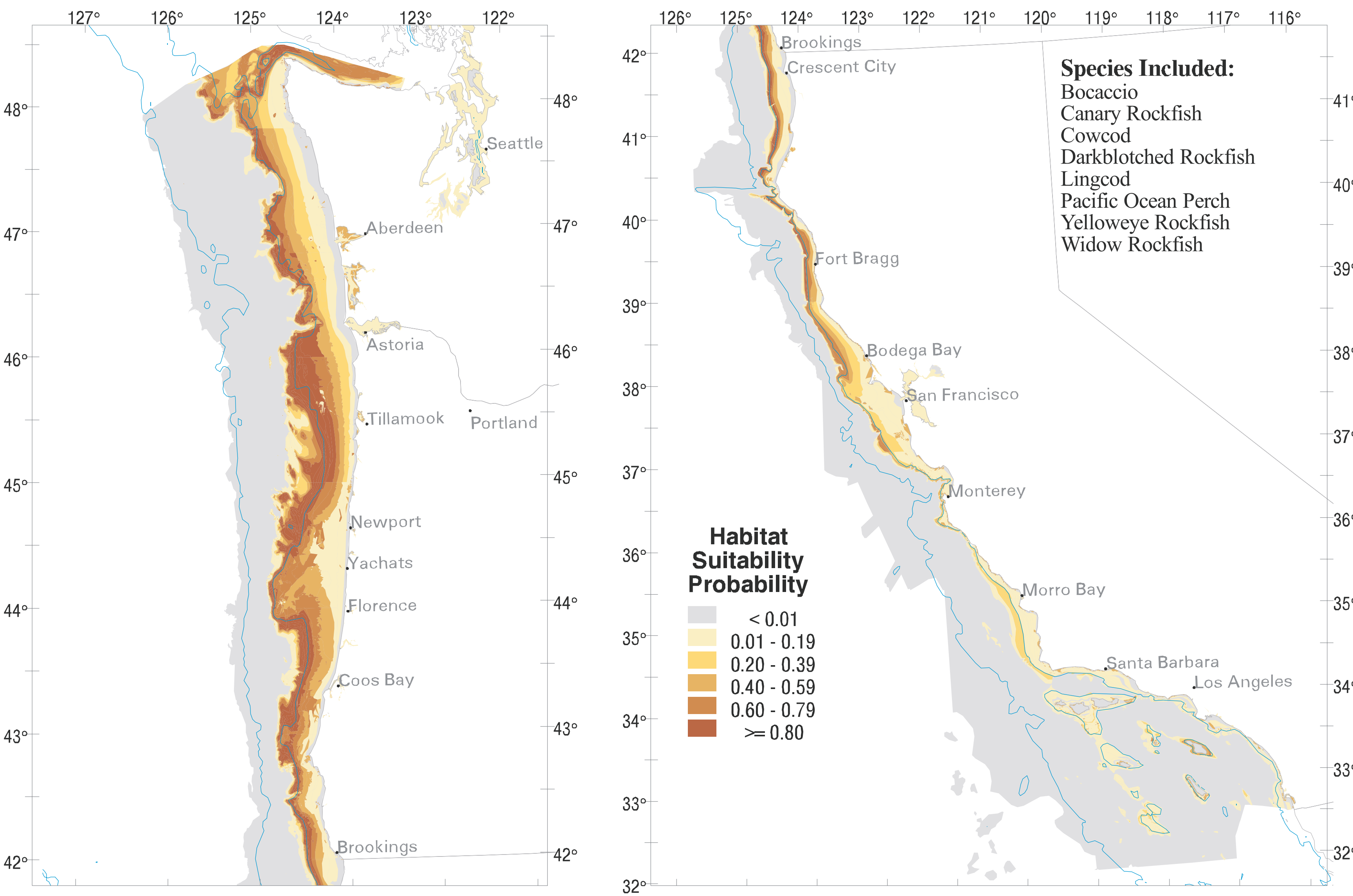

Figure 4. *Example output from the EFH model of habitat suitability at varying probability levels. The map depicts the maximum Habitat Suitability Probability (HSP) for the adult lifestage for the composite of eight overfished species, specifically, bocaccio* (Sebastes paucispinis), *canary rockfish* (S. pinniger), *cowcod* (S. levis), *darkblotched rockfish* (S. crameri), *lingcod* (Ophiodon elongatus), *Pacific ocean perch* (S. alutus), *yelloweye rockfish* (S. ruberrimus), *and widow rockfish* (S. entomelas). *The area encompasses marine and estuarine habitat off the coasts of Washington, Oregon, and California, from Puget Sound in the north to the southern California Bight. Depth contours of 200 m and 2000 m are indicated in blue.*

grounds and spawning areas for groundfish species, both benthic and pelagic, need to be identified, so that potential impacts to these areas can be considered. There is also a critical need to understand the relationship between large climate events and abundance, growth, spawning success, and survival of groundfish species.

Currently there are several efforts underway to create maps of seafloor habitats on the west coast, including those used here to identify EFH alternatives (Greene *et al.*, 2003; Goldfinger *et al.*, 2003; and, Romsos *et al.*, this volume). These efforts have been facilitated by the development of a unifying seafloor classification system for benthic habitats (Greene *et al.*, 1999, 2003). While these efforts represent a coastwide delineation of rocky and unconsolidated seafloor substrata, they are just the first step in describing, quantifying, and understanding benthic habitats throughout the entire range of groundfish species on the west coast. These databases and maps are currently considered preliminary because of varying levels of data quality and verification (groundtruthing), as well as the limited spatial coverage of some of the information. Detailed mapping of groundfish habitat has been accomplished in only a relatively few important areas, such as offshore banks of the southern California Bight (Goldfinger *et al*., 2005), Monterey Bay, California, and Heceta Bank, Oregon (Wakefield *et al.*, 2005), and is slowly being extended to other areas of the coast. It is absolutely imperative that the databases and maps be revised and improved on a regular schedule as new information is collected, as well as extended to incorporate change over time and oceanographic variability, and that these valuable baseline habitat maps be maintained and made easily accessible to the greater marine resources community. These data are critical not only in the identification of EFH but also in comparative risk assessment of anthropogenic (*e.g.*, fishing gears, pollution, dredging, *etc.*) and natural impacts (*e.g.*, tectonic, El Niño, and storm events) to these habitats.

Past research shows that settled juveniles and adults of many species of groundfishes, rockfishes in particular, are difficult (or impossible) to appraise accurately with traditional survey methods such as bottom trawl, (Zimmermann, 2003) fixed-gear, and acoustic surveys (Cooke *et al.*, 2003). This is due to the close association between many of these species and rugged, rocky heterogeneous habitats. Consequently, alternative techniques, using direct observation from *in situ* platforms (submersibles, ROVs, AUVs), advanced imaging technologies, such as laser-line scan systems and bioacoustic observations are being developed and applied to improve assessments over untrawlable habitat (O'Connell and Carlile, 1993; Jagielo *et al.*, 2003; Cooke *et al.*, 2003; Yoklavich *et al.*, 2003, 2004, and Wakefield *et al.*, 2005), characterize and conserve deepwater habitats (Yoklavich *et al.*, 2000), assist in designing and evaluating Marine Protected Areas (MPAs) (Yoklavich *et al.*, 2002), and track the recovery for some groundfish species. This approach is especially critical when focusing on benthic habitats of extreme heterogeneity and biological assemblages of high diversity.

Identifying EFH for pelagic stages of groundfish species is a critical line of research that is largely absent in the current EFH model. New technologies, such as airborne LIDAR, are being developed to identify near-surface pelagic stages of some species. Coastwide collection and modelling of relevant information, such as the multi-decadal databases developed from CalCOFI surveys of fish eggs and larvae and from mid-water surveys of newly recruited groundfishes and associated physical oceanographic aspects of habitat (*i.e.*, temperature and salinity from shipboard and satellite remote sensing), are ongoing efforts to better understand the relationship between the structure and function of pelagic habitats and the recruitment, survival, and productivity of managed fish species. Enhanced oceanographic monitoring systems are being developed to meet the need to understand species and climate/ocean interactions in affecting groundfish production.

Research on the distribution and function of structure-forming invertebrates, particularly as components of EFH for groundfish, is just beginning on the west coast (Tissot *et al.*, 2006). Ongoing research includes the systematics, distribution, and abundance of structure-forming invertebrates (particularly corals, sponges, anemones, sea pens, *etc.*) in deep water. A critical need is to understand the potential role of these species as a component of groundfish EFH in continental shelf and slope ecosystems. Because these large invertebrates provide structural components of fish habitat and are vulnerable to impacts by seafloor-tending fishing gear, they may represent HAPC and as such would be protected under the MSA.

Research on Anthropogenic Impacts to EFH

To date, the best available science on fishing impacts to benthic habitats has been limited to observations of modification to some physical and biogeochemical components of habitats and changes in the community structure (NRC, 2002; MRAG Americas *et al.*, 2004). Understanding functional impacts (*i.e.*, how physical modification of the ecosystem affects groundfish productivity) begins with baseline characterization and cataloging of habitats relevant to managed species.

The evaluation of impacts from fishing to EFH in the risk assessment described in this paper was based on sensitivity indices of various types of benthic habitats to disturbance or influence by various types of fishing gears, and on rates of recovery from such disturbances. These indices and rates were estimated from limited information, much of which derived from studies conducted outside our west coast region of interest (NMFS, 2005). A preliminary Bayesian Network "Impact" model (Figure 2) was developed to consider cumulative anthropogenic impacts to habitat (from fishing and non-fishing sources); however, this effort was hampered by a lack of data in several key areas including fine-scale fishing effort information and the relationship between fishing effort and ecological impact.

Some critical data and research needs, related to fishing impacts and groundfish populations, include:

- estimating rates of impacts of specific fishing gears on the diverse habitat types found on the west coast;
- routine collection of fishing effort data at a scale that allows spatio-temporal analysis of footprints from multiple fishing gears;
- estimating the rates of recovery for the full range of habitat types from both chronic and acute disturbances;
- quantifying population and ecosystem effects resulting from fishing impacts;
- describing trophodynamic changes related to fishing impacts;

- evaluating the role of MPAs in management of fisheries and habitats; and
- evaluating the influence of MPAs on production, rebuilding, and long-term sustainability of groundfish.

WEST COAST GROUNDFISH CASE STUDY: THE POLICY FRAMEWORK

In response to the mandates and scientific framework described in the preceding sections, the NMFS, on March 8, 2006, approved the Council's comprehensive 4-part strategy for EFH conservation including: (1) identification and description of EFH; (2) designation of HAPC; (3) measures to minimize adverse effects from fishing to EFH; and, (4) research and monitoring. The strategy was designed to take advantage of the best available information with precautionary adjustments where appropriate. The Council will have ongoing opportunities to adapt management plans as new information becomes available. A brief summary of the action follows.

EFH

Essential Fish Habitat is identified as 100% of the area where HSP is greater than zero for any species and any additional area in depths less than or equal to 3500 m (Figure 5). By including areas out to 3500 m water depth, this EFH definition includes all habitats where groundfish occur with the addition of 100 m depth as a precautionary adjustment in case of unobserved fish.

HAPC

Seagrass, canopy-forming kelp, rocky reefs, estuaries, and specific areas of interest (*e.g.*, seamounts, banks, canyons, *etc.*) are designated as HAPC. A map of HAPC is provided in Figure 6.

Measures to Minimize Adverse Impacts from Fishing

A suite of gear restrictions and area closures is being implemented to minimize adverse impacts to EFH from fishing. The following gear would be prohibited: dredge gear; beam trawl gear; bottom trawl roller gear greater than 19 inches; and, bottom trawl roller gear greater than 8 inches shoreward of 100 fathoms. Area closures would be distributed throughout the EEZ and apply to specified gear types as shown in Figure 7.

CONCLUSIONS

Geologists and fish ecologists have a new opportunity to learn from the application of habitat data to management decisions. For the US west coast, habitat data have been applied in a geographically comprehensive assessment that was tailored specifically to support management decisions. The assessment was designed to be "user-friendly", thereby influencing the design of the model and output. The spatially explicit probability profiles of habitat suitability that have resulted from this assessment have now been used by managers to identify EFH. Just as important, however, experience has been gained on the West Coast in organizing ecosystem data, specifically for management decisions, the results of which can feed back into tailored data collection programs.

At the scale of the Pacific Coast EEZ, it is perhaps surprising to realize how little is known about habitat and its function for fishes and the ecosystem. While a coastwide assessment of probable habitat suitability for groundfish is an impressive achievement, it is informative primarily at the most basic level. That is, it provides managers and researchers with the likely locations of suitable habitat, but does not predict the results of policy decisions in terms of fishery or ecosystem response. This limitation in knowledge has resulted in the application of precautionary management principles to regulate human activities when both the risk of inaction versus the effects of the regulations are not fully understood.

Researchers who will be implementing future habitat-related data collection programs can benefit from feedback provided by managers. Habitat data can be expensive to collect, particularly in deep offshore environments where ship time and sophisticated instrumentation are necessary. To justify such expenditures, it is useful to think of traditional stock assessments and their supporting data programs as a model that is compatible with, and exportable to, EFH and ecosystem management. In stock-assessment processes, data collection programs have been developed specifically to function in the assessment and policy process. The developing discipline of habitat studies can now take advantage of a similar approach, whereby data collection is cast in terms of EFH assessment and habitat- and ecosystem-based management.

ACKNOWLEDGMENTS

We would like to thank the Pacific Fishery Management Council family for inspiring careful consideration of habitat and ecosystem issues in fisheries management. The Council's *ad hoc* Groundfish Habitat Technical Review Committee (TRC) merits singular recognition for fostering good ideas and discarding the bad ones. The following people have served on the committee: Tim Athens, Rod Fujita, Chris Goldfinger, Gary Greene, Marion Larkin, Marc Mangel, Scott McMullen, Mark Powell, Waldo Wakefield, and Mary Yoklavich with additional support provided by Tom Jagielo, Milton Love, Hal Weeks, and Mark Wilkins. The authors are indebted to Andy Rosenberg for his guidance, wisdom, and compassion. And special thanks to Gretchen Arentzen, Joe Bizzarro, Randy Fisher, Colin Grayer, Churchill Grimes, Jane Hannuksela, Milton Love, Bruce McCain, Rick Methot, Stacey Miller, Steve Murawski, Steve Ralston, Bill Robinson, and Chris Romsos for their individual contributions to our work. Stephen Smith (Fisheries and Oceans Canada) and Frank Zimmermann (National Marine Fisheries Service) reviewed an earlier version of the manuscript and provided invaluable comments.

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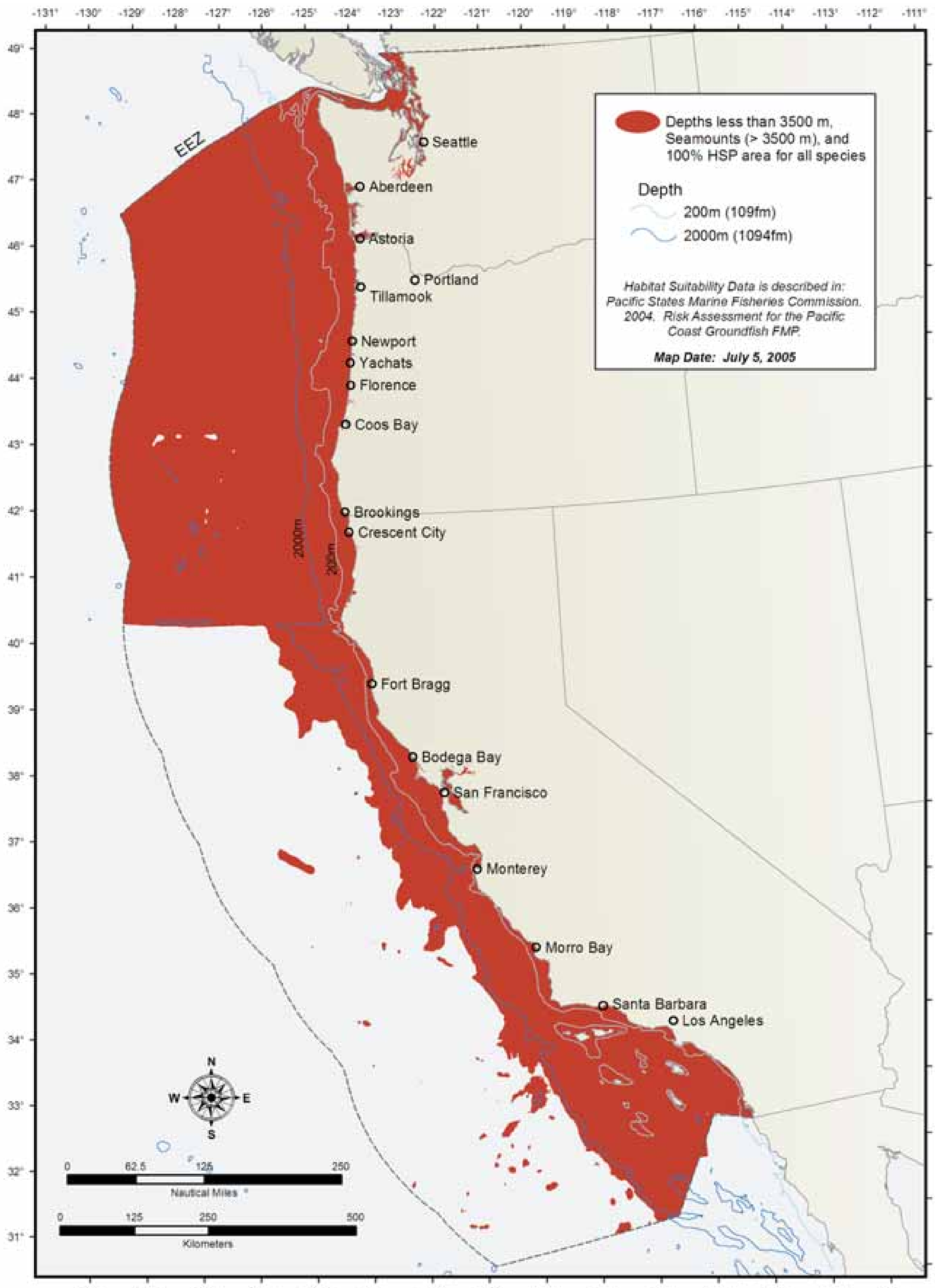

Figure 5. *Map of Essential Fish Habitat for groundfish off the US west coast.*

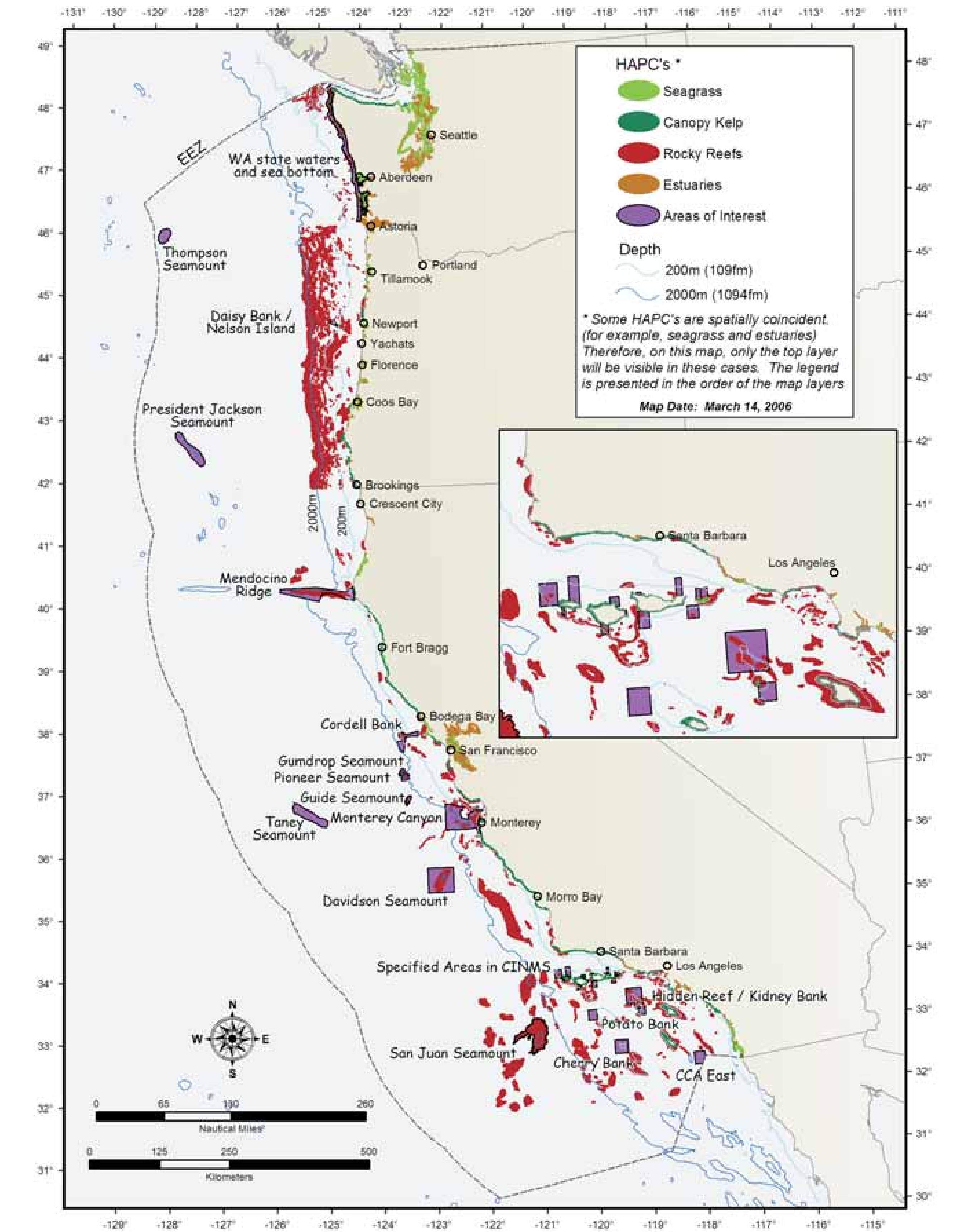

Figure 6. *Map of Habitat Areas of Particular Concern for groundfish off the US west coast.*

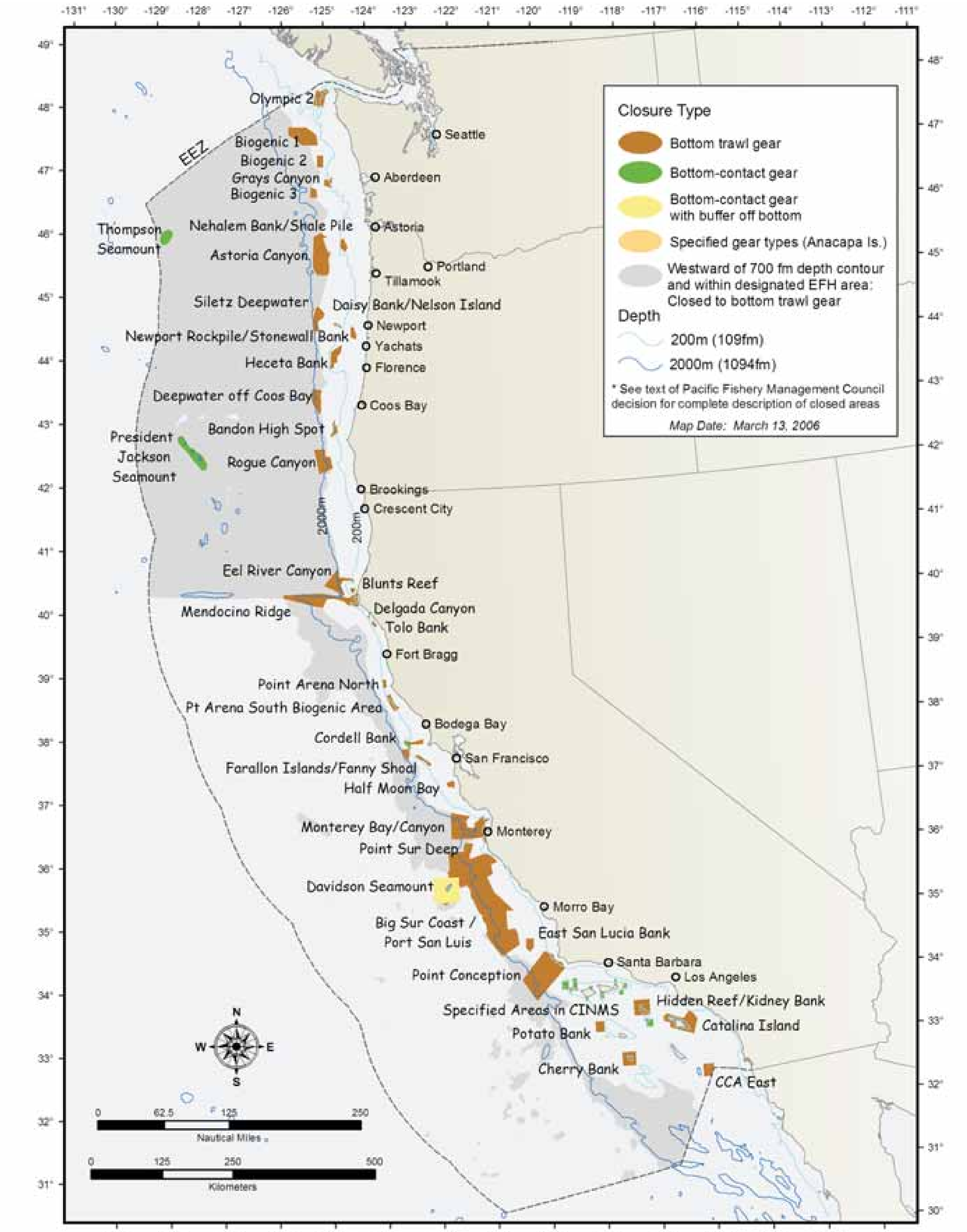

Figure 7. *Map of area closures to protect EFH for groundfish off the US west coast.*

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