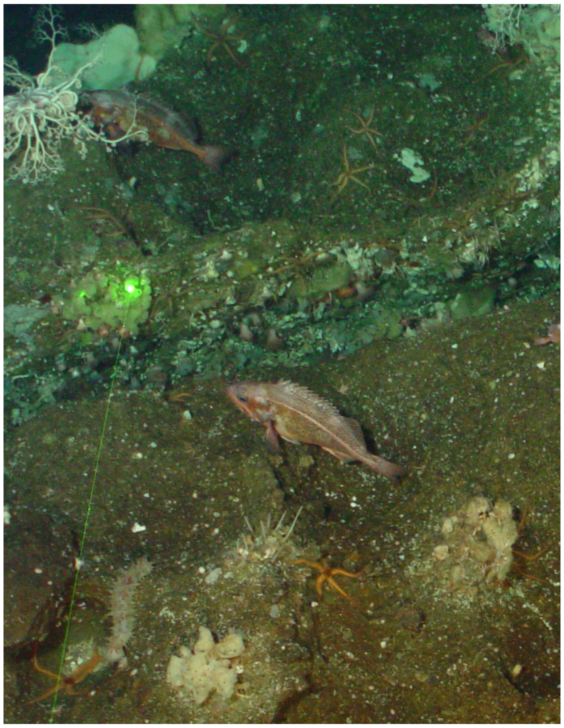
Groundfish Essential Fish Habitat Synthesis:

A Report to the Pacific Fishery Management Council

April 2013



NOAA FISHERIES

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This document should be cited as:
National Marine Fisheries Service (NMFS). 2013. Groundfish Essential Fish Habitat Synthesis: A Report to the Pacific Fishery Management Council. NOAA NMFS Northwest Fisheries Science Center, Seattle, WA, April 2013. 107 p.

This document is published by the National Marine Fisheries Service.

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ABOUT THE REPORT

Because the amount of information in the *Phase 1 Essential Fish Habitat Report* (Phase 1 Report) and its companion, *Groundfish Essential Fish Habitat Synthesis: A Report to the Pacific Fishery Management Council* (Synthesis Report), may be daunting, we present some approaches for using the Synthesis Report in both developing and evaluating future proposals to change Essential Fish Habitat (EFH) boundaries.

The NMFS Synthesis Report is not a comprehensive EFH analysis, but rather provides summaries and some interpretation of newly available information that supplements previous EFH work and can be used by stakeholders to assess and propose changes to existing spatial management boundaries. The report is intended to set the stage for proposals to articulate any perceived need for changes and to lay the groundwork for Groundfish EFH Request for Proposals. We provide five types of analyses or summarizations: a) the spatial distribution of physical and biogenic habitats of the West Coast across bioregions, depth zones, and areas with different regulatory protections; b) the association of representative species with habitat characteristics including depth, temperature and substrate; c) the distribution of fishing and non-fishing threats across habitat types; d) analyses of the overlap of high likelihood of species occurrence and threats to habitat; and e) a summary of the diets of select groundfishes.

All documents, as well as the underlying data layers for the Synthesis Report, are available online:

- Phase 1 Report:
  www.pcouncil.org/groundfish/background/document-library/pacific-coast-groundfish-5-year-review-of-efh/
- Synthesis data layers and data developed during Phase 1:
  http://efh-catalog.coas.oregonstate.edu/synthesis
- Groundfish EFH Environmental Impact Statement (2005):
  www.nwr.noaa.gov/publications/nepa/groundfish/final_groundfish_efh_eis.html.
- Synthesis Report:
  www.pcouncil.org/
- Synthesis Report Appendix:
  www.pcouncil.org/

Using this Report

Below are suggestions for using the Synthesis Report with respect to EFH consideration.

- **Read this document, look closely at both the Phase 1 Report and Synthesis Report, and consider information from the original groundfish EFH EIS.**

  A primary purpose of the Synthesis Report is to provide summarized data that are useful to the development of proposals for changes to EFH and/or regulatory measures to minimize adverse effects to EFH. We have worked to lay out our analyses sequentially; they should form the foundation of proposals. For topics that are not considered in this report, the Phase 1 Report and the initial EIS contain useful information.

- **Look at the distribution of habitats in areas with and without protections.**

  Different types of habitats (by depth, by substrate type, by biogeographic region) are differentially subject to fishing regulations and other protections. A logical argument for any change in EFH or related spatially-driven protections includes an articulation of the relative amount of different types of protected and unprotected habitat.

- **Assess protections relevant to individual species.**

  We focused on 6 ecologically distinct groundfish species that were selected to be generally representative of the west coast groundfish complex. Our analyses reveal that virtually all the marine habitat along the U.S. West Coast is likely to have a high probability of occurrence for the subadult through adult stage of at least one of these species. [Note that since species are not distributed randomly, we use the probability of occurrence based on habitat characteristics as a proxy for habitat preferences.] Moreover, the value of all areas will likely increase as additional life stages and species are more quantitatively considered. Because species are distributed across habitat types, any difference in protections among habitat types will have varying impacts on species, depending on their affinity to particular habitats. In some cases, such as when a species is subject to very little fishing pressure or other non-fishing stressors, this variance may be acceptable, at least to some stakeholders. Alternately, stakeholders may feel that protections for habitats where certain species are likely to be found are insufficient. Examining: a) the habitat characteristics associated with particular groundfish species; and b) the protections for habitats of those types (as described above) provides a first cut at whether particular species are likely to be affected by the differences in habitat protections.

- **Identify areas of low and high impacts from fishing and other stressors.**

  Current levels of impact from both fishing and other threats to habitat can affect the degree of risk or protection that is tolerable to stakeholders or the Council. For example, areas or habitats that are relatively unaffected by human activities may be in little need of additional EFH-related protection; however, if such areas are important for some species, they might be protected now to prevent future degradation. Some habitats or areas subject to both high fishing pressures and high levels of other impacts could be considered for regulations to improve the overall quality of the habitat.

- **Assess the correspondence of threats with habitats among species.**

  Ultimately, it is the combination of habitat type, the probability of seeing a species in that habitat, and the threats to which a habitat is subjected, that should inform decisions about changes to existing EFH protections. Protecting areas in which there is a low probability of occurrence for a particular species will have little impact on the long-term persistence and productivity of a species. Thus, probability of occurrence, and associations of species with habitat characteristics can be used to prioritize areas for species of particular concern. The combination of current ecological importance and fishing pressure allows stakeholders to evaluate how much 'important' habitat has fishing protection. The inclusion of non-fisheries stressors allows consideration of the suitability of areas for protection. For example, managers may choose to protect areas of the highest quality by prioritizing areas subject to low levels of pollution over areas with high levels of these threats. Or, they may determine that non-fishing threats are so great in some areas that reductions in fishing pressure might be needed to maintain the health of the species. Our 'occurrence by exposure' graphs provide a means of gauging how much total habitat is and is not protected where there is a high probability of finding a species.

- **Consider the major prey species of groundfish only when proposing prey-based changes to EFH.**

  The definition of EFH includes waters and substrate necessary to fish for feeding, and the presence of prey makes waters and substrate function as feeding habitat. Therefore, activities, both fishing and non-fishing, that reduce the availability of a major prey species, either through direct harm or capture or through adverse impacts to the prey species' habitat, may be considered adverse effects on EFH if such activities reduce the quality of EFH. While abundant prey can be an important component of EFH, the prey species themselves cannot be designated as EFH. In addition, EFH cannot be designated for prey species that are not managed by the Council.

  In this synthesis, we reviewed the available quantitative data for a representative subset of groundfish species and identified their major prey species, with greater taxonomic resolution than in the 2005 EFH designation process. Proposals that address prey abundance and availability (i.e., the quality of the foraging habitat) should focus on these major prey types, at this taxonomic resolution.

Conclusions

Below are some noteworthy conclusions that can be drawn from the data.

- ***Other sources of data are important.***
  Our analyses did not consider young-of-the-year juveniles or biogenic habitat other than corals and sponges. Information in the 2005 compilation of information for groundfish EFH designation is therefore still relevant. Similarly, the HSP designations made in that effort may be useful for considering habitats potentially important for all life stages.

- ***Areas in which there is a high probability of occurrence vary among species; all areas are likely important when the entire assemblage of 91 groundfishes is considered.***
  Overall, habitat areas important for each of the six representative species do not necessarily coincide; thus together, they cover virtually all locations along the coast. Identifying single areas that are important for all species is unlikely, and defining spatial management boundaries may involve prioritization and trade-offs. [Both models in this report rely heavily on bottom trawl survey data, although one also included visual survey data.]

- ***Areas with fishing protections vary geographically.***
  A large proportion of all habitat along the U.S. West Coast is included in EFH conservation areas. However, the bottom trawl closure of seabed seaward of 700 ftm accounts for the majority of the conservation area; ~10% of the upper slope and shelf areas have such protections.

- ***Fishing effort is disproportionate geographically.***
  Fishing pressure from federally observed groundfish fisheries is highest in the Northern region, and is heavily concentrated on the upper slope and shelf over soft habitats along the entire coast.

- ***Patterns of fishing pressure have remained moderately stable over the previous decade, but have likely varied over longer time periods.***
  Areas designated as EFH conservation areas tend to be areas that had relatively low fishing pressure from the groundfish fishery for several years before Amendment 19 was implemented, which established EFH boundaries and conservation areas in 2006, and continue to have relatively low fishing pressure. However, many of those areas may have received greater fishing pressure before the 2000 trawl footrope restriction and the implementation of Rockfish Conservation Areas. There does appear to be some displacement of trawling activity from the RCAs to areas more seaward.

- ***EFH conservation areas protect some groundfish species from fishing more than others.*** The proportion of habitat where there is a high probability of occurrence for one of six representative groundfish species that is also included within an EFH conservation area varies widely among species. Those species that occur in rocky or deeper areas (yelloweye rockfish, sablefish, and longspine thornyhead) have a relatively higher proportion of their 'high probability' habitat included within the EFH conservation areas than fish that are generally found in shallower or softer habitats (petrale sole, greenstriped rockfish, darkblotched rockfish).

- ***Fishing pressure was high in high-probability habitat for adults of some groundfish species but not others.***
  Species vary in the coincidence of habitat suitability and fishing pressure from the groundfish fishery. Sablefish has the highest proportion of areas that are heavily targeted by the fishery and also have a high probability of occurrence. Petrale sole has high probability of occurrence and high fishing pressure near the mouth of the Columbia River (Washington/Oregon border) and near San Francisco, California, but areas of lower fishery pressure (from federally observed fisheries) near shore. The estimated threat to yelloweye rockfish is generally low since yelloweye have a high probability of occurrence only in areas with a low exposure to bottom trawl fishing.

- ***Habitat areas of particular concern (HAPCs) are more exposed to high non-fisheries pressures than other areas.***
  On average, HAPCs and non-HAPC areas are similar in the total level of non-fisheries threat experienced. However, both cumulatively and with respect to individual threats, HAPCs have a greater proportion of areas exposed to 'high' non-fisheries threats than were present in non-HAPC areas. This is largely due to HAPCs in shelf areas exposed to land-based threats, and their selection to address non-fishing impacts.

- ***The level of taxonomic diversity of prey was significantly improved for 11 groundfish species over the level of information presented in the Phase 1 Report.***
  However, quantitative information on diet composition is limited for most of the other 80 species in the groundfish FMP. Additional studies are needed to establish trophic linkages for these species throughout the California Current system.

- ***Current EFH conservation areas protect many deep-sea coral and sponge habitats, but additional areas remain open to some or all bottom contact gears.***
  There are numerous sites outside EFH conservation areas where corals and sponges have been observed in relative high abundance; the known distribution of corals and sponges is heavily influenced by how they are sampled.

- ***Diet composition differed substantially among these 11 groundfish species.*** Such information should not be combined among species for subsequent analysis.

***Next steps for future habitat-related analyses include (but are not limited to)*:**
1) determining the coincidence of non-fishing pressures and high-probability habitats;
2) quantifying key prey species for remaining 80 species of FMP groundfishes; 3) evaluating habitat associations for key prey species; 4) further evaluating the association between groundfishes and biogenic habitats; and 5) incorporating community metrics (such as diversity) into habitat association models. In addition, impacts of climate change are expected to cause shifts in the locations of preferred habitats for different species due to changes in temperature, dissolved oxygen, or acidity, and future reviews of EFH should evaluate the potential need to change EFH designations to accommodate such habitat shifts.

1.0 INTRODUCTION

This report provides summaries and characterizations of information developed during Phase 1 of the EFH 5-year review (2012). It is not intended as a full EFH analysis, but rather, to provide supporting and contextual information for those making proposals or evaluating proposals in Phase 2. There are a variety of aspects that are not addressed in this work, including the importance of juvenile habitat and the association of groundfishes with biogenic habitat. Thus, information previously developed to support the 2005 EFH EIS is still relevant.

In this document, we provide an analysis of habitat associations for six representative species, using the NWFSC trawl survey data as a primary input, coupled with a range of environmental parameters. It also incorporates some information from visual surveys in rocky areas. Because it uses these recent data, this analysis reflects current distributions of these species and characteristics of the habitats they currently occupy, and projects those associations in areas that have not been sampled. It is an empirically based assessment of the likelihood of finding a species at a particular location under current conditions.

For the 2005 EFH EIS, an analysis termed the Habitat Suitability Probability (HSP) that also produced distributional maps was conducted. That analysis was based on habitat mapping, the Habitat Use Database (a multidimensional relational database of species and life stages related to substrate types), the literature, and was moderated by expert opinion. It presents a depiction of potential or idealized distribution, independent of current conditions – it estimates the intrinsic potential for a particular habitat to support each species. When using these analyses to support or evaluate proposals, stakeholders, managers and scientists should keep the different approaches in mind.

1.1 PURPOSE AND GOALS

The Sustainable Fisheries Act requires federal agencies to designate specific areas within the range of Council-managed species that are essential to population persistence. These areas are known as ‘‘essential fish habitat’’ (EFH), and include ‘‘waters and substrate necessary to fish for spawning, breeding, feeding and/or growth to maturity.’’ The Pacific Fisheries Management Council is conducting a 5-year review of current EFH for Pacific Coast groundfishes along the U.S. West Coast.

The goal of this report is to synthesize the existing, spatially explicit data about habitat, species’ distributions, fishing effort, and non-fisheries pressures for West Coast groundfishes to provide information germane to evaluating spatial management boundaries. In a Phase 1 effort, the PFMC Essential Fish Habitat Review Committee and NMFS scientists updated and compiled available ecological, habitat, and fishing effort data, and used this information to develop a set of maps intended to support Council decision making related to EFH. This document represents an effort to distill the large volume of data provided in the Phase 1 Report into a format that will facilitate effective use by the Council and its stakeholders as they consider revising current EFH designations. We were unable to deal with all aspects of habitat that we would have liked, so associations between groundfishes and biogenic habitat and habitat preferences of YOY juveniles are not treated in this document. .

In an ideal world, analyses supporting spatial management decisions would use relationships between habitat characteristics and species' fecundity, growth and survival over all life stages. These relationships could then be used to project species status (abundance, productivity, spatial structure, and potentially diversity) in a spatially-explicit modeling framework that also includes the impact of various stressors (fishing, noise, pollution, etc.) in order to identify the quantity, location and types of habitats needed to support populations meeting management targets for sustainability and harvest. Unfortunately, the relationships between vital rates and habitat are almost universally lacking for the groundfish species in this FMP. In their absence, we have organized our report around a series of questions designed to allow managers and other stakeholders to assess whether there is a bias in areas protected geographically or with respect to species and to evaluate the relative proportions of habitats for each species that are subject to spatial management. Again, we focus on the adult life stage, as the stage for which new information is available.

- **Section 2.0 – Habitat Distribution**. In this section, we evaluate the distribution and abundance of physical and biogenic habitat on the U.S. West Coast, as updated in the Phase 1 report. It does not include updates to the distribution of macro-algae or eelgrass, which were not available. Specifically, we ask how much area of each habitat type is subject to fishing restrictions, and whether there are any apparent biases in the types of habitat protected.
- **Section 3.0 – Species-Habitat Associations**. This section describes the results of two analyses using fish distribution data coupled with physical habitat information to identify areas with high likelihood of species-specific presence. We asked what the probability of finding each of 6 groundfish species across the West Coast is, and what habitat characteristics have the strongest association with each species' presence.
- **Section 4.0 – Stressors**. Both fishing and non-fishing stressors are included in this section. We describe the distribution of fishing, pollution and other stressors for groundfish across the West Coast, asking where threats are concentrated, and whether there is a bias in the type of habitats affected by these threats. In addition, we ask whether fishing patterns have changed in response to spatial regulations put in place in 2006.
- **Section 5.0 – Probability of Occurrence, Exposure to Fishing Pressure, and Spatial Management**. In this section, we evaluate each "pixel" (2x2km square) along the West Coast with respect to joint fishing pressure and its suitability for each species. This analysis asks how much habitat appears to be important for each species and is it also

subject to high or low fishing pressure. We also look at how pressures have changed before and after the designation of EFH conservation areas under Amendment 19.

- **Section 6.0 – Prey Species of West Coast Groundfish**. This section updates the prey matrix in the Phase 1 report to include more taxonomic specificity for 11 important groundfish species. It is independent of the other work in this report, but provides greater clarity about which prey species are particularly important within groups such as small schooling fishes for groundfish. A next step may be to evaluate preferred habitats for key prey species.
- **Appendix** – Methods, expanded results, and additional supporting materials for all sections are detailed in corresponding sections of the Appendix.

This information can be used in a variety of ways. Probability of occurrence, and associations of species with habitat characteristics can be used to prioritize areas for species of particular concern. The combination of current occupancy and fishing pressure informs an evaluation of how much "important" habitat has protections. The inclusion of non-fisheries stressors allows consideration of the suitability of areas for protection – managers may choose to prioritize areas subject to low levels of pollution for highest protection, for example, over areas with high levels of these threats in order to maintain areas of the highest quality. Or, they may determine that non-fishing threats are so great in some areas that reductions in fishing pressure might be needed to maintain the health of the species. This work uses up-to-date seafloor habitat mapping, distribution of threats, and species distribution and abundance information from the annual groundfish bottom trawl survey.

1.2 GEOGRAPHIC UNITS EVALUATED: BIOGEOGRAPHIC REGIONS

In order to be able to evaluate habitat distribution and impacts in an ecologically meaningful way, we divided the West Coast into 10 geographic and depth regions, based on biogeographic considerations and depth zones. The biogeographic provinces included the Northern, Central, and Southern coastal areas, along with the Salish Sea. These provinces were selected with an eye toward oceanographic similarities and potential for larval exchange between regions. The Northern and Central provinces were divided at Cape Mendocino, the most prominent headland in California. Cape Mendocino is known to have distinctive oceanographic features such as strong upwelling and cyclonic eddies (Hayward and Mantyla 1990, Magnell et al. 1990), which may act to reduce larval exchange between the provinces and to create phylogeographic breaks (Kelly and Palumbi 2010). Point Conception separated the Central and Southern provinces. This area is widely recognized as an oceanographic convergence zone in which the temperate, southward flowing California Current meets the subtropical Southern California eddy. It is also thought to represent a significant phylogeographic break point for a variety of marine species (Pelc et al. 2009). The final biogeographic province, the Salish Sea, is a semi-enclosed body of marine water subject to strong terrestrial influences from several urban centers (including Vancouver, Canada, and Seattle, Washington, USA) and distinguished by an oceanographic regime unique from the rest of the West Coast (Sutherland et al. 2011). We also included three depth zones: a) Shelf (coastline to continental shelf break), b) Upper Slope (shelf break to 700 ftm, which is the shoreward boundary of the "Bottom Trawl Footprint Closure"), and Lower Slope (700ftm to the EEZ seaward boundary) (Figure 2.1).

We also examined habitat with respect to spatial management boundaries. There are many spatial management designations in the U.S. West Coast marine waters relevant for groundfish. The largest designation is EFH (Figure 1), which is designated to include ''waters and substrate necessary to fish for spawning, breeding, feeding and/or growth to maturity.'' In our region, it encompasses most marine habitats including waters and substrate out to 3,500 m water depth and seamounts deeper than 3,500 m. It does not carry with it any mandatory regulatory implication, other than that NMFS will consult on activities that affect such habitat. Habitat areas of particular concern (HAPCs) are a subset of areas within EFH that are noted to be of special importance. They also carry no regulatory requirements, but in this region are used to alert other entities that these areas are important when they are designing projects in those areas. Amendment 19 of the Groundfish FMP established permanent conservation areas (Marine Protected Areas), in which fishing is regulated – entirely prohibited in some, and restricted to various types of gear in others. In addition, Rockfish Conservation Areas, which are not part of EFH, but rather implemented under the overfishing provisions of the Act, change through space and time, and typically regulate the use of specific gear in areas of importance to species subject to overfishing. Finally, states and other entities (e.g. Marine Sanctuaries) can implement fishing regulations in areas under their jurisdiction. For this synthesis, we developed three sets of "protected" areas:

- Only the 51 EFH conservation areas established in Amendment 19. These are referred to in this document as "EFH conservation areas." Some fishing is allowed in much of these areas.
- All areas in which bottom trawl, mid-water trawl and/or fixed gear is prohibited.
- All MPAs where commercial fishing is either "prohibited" or "restricted," based on the definition and classification system developed by the NOAA's National MPA Center (NMPAC, 2012).

We primarily focus on the first (EFH conservation areas established in Amendment 19) in this document; future work will look at the other sets in greater depth.

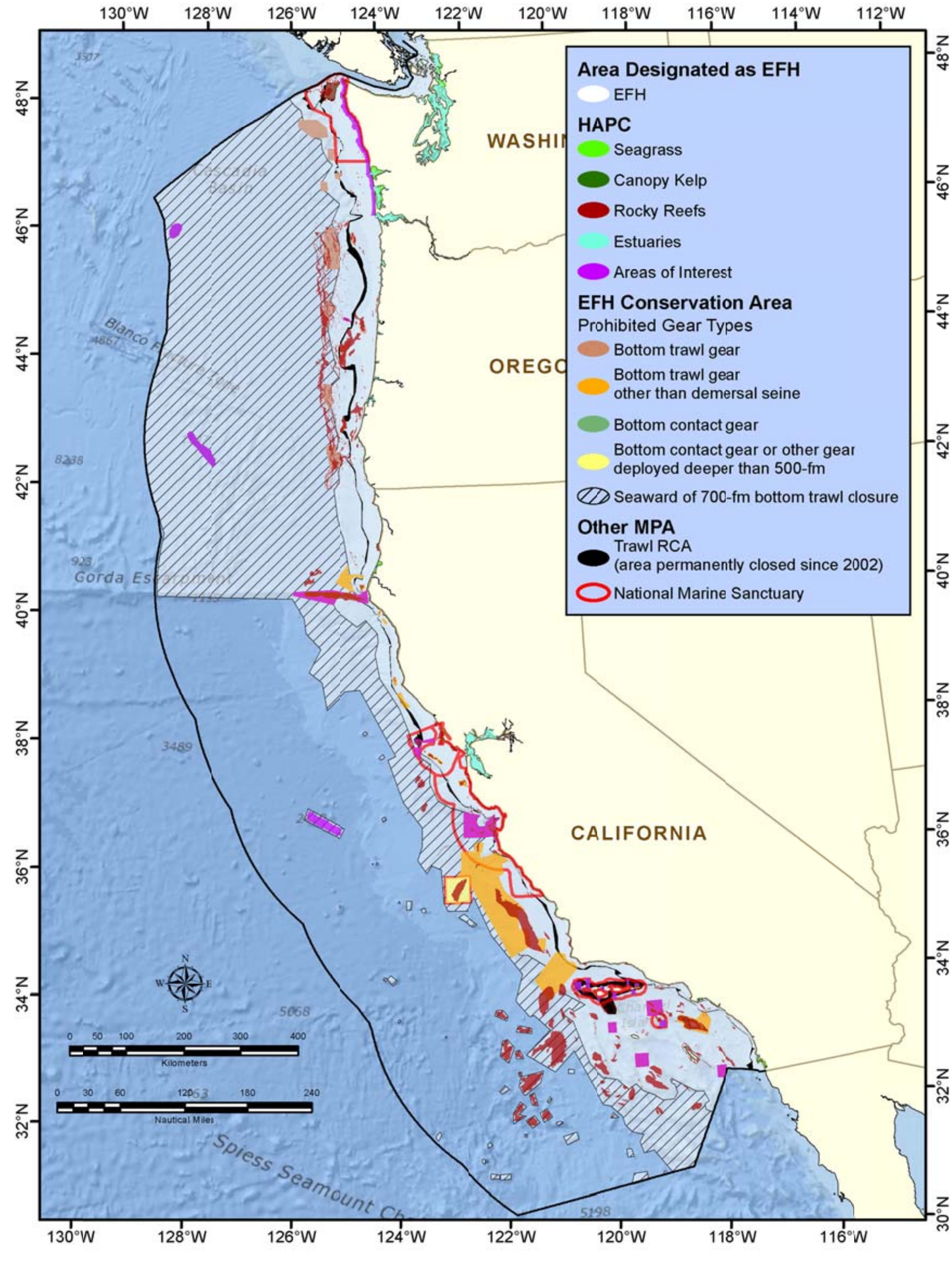

Figure 1. Essential Fish Habitat (EFH) is the largest designation of the many spatial management designations in the U.S. West Coast marine waters relevant for groundfish.

1.3 CHOICE OF SPECIES FOR EVALUATION

We evaluated a subset of species managed under the Council's FMP. We selected six focal groundfishes to represent i) multiple taxonomic groups, ii) the range of depths sampled in the trawl survey, iii) a variety of substrate habitat affinities (from species that prefer rocky, high-relief habitats to those that prefer mud or silt substrates), iv) a range of overall abundance in the trawl survey (from relatively rare to very frequently observed), and v) a range of current stock status (Table 1). These are: darkblotched rockfish (*Sebastes crameri*), yelloweye rockfish (*Sebastes rubberimus*), sablefish (*Anoplopoma fimbria*), longspine thornyhead (*Sebastolobus altivelis*), and greenstriped rockfish (*Sebastes elongatus*).

The chosen species are necessarily a rough proxy for the diversity of species among assemblages of West Coast groundfishes. However, we note that the focal species selected belong to distinct guilds constructed using diet and trophic information (Horne et al. 2010 ATLANTIS) and to 5 different groups based on cluster analyses of the trawl data itself (Cope and Haltuch 2012). Therefore, we view them as a reasonable first group that spans many of the axes of diversity of West Coast groundfish. Future work will expand the number of species analyzed using the techniques developed here.

Table 1. Characteristics of species used in the analyses showing broad taxonomic groupings, depth categories, substrate preferences, occurrence, and stock status. Depth ranges are shelf (shelf and upper slope): 50-400 m and slope: 400-1200m.

Species	Taxonomic Group	Depth Category	Preferred Substrate	Proportion of survey trawls with at least one fish observed	Stock Status
Darkblotched Rockfish (*Sebastes crameri*)	Rockfish	Slope	Soft	~15%	Rebuilding
Yelloweye Rockfish (*Sebastes ruberrimus*)	Rockfish	Shelf	Rocky	~2%	Overfished
Sablefish (*Anoplopoma fimbria*)	Roundfish	Slope	Soft	~65%	Below target of $SB_{40\%}$ and declining.
Longspine Thornyhead (*Sebastolobus altivelis*)	Rockfish	Slope	Soft	~35%	Target
Greenstriped Rockfish (*Sebastes elongatus*)	Rockfish	Slope	Mixed	~25%	Target
Petrale Sole *(Eopsetta jordani)*	Flatfish	Shelf	Soft	~40%	Rebuilding

1.3.1 Using Information in this Synthesis

This information can be used in a variety of ways. Probability of occurrence and associations of habitat characteristics with species can be used to prioritize areas for species of particular concern. The combination of occupancy and fishing pressure informs an evaluation of how much "important" habitat is protected. The inclusion of non-fisheries stressors allows consideration of the suitability of areas for protection – managers may choose to prioritize areas subject to low levels of pollution, for example, over areas with high levels of these threats for highest protection in order to maintain the highest quality habitats. Or, they may determine that non-fishing threats are so great in some areas that reductions in fishing pressure might be needed to maintain the health of the species. Such decisions might be informed via future development of a return-on-investment framework that considers both the costs and benefits of changes in spatial management designations (Withey et al. 2012). This work uses up-to-date seafloor habitat mapping, distribution of threats, and species distribution and abundance information from the annual groundfish bottom trawl survey.

References

Withey, J.C. et al. 2012. Maximizing return on conservation investment in the conterminous USA. Ecology Letters. doi: 10.1111/j.1461-0248.2012.01847.x

2.0 HABITAT DISTRIBUTION

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Overview:

- New physical habitat sources applied in synthesis: New habitat map sources from the Phase 1 report were incorporated with the existing (2005) habitat maps updating and improving the knowledge of probable hard, soft, and mixed seabed type distribution and abundance.
- Physical habitat knowledge is non-uniform: Seabed habitat mapping has been undertaken over continental shelf and slope and inland seas only. The abyssal plain and continental rise remain largely un-described for seabed type.
- Regional patterns in seabed habitat types: Hard seabed habitat types are less abundant, or rare, in comparison to soft seabed though the relative proportions of each type within depth strata are fairly consistent across biogeographic sub-regions.
- New biogenic habitat sources applied in synthesis: Much of the new information on biogenic habitat is in the form of a large database of records of deep-sea corals and sponges. This database contains almost 174,000 records of corals and sponges collected between 1989 and 2012 off the west coast. Roughly 95% of these records are direct, visual observations of corals and sponges in situ, while most of the remaining records (5%) are from surveys using benthic trawls, dredges, or grabs.
- Biogenic habitat knowledge is non-uniform: No systematic regional survey of coral and sponge distributions and abundance has been conducted. A large majority of observations have been made over the past two decades, primarily during targeted studies on habitats suspected to support coral and sponge communities.
- Regional patterns in biogenic habitat types: On the continental shelf and upper slope, most areas where corals and sponges have been observed are outside EFH conservation areas. On the lower slope, coral and sponge habitats are largely protected from bottom trawling although not from use of fixed gears.

The purpose of this Habitat Section is to characterize the spatial distribution and abundance of seabed habitats and spatial management areas (e.g., marine protected areas) relevant to groundfishes within the U.S. exclusive economic zone (EEZ) off Washington, Oregon and California. A coast-wide database and map series of bathymetry (i.e., seafloor imagery) and lithologic habitat types were compiled for the 2012 EFHRC Phase 1 Report including 261 new sources of lithologic habitat information updating the 2005 maps. Mapping methods varied widely among sources, and the seabed habitat types mapped are probable soft sediment, probable rock, or a mixture of soft sediment and rock. The analysis of substrate type was performed on the aggregated seafloor lithological data, resulting in a composite map showing the spatial distribution of the three major seabed habitat types (Figure 2.2).

Observations of biogenic habitat (deep-sea corals and sponges) were compiled for 2005, and then updated for the EFHRC Phase 1 report and considered in the current synthesis. Maps of continuous biogenic habitats were not available, so records of observations of corals and sponges were compiled as presence data and summarized within the four biogeographic sub-regions and three depth zones.

While this report focuses on adult habitat, there is no question that for many species, quantity or quality of juvenile habitat can play a critical role in the population dynamics of groundfishes. In 2005, the Pacific Coast Groundfish EFH FEIS noted a general lack of habitat information for most juvenile groundfishes (Appendix B 1, Assessment Methodology for Groundfish Essential Fish Habitat, December 2005), and used a basic literature review on depth, latitude and substrate (Appendix B 2 Assessment Methodology for Groundfish Essential Fish Habitat, December 2005) to populate a juvenile habitat use database. This information was then used to generate the juvenile habitat suitability profiles used in the 2005 EFH process.

Overall, there has been very little change in the state of our knowledge of juvenile habitat use that would alter the results of the 2005 EFH analysis for juveniles. A general lack of age-0 surveys and habitat-specific survival or growth rates limit our ability to improve on the 2005 analysis. We thus refer the reader to the 2005 document for the best available science on juvenile groundfish EFH.

An important conclusion from the 2005 work is the importance of nearshore, hard-bottom substrate for a number of rockfish species. Much of the habitat use database builds on the observations of Love and colleagues (1991). They reported that 70% of the 58 species of Pacific rockfish they examined used hard substrate. In addition, Love et al. highlight the importance of kelp and other macroalgae for juvenile rockfish—53% of the rockfish they examined were associated with macroalgae. Indeed, observational studies and experimental manipulations of kelp forests confirm the general importance of kelp forests and their understory for rockfishes. The structural complexity of kelp forests influences the recruitment of age-0 rockfish, their density, and their species composition (Ebeling et al. 1991, Carr and Syms 2006). Loss or degradation of kelp forests can result in large decreases in the density of age-0 fish (Carr 1991, Stephens et al. 2006), and can change rates of predation as well as the importance of predation in population dynamics (Johnson 2006).

The importance of juvenile habitat will likely vary among species with life history strategies. Mangel and colleagues (2006) show that the importance of juvenile rockfish habitat will vary with a number of life history parameters, particularly, life span and age of maturity. In general, longer lifespan and greater age of maturity increases the sensitivity of population dynamics to changes in juvenile survival or growth. Thus, to the extent that juvenile survival and growth are associated with habitat quality, we can infer that juvenile habitat is likely to be more import to the dynamics of those groundfish species with relatively long lives and late reproduction (Mangel et al. 2006).

2.1 PHYSICAL HABITAT

The distribution of seabed habitat types by depth zone, both coast-wide and in four biogeographic sub-regions, is summarized in Table 2.1 and shown in Figure 2.3. With the exception of the Salish Sea, the total area of seabed is divided more or less evenly between the three remaining biogeographic sub-regions, Northern (37.2%), Central (35.7%), and Southern (26.2%) (Table 2.1). However, the area of seabed within each sub-region differs by depth zone. Washington and northern Oregon have the broadest continental shelf, anchoring a north-south trend of decreasing width of the continental shelf reflected in the areas for the three outer coast sub-regions (North = 11.1%, Central 5.8%, and Southern 3.6%) (Table 2.1, Figure 2.3) The Southern sub-region includes the bathymetrically complex area known as California's Continental Borderland, and differs dramatically from areas to the north. The waters of this region are also known as the Southern California Bight. The Shelf generally is very narrow, but widens in some areas of the Bight and includes several offshore islands that are an expression of the ridge and basin topography. The number and size of the basins account for the large area of Upper Slope soft substrate (4,400,561 ha).

Coast-wide, the Lower Slope depth zone dominants the EEZ with 79.8% of the total area for combined habitats followed by the Upper Slope (12.2%) and Shelf (8%). The Lower Slope depth zone extends from the 700 ftm boundary of the Upper Slope seaward across the continental rise and abyssal plain to the seaward boundary of the EEZ, and contains a large area of undefined seabed habitat (57,503,645 ha) (Figures 2.2 and 2.3). Seabed lithologies were only mapped from the shoreline to the base of the continental slope (water depth ~3000 m) accounting for the undefined seabed in deep water. If one excludes the category of undefined substrate, then the Shelf, Upper Slope and Lower Slope depth zones represent 24.2%, 41.4% and 34.4% of the continental margin. Only the shallowest (Shelf) depth zone is present in the Salish Sea.

Hard and mixed substrates appear to be relatively rare (7.2% and 3.3%, respectively) when compared coast-wide to soft substrate (89.5%) (Figure 2.3, Table 2.1). The north to south decrease in the areal extent of soft substrate on the shelf mirrors the latitudinal decrease in width of the continental shelf; however, relative proportions of all three substrates on the shelf are fairly consistent across sub-regions despite large changes in total area (Figure ES-3, Table ES-2). For the Lower Slope depth zone, only hard and soft substrates were coded. The relatively large area of hard substrate in the Lower Slope depth zone of the Northern sub-region (324,537 ha) is partly due to the classification of seabed as “inferred rock” derived from a model that was applied to the Oregon margin (PFMC 2012).

The distribution of seabed habitat types, both inside and outside EFH conservation areas, and by depth zone and habitat type for each of the sub-regions is presented in Figure 1.4 and Appendix 1: Tables A1.3.2a-d). No EFH Conservation Areas are located in the "Salish Sea", and no "mixed" habitat types are known to occur with the Lower Slope of any biogeographic sub-region. Between 15-35% of hard and mixed shelf habitats are protected by EFH conservation areas, Protections of hard and mixed habitats on the upper slope vary widely between 3% (central, mixed) and 63% (southern, mixed). The two bottom trawl prohibition types make up the largest proportions of area coast-wide. Due to the 700-ftm bottom trawl closure, large portions of the lower slope in the northern, central and southern sub-regions are closed to either all bottom trawls or bottom trawl except demersal seines (central and southern sub-regions). All known areas of hard habitat in the lower slope are closed to trawling.

The distribution of seabed habitat types, both inside and outside areas prohibiting the use of three main commercial fishing gear types (bottom trawl, mid-water trawl and fixed gear), and by depth zone and substrate type for each of the sub-regions is presented in Appendix 1: Tables A1.3.3a-d and Appendix 1: Figures A1.3.5-1.3.8). Again, the 700-ftm bottom trawl closure accounts for a large proportion of the area in each of the sub-regions. Shoreward of the 700 ftm depth contour and at Shelf and Upper Slope depths, bottom trawling is prohibited in 4.3%, 21.3%, and 25.3% of the Northern, Central and Southern sub-regions, respectively. Bottom trawling is prohibited in 100% of the Salish Sea. The proportion of hard substrate closed to bottom trawling shown in Appendix 1: Figure A1.3.5 in the Shelf and Upper Slope depth zones is a reflection, in part, of the Amendment 19 prohibition of bottom trawl gear in rocky reef areas. This can also be seen in Appendix 1: Figure A1.3.6, the map showing the composite area closed to bottom trawling overlain on the three seabed habitat types. In addition, the map figure clearly shows the area along the continental shelf break where bottom trawling is prohibited in the Rockfish Conservation Area. Bottom trawl prohibitions in the territorial seas of Washington and California are also shown. The aerial extent of the prohibition for bottom trawling far exceeds the two other fishing gear types (Appendix 1: Figure A1.3.8).

The distribution of seabed habitat types, both inside and outside areas where commercial fishing is either allowed, restricted or prohibited, and by depth zone and substrate type for each of the sub-regions is presented in (Appendix 1: Tables A1.3.4a-d, Appendix 1: Figure A1.3.9, and Appendix 1: Figure A1.3.10). The map shows the composite area where commercial fishing is either restricted or completely prohibited over lain on the three seabed habitat types. Prohibitions accounted for only a small fraction of the total area within the four sub-regions, whereas commercial restrictions accounted for 84.5%, 25.4%, 27.9% and 100% of the Northern, Central and Southern, and Salish Sea sub-regions, respectively. The large area of commercial restriction on the Lower Slope along the open coast is due to the Bottom Trawl Footprint Closure seaward of the 700ftm depth contour. The "Salish Sea" is entirely within Washington's state territorial sea and encompasses only the shelf depth zone. Commercial fishing is restricted and bottom trawling is prohibited within the entire territorial sea off Washington and almost the entire territorial sea off California.

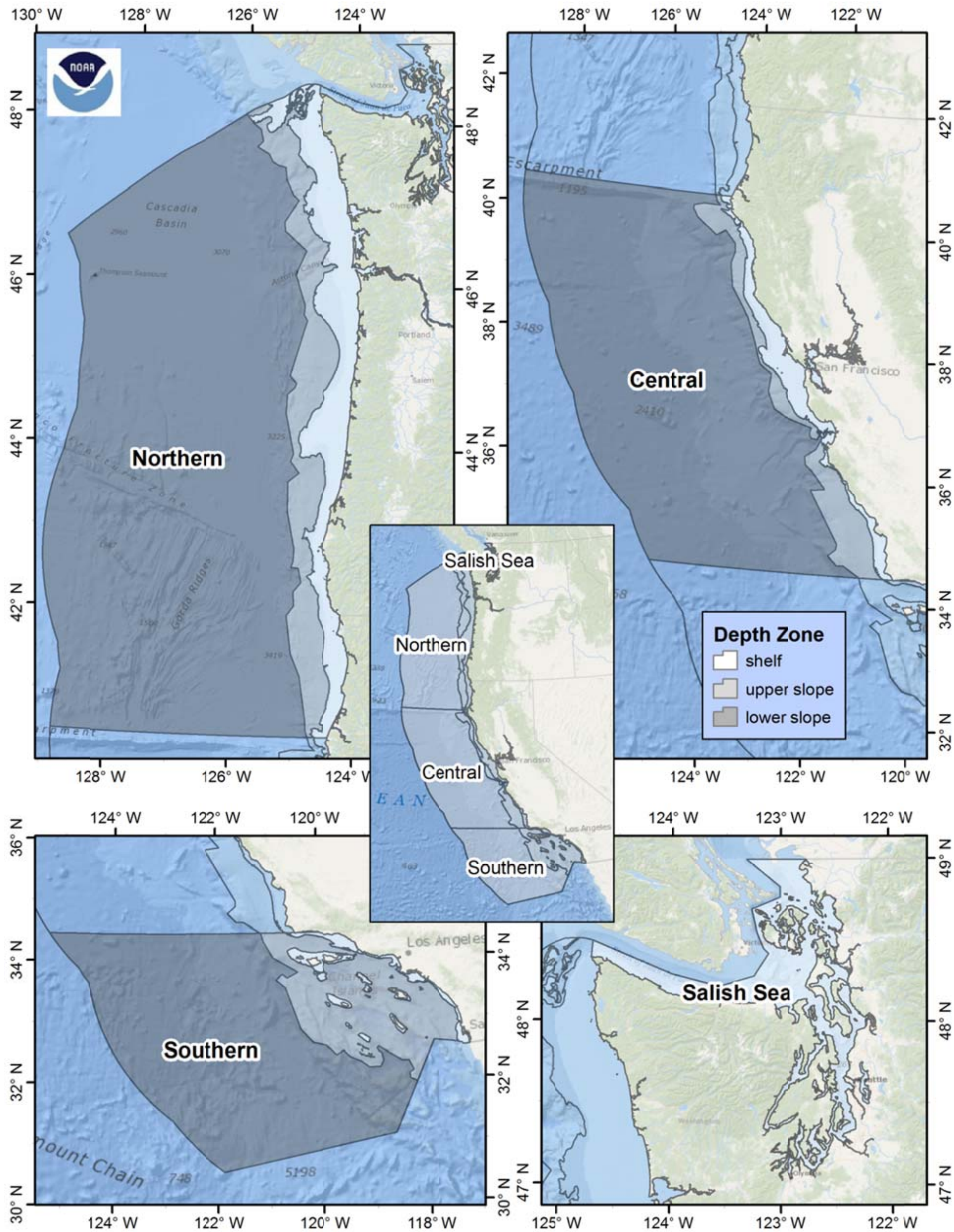

Figure 2.1. Map showing the spatial stratification, including four biogeographic sub-regions and three depth zones.

2.2 BIOGENIC HABITAT

Biogenic habitats are very diverse, and include sponges, corals, macroalge (including kelp beds), eelgrass beds and more. Kelp beds are known to be important for many species of groundfishes, especially YOY juveniles. Little new information since the initial West Coast Groundfish EFH review has been collected about other biogenic areas; the previous work is still the best compilation of this information.

Here, we summarize direct and indirect observations of deep-sea corals and sponges. Not all areas within the FMP area have been surveyed for presence of corals and sponges, and areas that are surveyed but found not to support coral and sponge communities are not always documented. Much of what is known about the overall spatial distribution of corals and sponges in the region has been compiled by NOAA's Deep-Sea Coral Research & Technology Program (NOAA, 2013). Roughly 95% of its 174,000 records are direct, visual observations of corals and sponges in situ, while most of the remaining records (5%) are from surveys using benthic trawls, dredges, or grabs. Differences in how data were collected make it challenging to estimate relative abundance. For example, some studies summarized counts over individual photo or video frames, while others summarized over the course of entire dive. In order to compare the distributions in a standardized manner, presence data were summarized within 1x1 km contiguous grid cells (Figure 1.5). Because of differences in habitat affinities, observations were summarized for two groups of taxa: 1) corals (excluding pennatulids) and sponges (Figure 2.5a), and 2) pennatulids (Figure 2.5b).

Out of the over 843,000 1x1 km cells within the FMP area, just over 4,103 (0.5%) had records of coral-sponge presence, and 3,943 (0.5%) had records of pennatulids (sea pens). This only represents where corals and sponges have been observed over the last 23 years, not necessarily where they don't occur. Most (62%) areas of coral and sponge presence are located within the upper slope, with 28% and 10% of presence in the shelf and lower slope, respectively (Table 2.2). The northern biogeographic sub-region had the most (48%) areas with coral and sponge presence, followed by the southern, central and Salish Sea. This rank order may be largely influenced by survey effort. Pennatulid presence shows a similar relative distribution to that of corals and sponges with about half of known areas on the upper slope, 38% on the shelf and 12% on the lower slope (Table 1.2). Distribution of pennatulids by sub-region was also similar to that of corals and sponges, with the northern sub-region having 45% of cells, followed closely by the central (42%). Only 11% and <1% of cells where pennatulids have been observed are within the southern sub-region and Salish Sea, respectively.

Similar to physical habitats, the distribution of two coral-sponge taxonomic groups was compared to the three types of MPA categories: 1) EFH conservation areas (Figure 1.6a-b and Appendix 1: Table A1.3.6a-b), 2) areas prohibiting one or more of three major commercial gear types (Appendix 1: Figure A1.3.14a-b-1.3.15a-b and Appendix 1: Table A1.3.7a-b), and 3) areas where commercial fishing is either allowed, restricted or prohibited (Appendix 1: Figure

A1.3.16a-b and Appendix 1: Table A1.3.8a-b). Out of the over 4,100 grid cells with coral-sponge presence, 71% remain outside EFH conservations areas, and 55% of those occur in the northern sub-region (Appendix 1: Table A1.3.6a). Out of the over 4,100 grid cells with coral-sponge presence, 62% are in areas open to all commercial gear types, and 60% of those occur in the northern sub-region (Appendix 1: Table A1.3.7a). While 38% of grid cells with coral-sponge presence are in areas closed to bottom trawls, only 1.3% of cells are in areas closed to fixed gears or mid-water trawls (Appendix 1: Table A1.3.7a). For grid cells with pennatulid presence, 73% are outside EFH conservation areas, and 52% of those occur in the northern sub-region (Appendix 1: Table A1.3.6b). Roughly 65% of cells with pennatulids are in areas open to all three commercial gear types, and 58% of those are in the northern sub-region (Appendix 1: Table A1.3.7b). While only 24 cells are in areas closed to fixed gears or mid-water trawls, 1,385 (35%) are in areas closed to bottom trawling (Appendix 1: Table A1.3.7b).

Because of the 700-ftm closure, all biogenic habitats in the northern lower slope are protected from bottom trawling, while a large majority (≥ 90%) of the lower slope is protected in the central and southern sub-regions (Appendix 1: Figures A1.3.14a-b and A1.3.16a-b). Since bottom trawling is prohibited in the state territorial sea of Washington, all biogenic habitats in the Salish Sea are protected from that gear type (Appendix 1: Figure A1.3.14a-b).

There are numerous sites outside EFH conservations areas where corals and sponges have been observed in higher relative numbers (see Appendix 1: Figure A1.3.17 map plates). These include just west of the Olympic 2 area and just north of the Grays Canyon area (Map A2), Hydrate Ridge (B2), off Cape Arago, OR (C2), north of the Eel River Canyon area (D2), in the Gulf of the Farallones National Marine Sanctuary (E2), portions of Monterey Bay and near the shoreward boundary of the Big Sur Coast/Port San Luis area (E3), and several sites on the shelf and offshore banks in the southern California Bight (F3, F4, G4).

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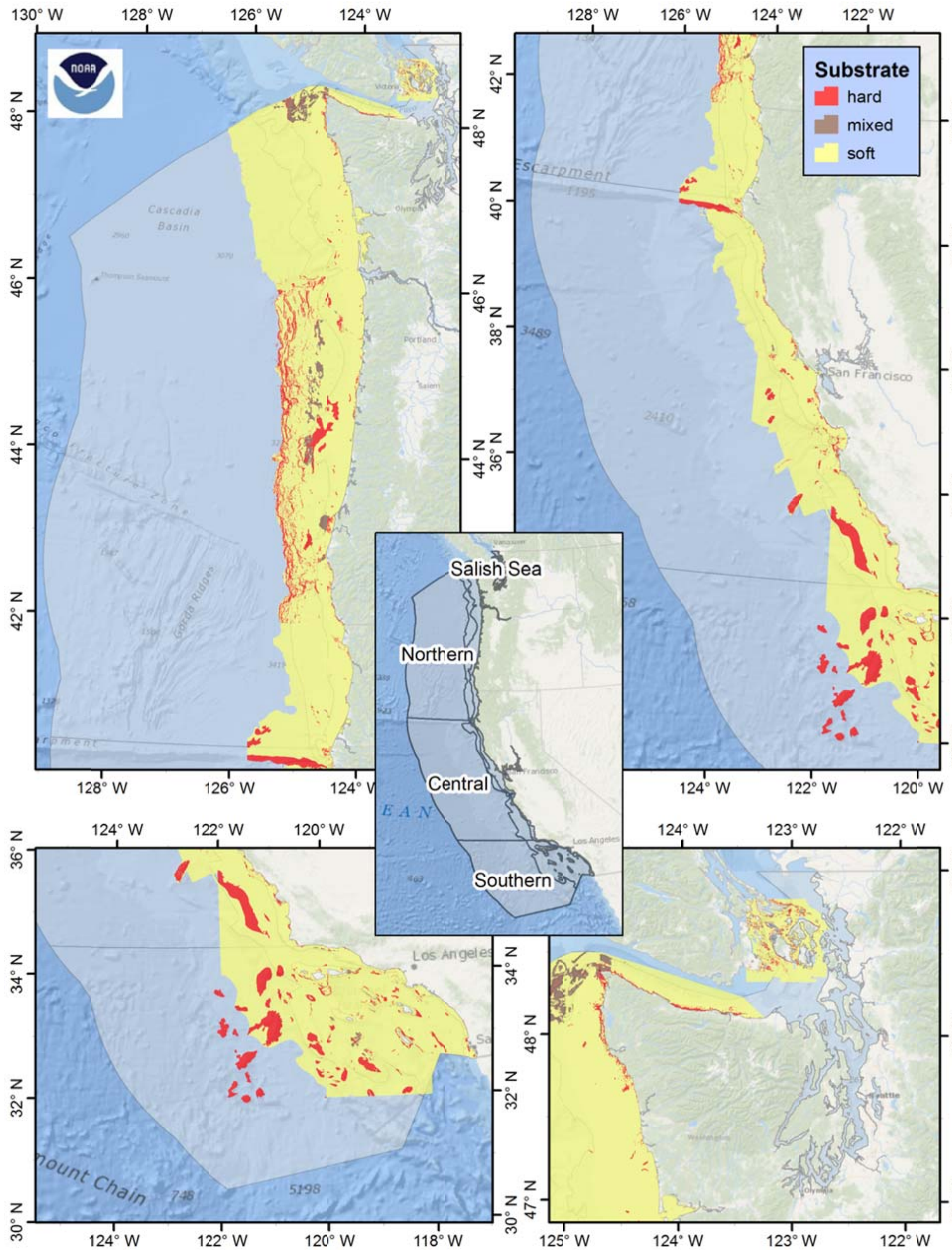

Figure 2.2. Spatial distribution of three major seabed habitat types: hard, mixed and soft.

Table 2.1. Distribution of seabed habitat types by depth zones both coast-wide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Last row shows relative contribution to the sub-region.

		BIOGEOGRAPHIC SUB-REGION								COAST-WIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	Substrate	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Shelf[1]	Total	3,404,867	11.1%	1,715,270	5.8%	775,396	3.6%	739,957	100.0%	6,635,491	8.0%
	hard	170,661	0.6%	104,228	0.4%	52,064	0.2%	15,701	2.1%	342,655	0.4%
	mixed	94,430	0.3%	5,277	0.0%	15,054	0.1%	7,469	1.0%	122,230	0.1%
	soft	3,049,609	9.9%	1,469,779	5.0%	691,704	3.2%	213,668	28.9%	5,424,760	6.6%
	undefined	90,167	0.3%	135,986	0.5%	16,574	0.1%	503,119	68.0%	745,846	0.9%
Upper Slope[2]	Total	3,021,125	9.8%	2,389,292	8.1%	4,669,633	21.6%	0	0.0%	10,080,050	12.2%
	hard	103,766	0.3%	267,468	0.9%	242,023	1.1%	0	0.0%	613,257	0.7%
	mixed	105,496	0.3%	3,175	0.0%	18,555	0.1%	0	0.0%	127,226	0.2%
	soft	2,811,725	9.1%	2,107,156	7.1%	4,400,561	20.3%	0	0.0%	9,319,442	11.3%
	undefined	138	0.0%	11,493	0.0%	8,495	0.0%	0	0.0%	20,125	0.0%
Lower Slope[3]	Total	24,311,081	79.1%	25,381,145	86.1%	16,184,376	74.8%	0	0.0%	65,876,603	79.8%
	hard	324,537	1.1%	143,068	0.5%	578,992	2.7%	0	0.0%	1,046,598	1.3%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,525,125	8.2%	2,681,556	9.1%	2,119,680	9.8%	0	0.0%	7,326,361	8.9%
	undefined	21,461,420	69.8%	22,556,521	76.5%	13,485,704	62.3%	0	0.0%	57,503,645	69.6%
Column Total		30,737,074	100.0%	29,485,708	100.0%	21,629,405	100.0%	739,957	100.0%	82,592,144	100.0%
Sub-Region		30,737,074	37.2%	29,485,708	35.7%	21,629,405	26.2%	739,957	0.9%	82,592,144	100.0%

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

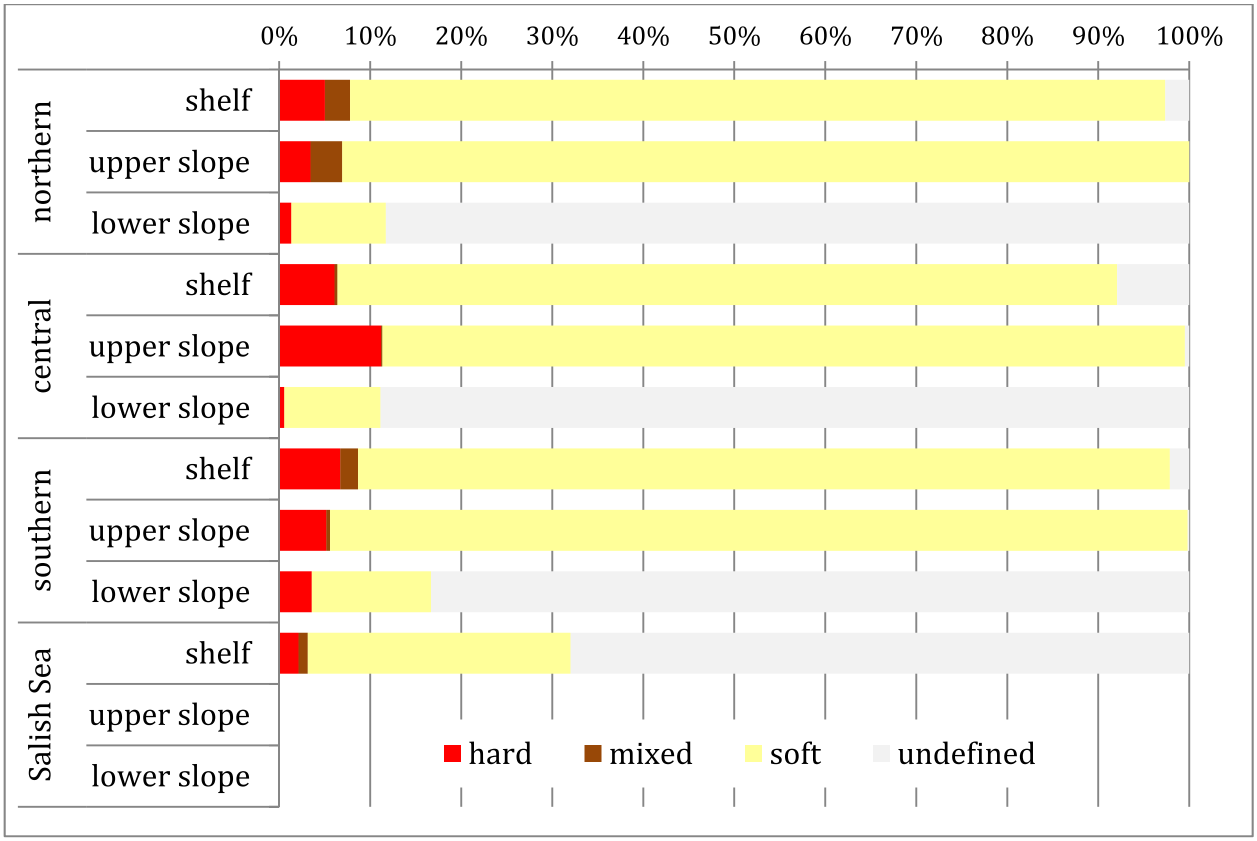

Figure 2.3. Relative distribution of seabed habitat types by depth zones in four biogeographic sub-regions. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

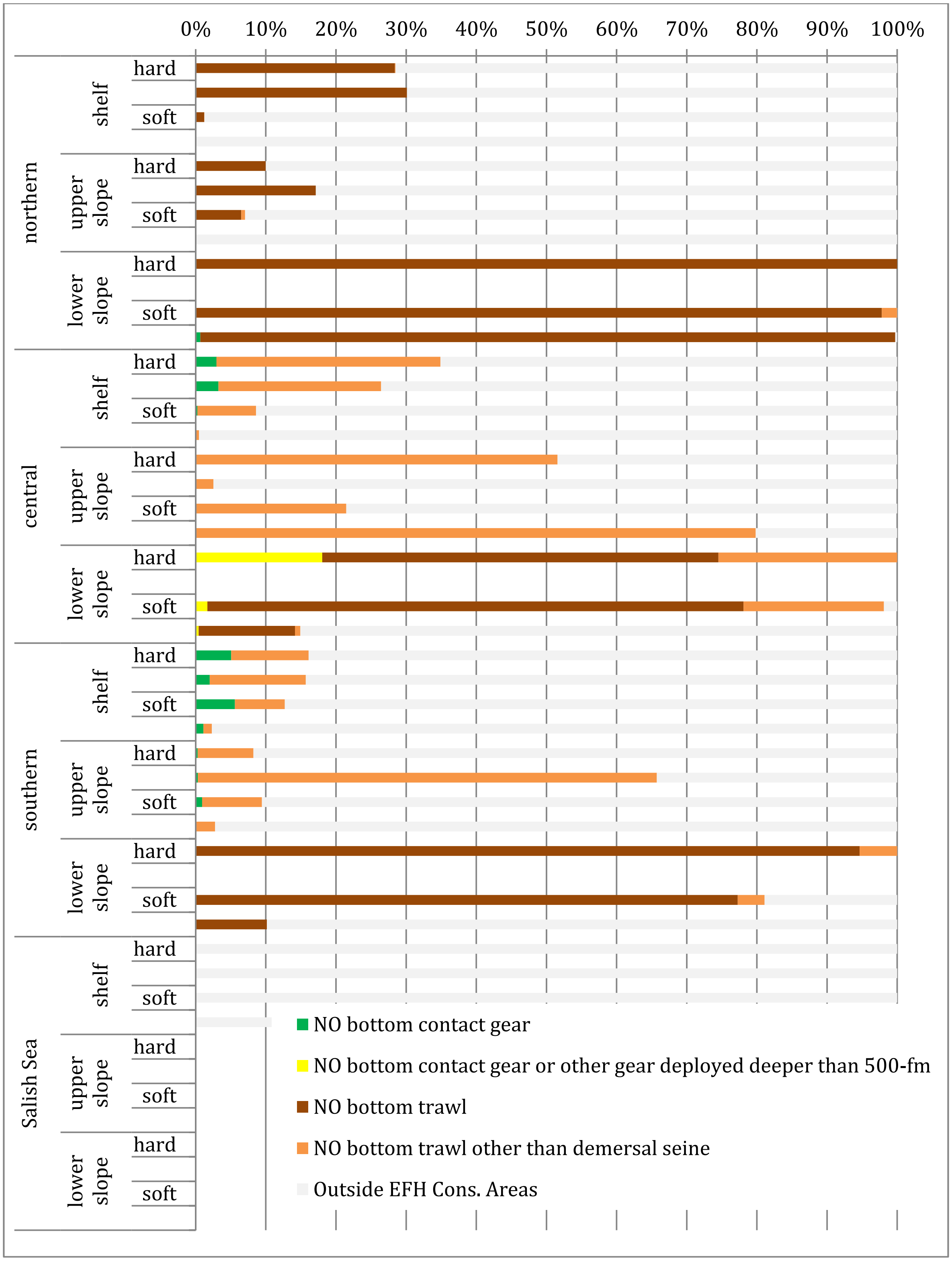

Figure 2.4. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the "Salish Sea" and no "mixed" substrate types are known to occur with the lower slope of any biogeographic sub-region.

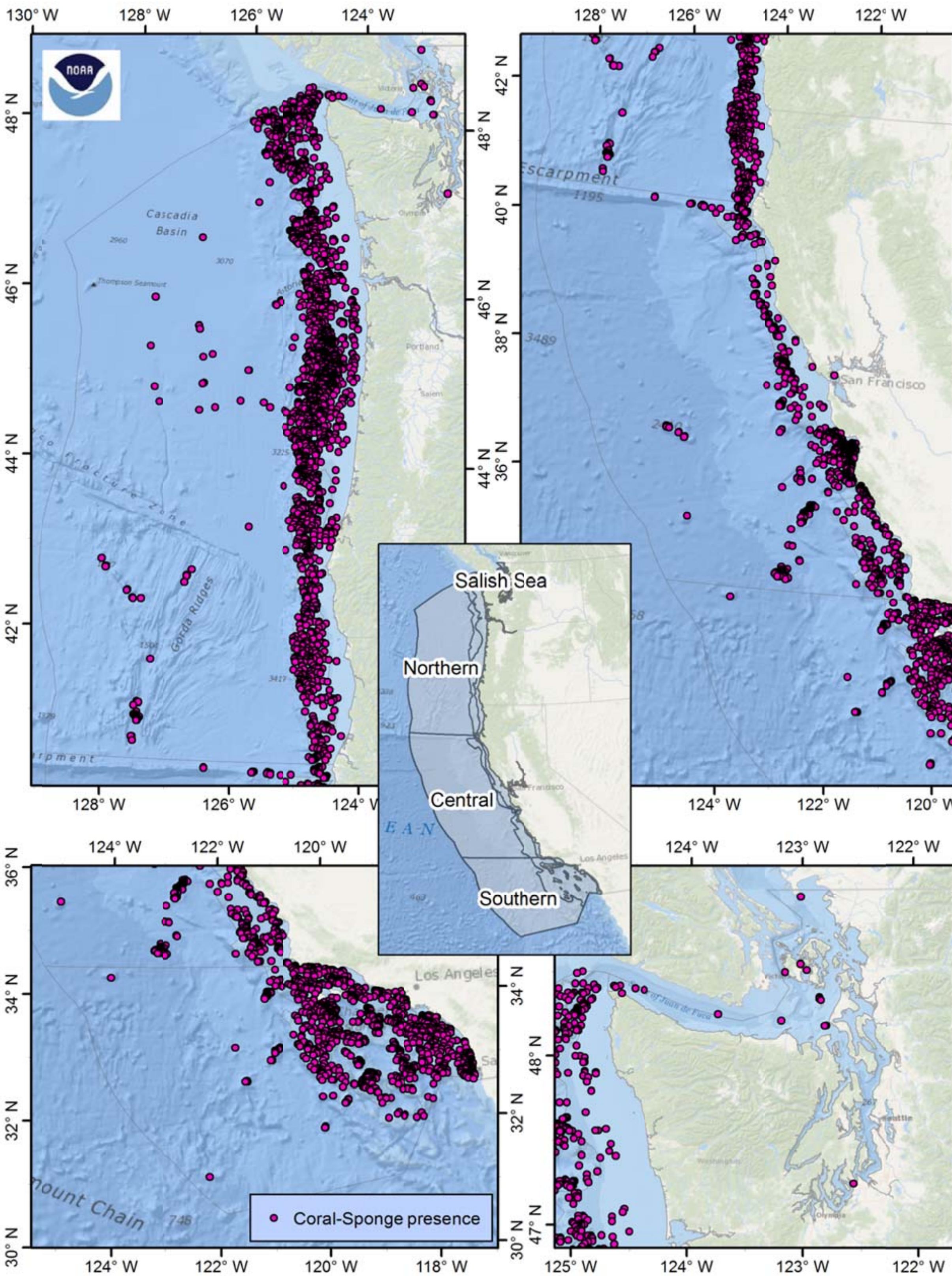

Figure 2.5a. Map showing the spatial distribution of coral (excluding pennatulids) and sponge presence, summarized by 1x1 km cells.

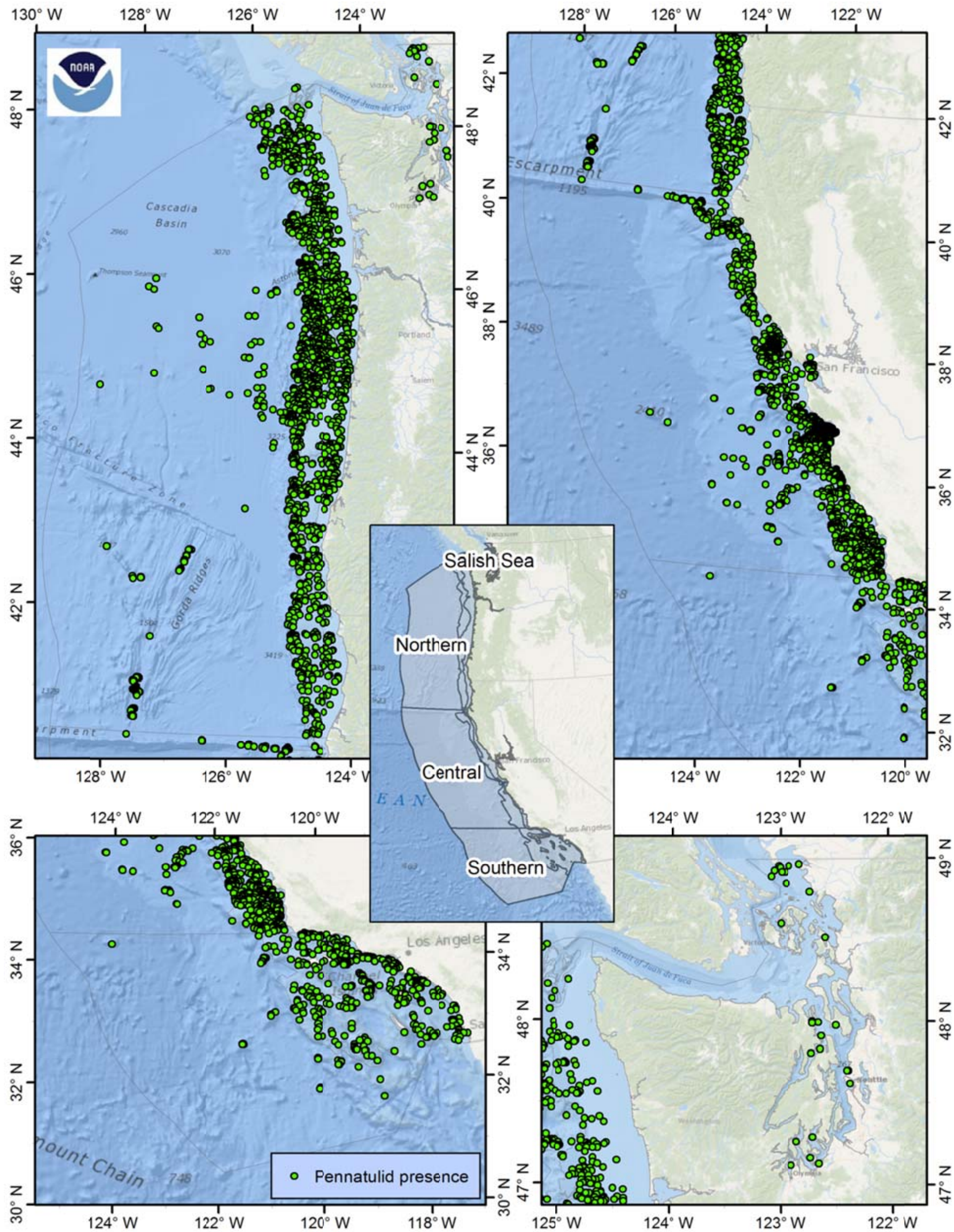

Figure 2.5b. Map showing the spatial distribution of pennatulid presence, summarized by 1x1 km cells.

Table 2.2. Distribution presence of two groups of biogenic taxa [coral (excluding pennatulids) and sponge (top); pennatulid (bottom)] by depth zones both coast-wide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Percentage values represent relative contribution to the sub-region. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

	BIOGEOGRAPHIC SUB-REGION								COAST-WIDE	
	Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	Count	%	Count	%	Count	%	Count	%	Count	%
Shelf[1]	426	21.7%	395	38.4%	323	29.4%	16	100.0%	1,160	28.3%
Upper Slope[2]	1,448	73.8%	396	38.5%	697	63.5%	0	0.0%	2,541	61.9%
Lower Slope[3]	87	4.4%	238	23.1%	77	7.0%	0	0.0%	402	9.8%
Total	**1,961**	**47.8%**	**1,029**	**25.1%**	**1,097**	**26.7%**	**16**	**0.4%**	**4,103**	**100.0%**
	Coral (excluding pennatulids) and Sponge Presence [above] | Pennatulid Presence [below]									
Shelf[1]	586	32.7%	736	44.0%	149	33.1%	27	100.0%	1,498	38.0%
Upper Slope[2]	1,060	59.1%	660	39.5%	258	57.3%	0	0.0%	1,978	50.2%
Lower Slope[3]	148	8.2%	276	16.5%	43	9.6%	0	0.0%	467	11.8%
Total	**1,794**	**45.5%**	**1,672**	**42.4%**	**450**	**11.4%**	**27**	**0.7%**	**3,943**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

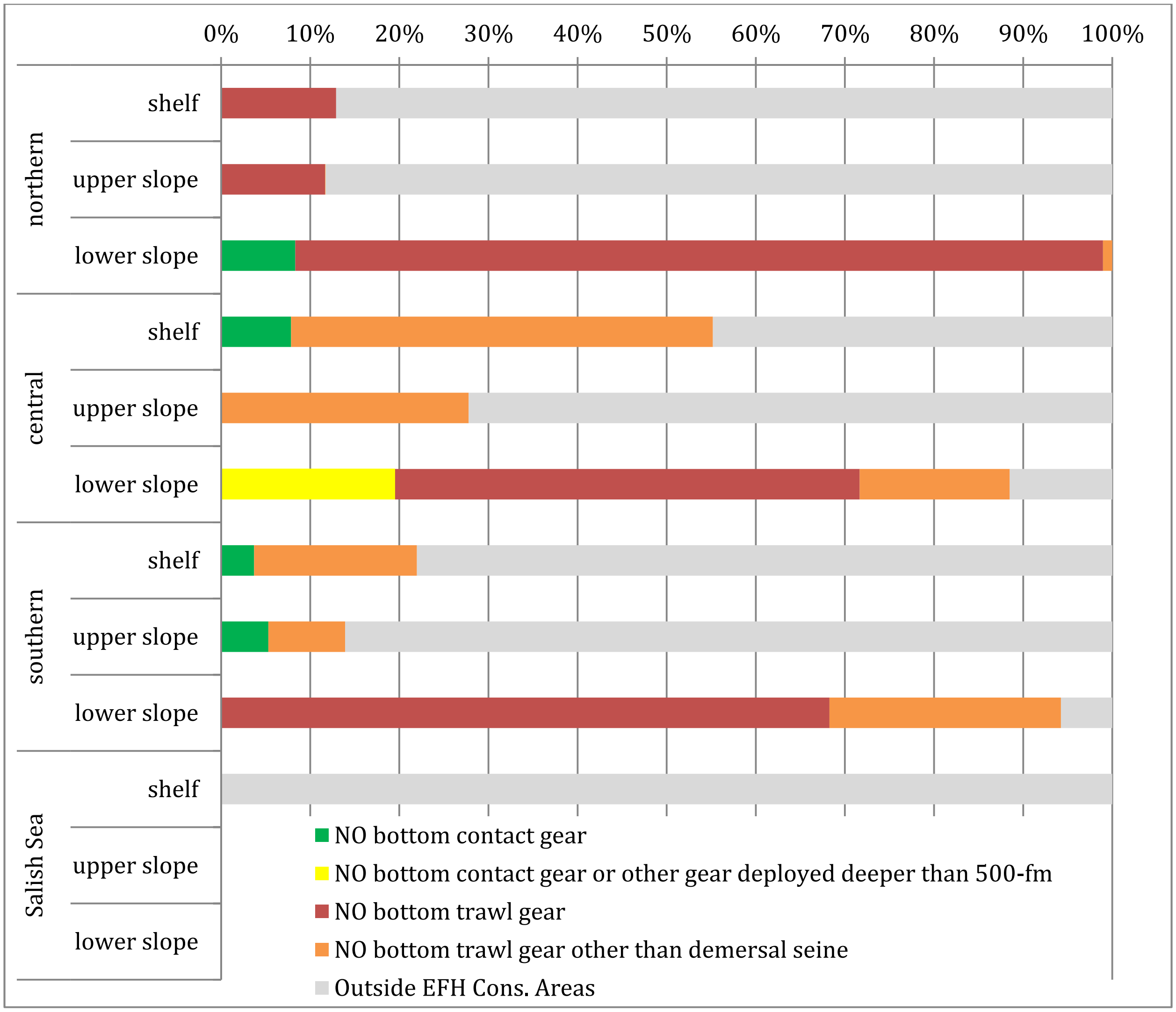

Figure 2.6a. Percentages of coral (excluding pennatulids (sea pens)) and sponge presence by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the “Salish Sea”.

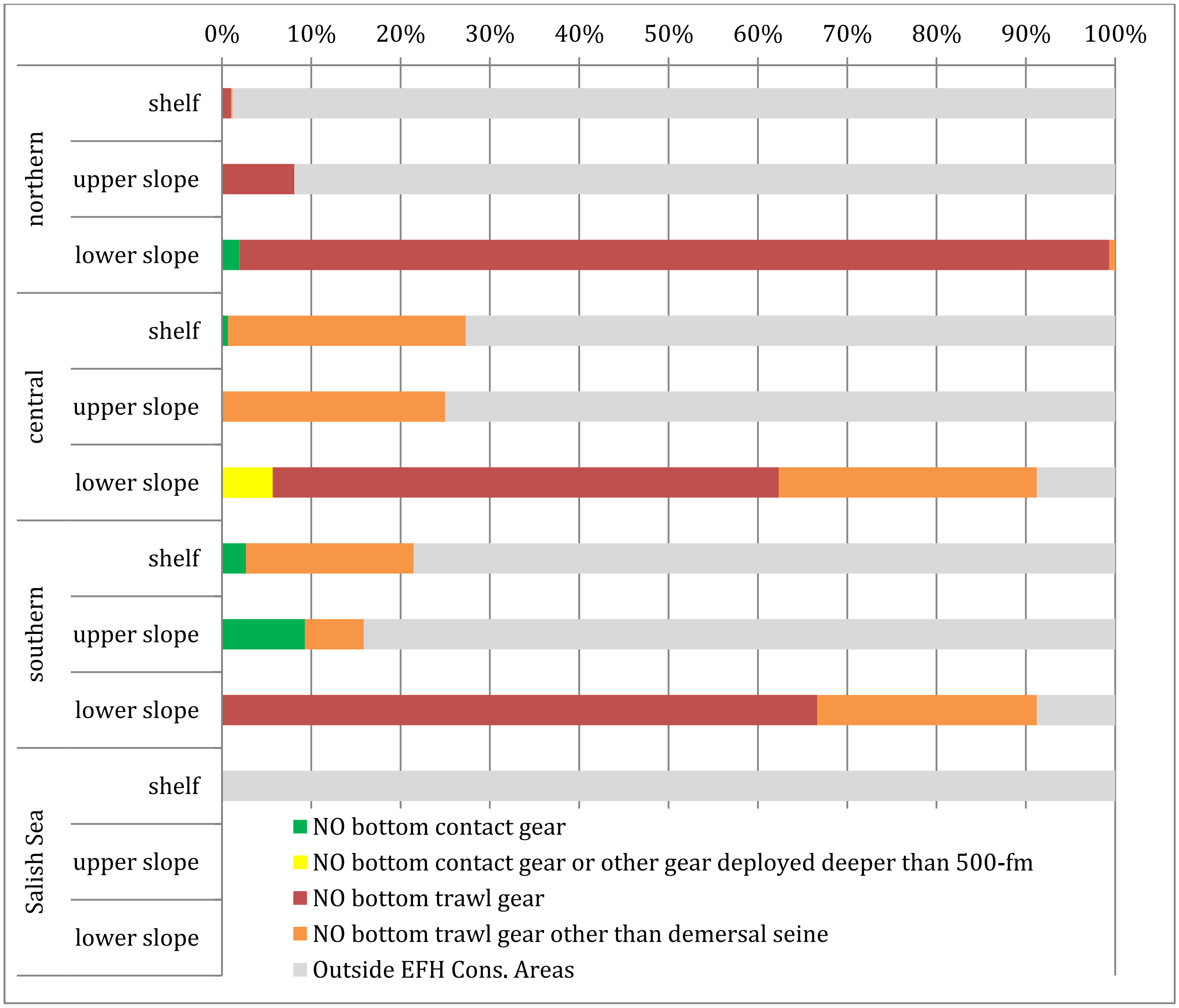

Figure 2.6b. Percentages of pennatulid presence by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the "Salish Sea".

3.0 SPECIES-HABITAT ASSOCIATIONS

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Overview:

- We identify habitat variables that are important predictors of occupancy and abundance for six focal groundfish species as measured primarily by the NOAA trawl survey (years 2003 to 2011), but also including some visual observation data (e.g. ROV surveys).
- Due to available data we focus on age 1+ juvenile and adult life stages (individuals > ~15 cm standard length).
- We provide statistically well-supported spatial maps of occurrence and abundance for each species using two new models.
- Despite methodological differences, the two modeling approaches show strong agreement in the predicted occurrence of each species.
- Patterns of occurrence and abundance vary among species but show high probability of occurrence for at least one of the six species at virtually all locations along the coast.
- For all species considered, depth, bottom temperature, and sediment grain size were important covariates in predicting probability of occurrence (Table 3.1). Depth and bottom temperature were also key predictors of abundance for all species considered, but sediment grain size was not (Table 3.2).

3.1 SPECIES-HABITAT RELATIONSHIPS FOR SEVERAL EXAMPLE SPECIES

3.1.1 Introduction

We use observed patterns of occurrence and abundance to estimate the importance of a set of habitat variables for the occupancy and abundance of each species. Past approaches have focused on estimating probabilities of habitat suitability for each species and life stage as a function of a number of covariates, including depth, latitude and substrate, and expert opinion (NMFS 2005). In our approach, we also use a number of habitat covariates to estimate the probability that a species will be found at a particular location. Since species show habitat preferences, their presence or absence can be used as an indicator of habitat preferences and potentially suitability. [We also evaluate abundance, but interpretations are more complicated since removal of fish by the fishery can affect abundance and interpretations thereof.] Nonetheless, evaluating likelihood of occupancy is a data-drive, testable approach to determining habitat associations. Here we provide two new frameworks to address the EFH problem (referred to as the NWFSC model and the NCCOS model). Both approaches use spatial regression approaches and use habitat variables to explain both the occurrence and abundance of each species. Both models provide patterns of species occurrence and abundance at the scale of the U.S. West Coast and use the NOAA Fisheries West Coast Bottom Trawl Survey (WCBTS) as the primary data source.

However, the two models make different assumptions about the mathematical structure and interaction between model structure and data that have real consequence for model estimation, interpretation, and prediction. Very briefly, we can summarize the main differences between the NWFSC and NCCOS models in three points (see Appendix, Section 3 for a more detailed explanation of all three points): 1) The models use slightly different data sets. The NWFSC model includes survey trawl data from 2003-2011 while NCCOS only uses data from 2003-2010. Additionally, NWFSC includes a small set of non-trawl data from direct count visual surveys using human occupied submersibles, resulting in more observations in untrawlable habitat, and improving upon one of the challenges inherent in using the trawl survey data (e.g. Figure 3.4); 2) The NCCOS model assumes that all trawl survey samples are from a single stationary distribution while the NWFSC model attempts to explicitly model among year variation in the occurrence and abundance. As a result, the NCCOS model will be able to identify smaller scale spatial clustering than the NWFSC model. However, the NWFSC model accounts for year to year variability in occurrence more transparently. (Appendix, Section 2); 3) The NCCOS model is developed, estimated, and evaluated in a maximum likelihood framework while the NWFSC model uses a Bayesian framework. Consequently, NCCOS will generally identify more habitat variables as important descriptors of species-habitat relationships than the NWFSC model while the NWFSC model will generally have larger spatial variability than the NCCOS model. Overall, it will be important to consider results from both models, but the NWFSC model will be more reliable in areas of untrawlable habitat.

Further methodological details and references for the NWFSC and NCCOS models can be found in the methods appendix (Appendix, Section 3).These analyses use available data well, but, like all analyses, have limitations due to the data that can be used. Because trawls sample over large areas, these results smooth potentially important small-scale habitat variation. The somewhat larger scale in our analyses is more relevant to the large-scale decision-making in EFH, however. Second, rocky, high relief and deep (>1,300m) habitats are not well-sampled by the trawl survey, so species that are more restricted to these habitats are not well represented. The poor sampling in these areas does not mean that these habitats are unimportant, and clearly, better data in these areas would be of great value. Finally, while the trawl survey does sample 1+ juvenile fishes, it does not sample pelagic juveniles and the smaller size range of newly settled juveniles well. However, it is known that kelp beds are important for many groundfish at this stage; again, the best information currently available is that compiled for the most recent EFH designation effort (NMFS 2005).

3.1.2 General Results

We were able to estimate species-habitat relationships for the age 1+ juvenile and adult life stages (individuals > ~15 cm standard length) and to identify habitat covariates that helped describe their occurrence and abundance for all six focal species. For each of our focal species, we present three main figures. First, we show the predicted mean probability of occurrence for all years and the predicted mean estimated abundance from the NWFSC model (e.g. Figure 3.1 for sablefish). For the second, we show the predicted mean probability of occurrence for all years and the predicted mean abundance from the NCCOS model (e.g. Figure 3.2 for sablefish). For both models, the probability of occurrence map is interpreted as the predicted probability of observing at least one individual of the species if you were to sample 1 hectare (0.01 km^2) of seafloor. The abundance map is interpreted as the expected biomass (kg) that would be collected if 1 hectare of seafloor were sampled. Since the NWFSC makes a prediction of probability of occurrence and abundance for each year, these plots present the average of the mean prediction in the individual years (2003 to 2011). Unlike the NWFSC model, the NCCOS model uses all years of the trawl data simultaneously to present a single prediction map that represents the long-term mean probability of occurrence and abundance. The NCCOS effort also uses a slightly different set of years (2003-2010) than the NWFSC model. The third figure (e.g. Figure 3.3 for sablefish) shows the probability of occurrence maps from NWFSC (from Figure 3.1) and NCCOS (from Figure 3.2) in the first two panels while the third panel shows the location and magnitude of difference between the NWFSC and NCCOS model predictions. We do not present a comparison of the abundance portion of the models because the results for abundance were poorly resolved in some cases. Overall, the differences between the modeling efforts emphasize that there is uncertainty associated with the probability of occurrence and abundance of each species at each location.

Both models agree that areas with highest probability of occurrence and abundance are not coincident among species (Figures 3.1 to 3.18) – a reassuring conclusion, since species were chosen to represent different ecological characteristics. Petrale sole tend to be in the shallow waters of the continental shelf, darkblotched and greenstriped rockfishes occupy the middle depths, and longspine thornyhead and sablefish inhabit deeper waters. Each species occupies a distinct habitat with respect to the other habitat covariates as well (Tables 3.1 to 3.4). Taken together, at least one of the focal species is predicted to occur with reasonably high probability in each predicted grid cell – indirectly confirming that our choice of proxy species spanned a wide range of ecological axes. Designation of spatial management boundaries will thus likely involve prioritization and potentially trade-offs in protection among species (or species groups).

In general, the models have similar predictions of areas occupied by each species. For abundant, well-sampled species such as sablefish and longspine thornyhead, differences between the models tended to be within ± 5% (e.g. Figures 3.3, 3.12). For species with lower overall abundance the differences between models are larger, with the NCCOS model tending to estimate slightly lower probability of occurrence than the NWFSC model. This is a systematic bias arising from the link function used in the NCCOS GLM model. The details accounting for this and to make adjustments are described in greater detail in Section 2 of the Appendix. The models also tend to differ along the edges of the prediction area and in areas where the predicted probabilities of occurrence are changing rapidly. Model differences are particularly pronounced in yelloweye rockfish (Figure 3.6) – a species associated with rocky, untrawlable habitats. These differences largely reflect the inclusion of non-trawl survey information in the NWFSC model but not the NCCOS model, and again emphasize the importance of additional sampling. Given the inclusion of this additional information, the NWFSC model is likely to be more reliable in these areas.

In all cases and both models, spatial models (models that explicitly account for spatial autocorrelation, or likelihood of an individual of a species being found near other individuals of the same species) were preferred over non-spatial models, indicating that incorporating the spatial organization of observations was an important determinant of species occurrence and abundance. Depth and some aspect of temperature were important predictors of occupancy in all models for all species; proximity to rocky outcrops was an apparent driver for several species.

To summarize the intersection of the probability of occurrence and EFH Conservation Areas, we calculated the proportion of high probability of occurrence that occur within those areas. We summarized the probability of occurrence on a 2x2km grid for the entire coast and overlaid the amendment 19 regulation areas (see also sections 3 and 5). For the EFH conservation areas, we included all areas where bottom trawl or bottom contact gear were prohibited. As in section 5, if any portion of each grid cell contained gear restrictions, we designated it as protected. For each species, we had to define a cutoff for classifying each grid cell as containing a high probability of occurrence. This choice of a cutoff is a subjective exercise. For the three abundant focal species (sablefish, longspine thornyhead, and petrale sole) we used a cutoff probability of occurrence of 0.50. For the three less abundant species (yelloweye, greenstriped and darkblotched rockfish), we used a cutoff of 0.25. We found the following proportion of high probability areas falling within EFH conservation areas: yelloweye rockfish 35%; sablefish 20%; longspine thornyhead 22%; petrale sole 7%; darkblotched rockfish 7%; and greenstriped rockfish 10%. The apparent trend is that both greater depth and some affinity for rocky habitats (either being found in rocky habitats, or with proximity to rocky habitats as a significant predictor) increase the proportion of 'high probability' areas that have these protections.

Sablefish (*Anoplopoma fimbria*)

Sablefish are a widespread species in deep-water habitats along the entire west coast (present in ~65% of survey trawls; Figures 3.1 to 3.3). They are among the most commonly observed species in the trawl survey (Table A2.1.4) and were well described by both the NWFSC and NCCOS models. For both models, the preferred model incorporated a large number of habitat covariates to explain both probability of occurrence and abundance (Tables 3.1 to 3.4), with depth and bottom temperature being particularly important habitat covariates. There is a notable decline in both the probability of occurrence and abundance in sablefish south of Pt. Conception that is not well explained by the explicit habitat variables included in either model. However, such regional variation is well captured by the regional position effect in the NCCOS model and the spatial variance in the NWFSC model. Both NWFSC and NCCOS found the abundance model difficult to estimate due to rare occasional extremely high catches in the trawl survey (occasional trawl survey catches of > 1000 kg/ha).

Yelloweye Rockfish (*Sebastes ruberrimus*)

Yelloweye Rockfish exhibit strong site fidelity to rocky bottoms and steep outcrops that are poorly sampled by the trawl survey (present in ~2% of survey trawls; Figs 3.4 to 3.7), and this rarity made estimating species-habitat relationships difficult. As a result, NWFSC did not attempt to estimate year effects or year-specific spatial covariances for the probability model and did not estimate an abundance model at all. Instead, the NWFSC contrasts the probability of occurrence model that includes only data from the trawl survey with a model that includes both the trawl survey and visual surveys that disproportionately sample rocky, high relief habitats (Figure 3.4). Though the visual surveys only include 81 additional observations, these data are disproportionately influential in determining the probability of occurrence map. The NCCOS model, which does not include visual survey data, produced a map qualitatively similar to the NWFSC model that did not include visual survey data (Figures 3.5 and 3.6). For both models, depth and association with rocky habitats were important covariates for yelloweye, with the highest probability of occurrence associated with the offshore banks of Washington and Oregon (e.g. Heceta Bank). The abundance model results from the NCCOS model are considered somewhat unreliable due to low sample sizes and should be interpreted with caution (see Section 3 of the Appendix).

Petrale Sole (*Eopsetta jordani*)

Petrale sole are a widespread, abundant species in the shallow shelf waters along the entire coast (present in ~40% of survey trawls; Figures 3.7 to 3.9). The NWFSC model used a fairly simple statistical model that includes only depth and bottom temperature as explanatory variables. The NCCOS model also found depth and bottom temperature to be important habitat variables but included additional predictors and interaction terms in the model such as alongshore position, regional position, and chlorophyll a concentration. The highest probabilities of occurrence were found in a relatively continuous band from the northern most extent of the study area to Point Conception and from 150 m to the shallowest extent of the study area. Abundance models were more heterogeneous with catch hotspots predicted off of Cape Flattery, the Columbia River, Point Reyes, Monterey Bay, and Point Sur.

Longspine Thornyhead (*Sebastolobus altivelis*)

Longspine thornyhead occur regularly in the trawl survey (present in ~35% of survey trawls) and are well described by both modeling efforts (Figures 3.10 to 3.12). Both NWFSC and NCCOS models predict a band of high probability of occurrence in the deeper waters (>400m deep) of the trawl survey (Figures 3.10 to 3.12). This species is notable for a lack of variation in probability of occurrence and abundance along the coast. Depth and bottom temperature were important predictors of longspine thornyhead in both models. The NWFSC model also included sediment characteristics as explanatory variables and NCCOS included a number of additional variables including alongshore position, sea surface temperature, regional position, and a number of interaction terms. With a small exception for some areas off southern California, the NWFSC and NCCOS models were very similar for longspine thornyhead.

Greenstriped Rockfish (*Sebastes elongatus*)

Greenstriped rockfish are generally found in habitats well sampled by trawls and are well represented in the trawl dataset (present in ~25% of survey tows; Figures 3.13 to 3.15). While greenstriped are susceptible to trawl gear, both the NWFSC and NCCOS models found depth and proximity to rocky outcrops to be important predictors of occurrence. Furthermore, both models found evidence of regional variation in probability of occurrence and abundance that was not well explained by habitat variables. Generally, greenstriped are most common and abundant north of Monterey Bay in moderate depths (100-250m).

Darkblotched Rockfish (*Sebastes crameri*)

Darkblotched are generally found in habitats well sampled by trawls and are reasonably represented in the trawl dataset (present in ~15% of survey tows; Figures 3.16 to 3.18). The most notable aspects of darkblotched distribution are the narrow range of depths they occupy (from ~100m to 400m) and their virtual disappearance south of approximately Pt.

Reyes. This geographic associated change can be modeled by both NWFSC and NCCOS but it is poorly explained by any of the habitat variables in either model. Perhaps due to this strange observed distribution, the maps of predicted probability of occurrence maps differ substantially in many places between the NWFSC and NCCOS models (Figure 3.18). NCCOS found sea surface temperature to be an important explanatory variable while the NWFSC model included bottom temperature and sediment grain size.

Other species

In addition to the six species discussed here, we include results for the NCCOS model applied to five additional species in Section 3 of the Appendix (lingcod, *Ophiodon elongatus*; Dover sole, *Microstomus pacificus*; shortspine thornyhead, *Sebastolobus alascanus;* Pacific ocean perch, *Sebastes alascanus;* chilipepper, *Sebastes goodei*).

Table 3.1. Habitat covariates included in the preferred NWFSC probability of occurrence model for the six focal species. "X" indicates the covariates included in the preferred model. All columns are habitat covariates except "Year" which designates a categorical offset for each year, and "Single Variance?" which designates if a single spatial variance parameter was estimated for all years ("Y") or if a spatial variance parameter was estimated for each year ("N").

Species	Year	Log (Depth) and log (Depth^2)	Bottom Temperature	(Bottom Temperature)^2	Sediment Grain Size	(Sediment Grain Size)^2	Sqrt(km to rock)	Single Variance?
Sablefish	X	X	X	X	X	X	X	N
Yelloweye rockfish		X	X		X		X	Y
Petrale sole	X	X	X	X				N
Longspine thornyhead		X	X	X	X	X	X	Y
Greenstriped rockfish	X	X	X	X	X		X	N
Darkblotched rockfish		X	X	X	X	X	X	N

Table 3.2. Habitat covariates included in the preferred NWFSC abundance model. “N/A” indicates that the abundance model was not estimated. See Table 3.1 for more explanation.

Species	Year	Log (Depth) and log (Depth^2)	Bottom Temperature	Bottom Temperature^2	Sediment Grain Size	(Sediment Grain Size)^2	Sqrt(km to rock)	Single Variance?
Sablefish	X	X	X	X	X		X	N
Yelloweye rockfish	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petrale sole		X	X	X				N
Longspine thornyhead		X	X	X	X	X	X	Y
Greenstriped rockfish		X	X				X	N
Darkblotched rockfish	X	X	X					Y

Table 3.3. Probability of occurrence parameters included in the plotted NCCOS models. "X" indicates a covariate used as a main effect, "Y" indicates a covariate used as part of an interaction term, and "N/A" indicates a term that was omitted from the model.

Species	Depth	Depth Polynomial	Alongshore distance	Region	Bathymetric Position Index	Rugosity	Slope	Near-bottom temperature	Surface temperature	Surface Chlorophyll	Distance to hardbottom
Sablefish	X	X	Y	X	Y	Y	Y	X	Y	Y	
Yelloweye rockfish	X		X		X				X	X	
Petrale sole	X	Y	Y	X	Y	Y	Y	X	Y	X	Y
Longspine thornyhead	X	X	X	X	Y	X	X	X	X	Y	
Greenstriped rockfish	X	N/A	X	Y	X	X		X	Y	X	X
Darkblotched rockfish	X	X	X	X					X		
Dover sole	X	X	Y	X	X	Y	X	X	Y	X	X
Lingcod	X	Y	X	X	Y	X	X	X	X	X	
Shortspine thornyhead	X	X	X	X	Y		X	Y	Y	X	Y
Pacific ocean perch		X	Y	X				X			
Chilipepper	Y	X	X	X	X	Y		X	X		X

Table 3.4. Abundance parameters included in the plotted NCCOS models. “X” indicates a covariate used as a main effect, “Y” indicates a covariate used as part of an interaction term, and “N/A” indicates a term that was omitted from the model.

Species	Depth	Depth Polynomial	Alongshore distance	Region	Bathymetric Position Index	Rugosity	Slope	Near-bottom temperature	Surface temperature	Surface Chlorophyll	Distance to hardbottom
Sablefish	X	X	Y	Y			X		Y	Y	Y
Yelloweye rockfish			X		X		X	X			
Petrale Sole	X	Y	Y	X	Y	X	Y	Y	X	X	Y
Longspine Thornyhead	X	Y	Y	X	Y	X	X	X	X	Y	Y
Greenstriped rockfish	Y	N/A	Y	X	X		Y	X	X	X	X
Darkblotched rockfish	X	X			X			X			
Dover sole	X	X	Y	X		Y	X		Y	Y	X
Lingcod		X			X			Y	X	X	
Shortspine thornyhead	Y	Y	X		Y		Y	Y	X	X	Y
Pacific ocean perch		X	X				X	X	X		
Chilipepper	Y	X		X	X	Y		Y			

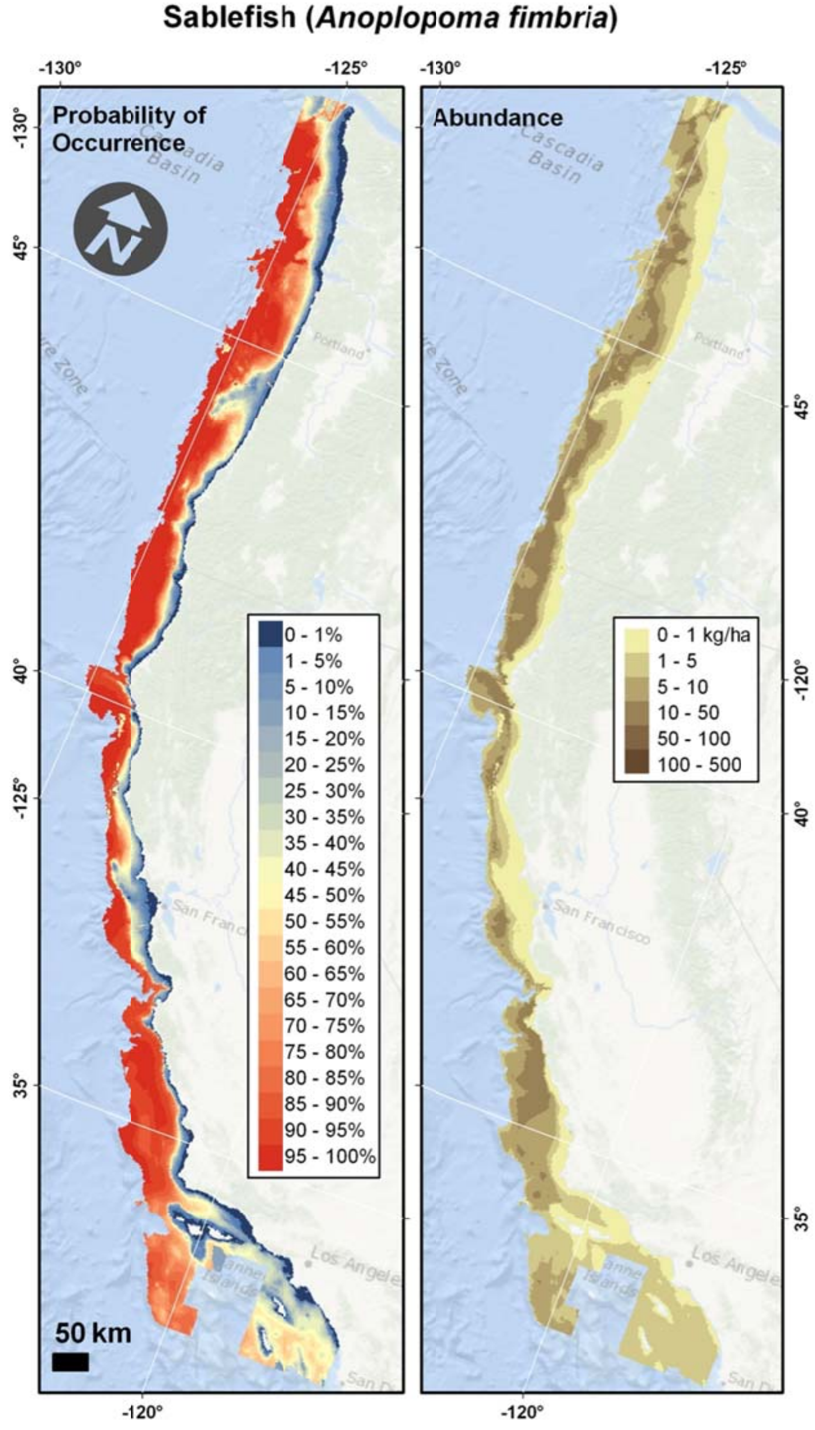

Figure 3.1. Sablefish mean predicted probability of occurrence and mean predicted abundance. NWFSC model projections.

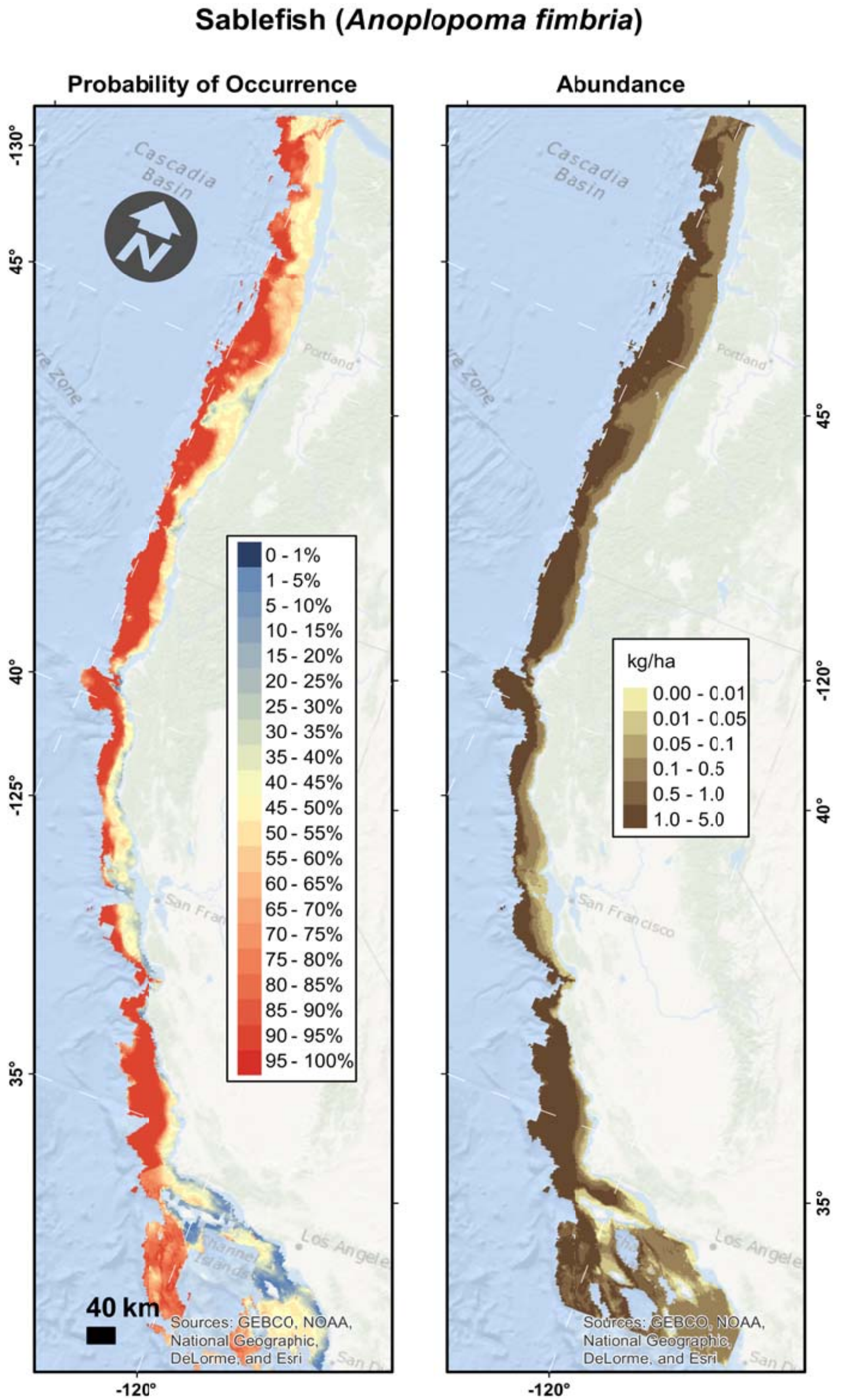

Figure 3.2. Sablefish mean predicted probability of occurrence and mean predicted abundance. NCCOS model projections.

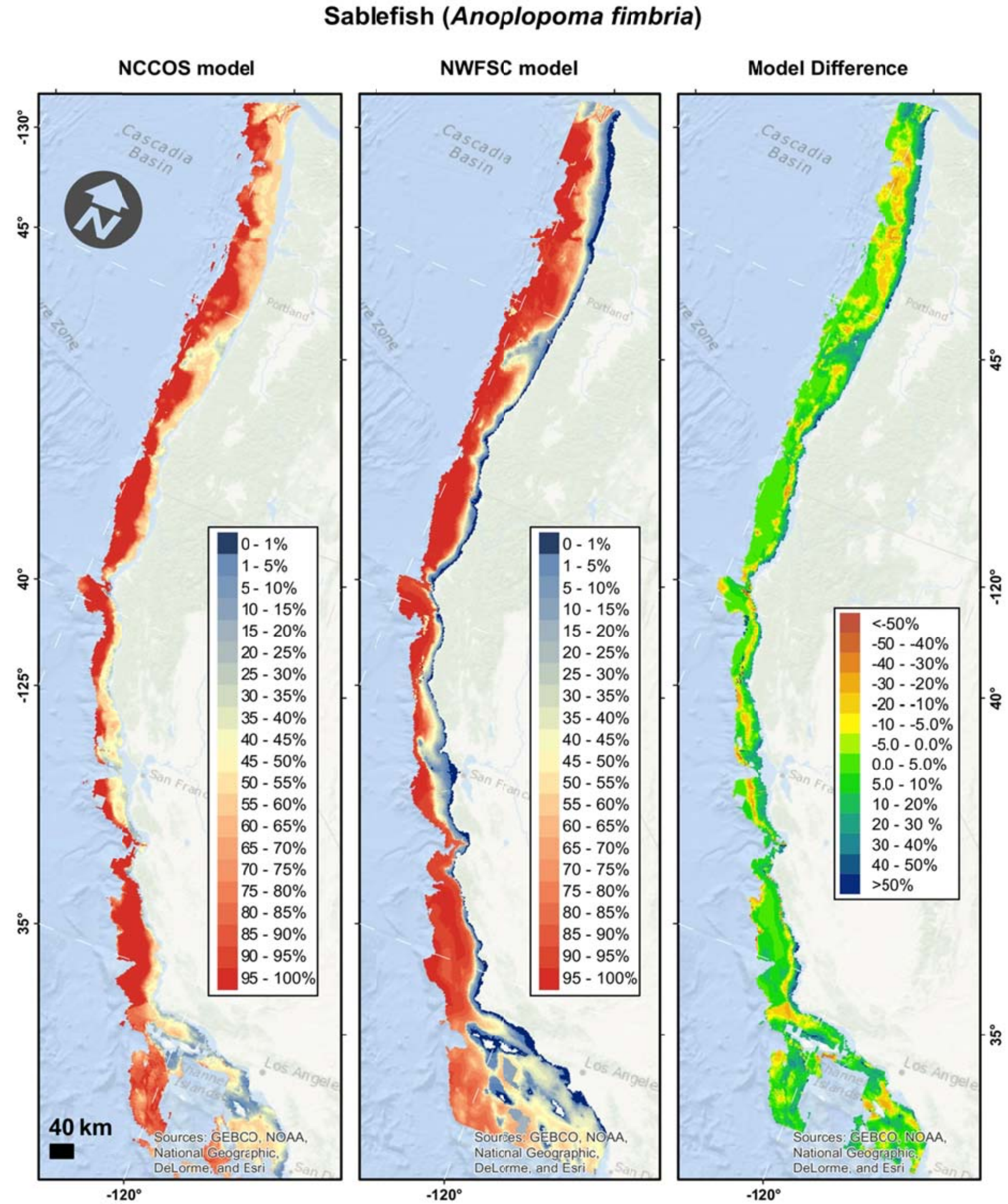

Figure 3.3. Sablefish predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS is greater than NWFSC.

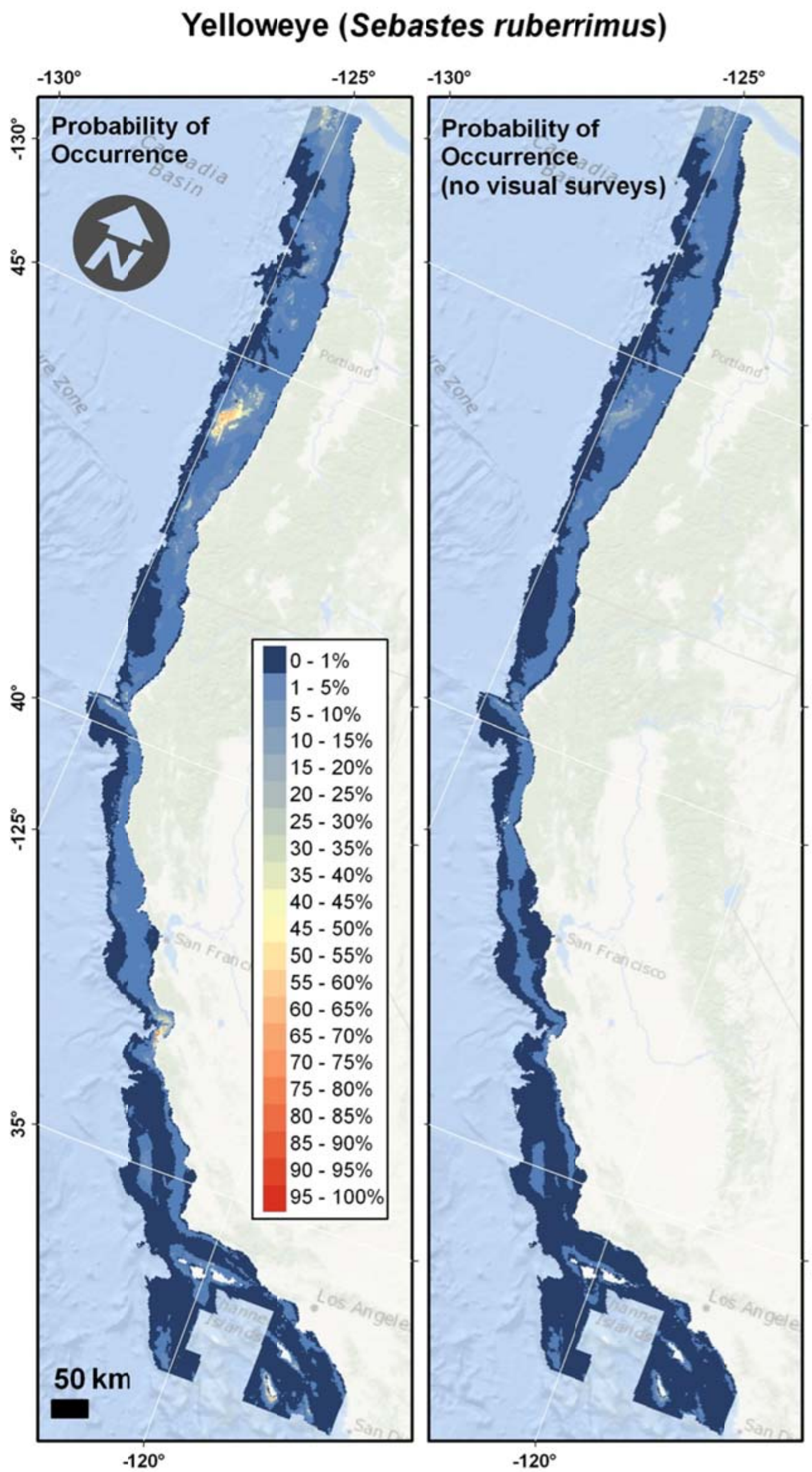

Figure 3.4. Yelloweye rockfish mean predicted probability of occurrence. NWFSC model projections. Left panel shows results using trawl survey data and visual survey data from submersible transects. Right panel shows results using only trawl survey data. NWFSC did not construct an abundance model for yelloweye.

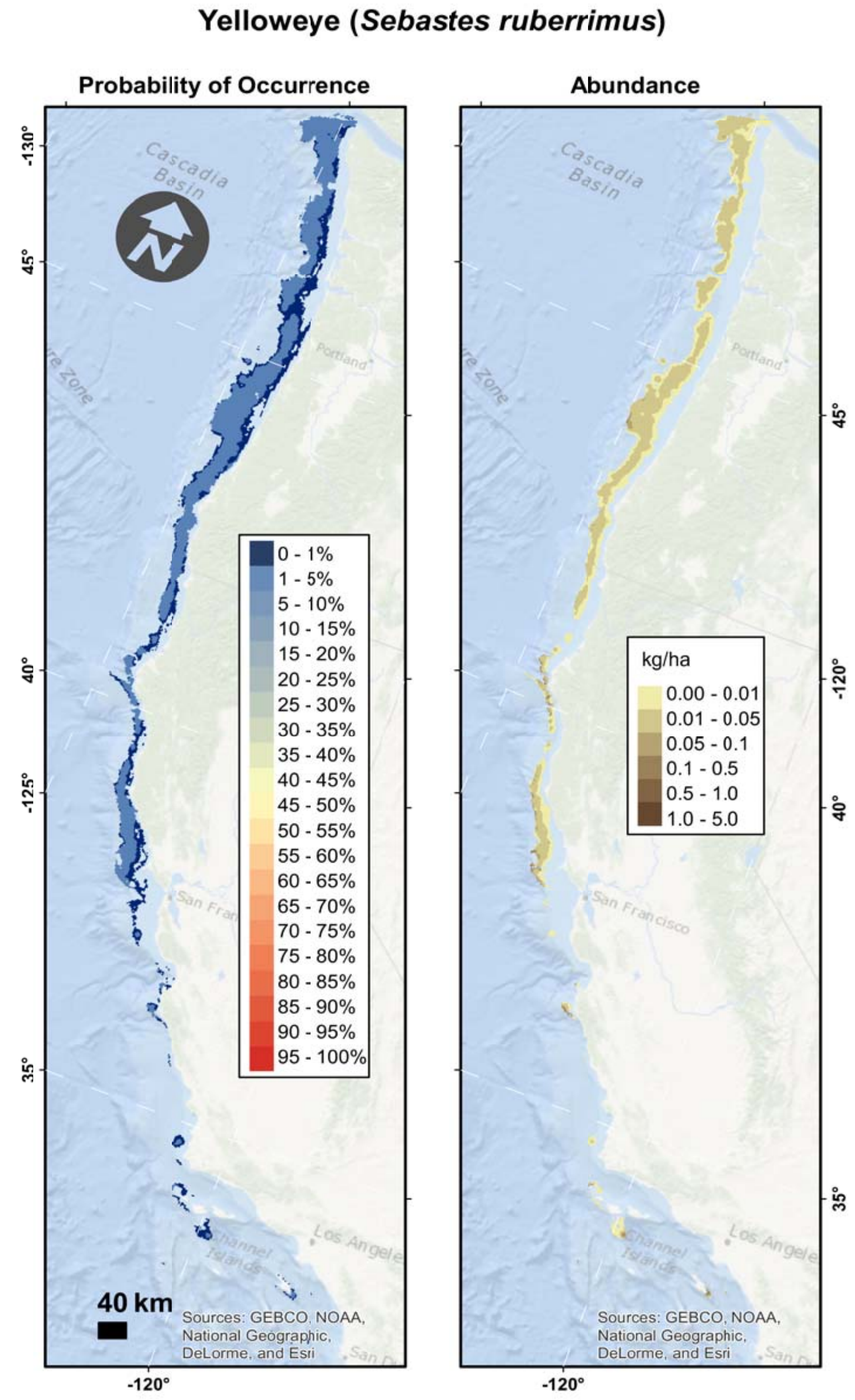

Figure 3.5. Yelloweye rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

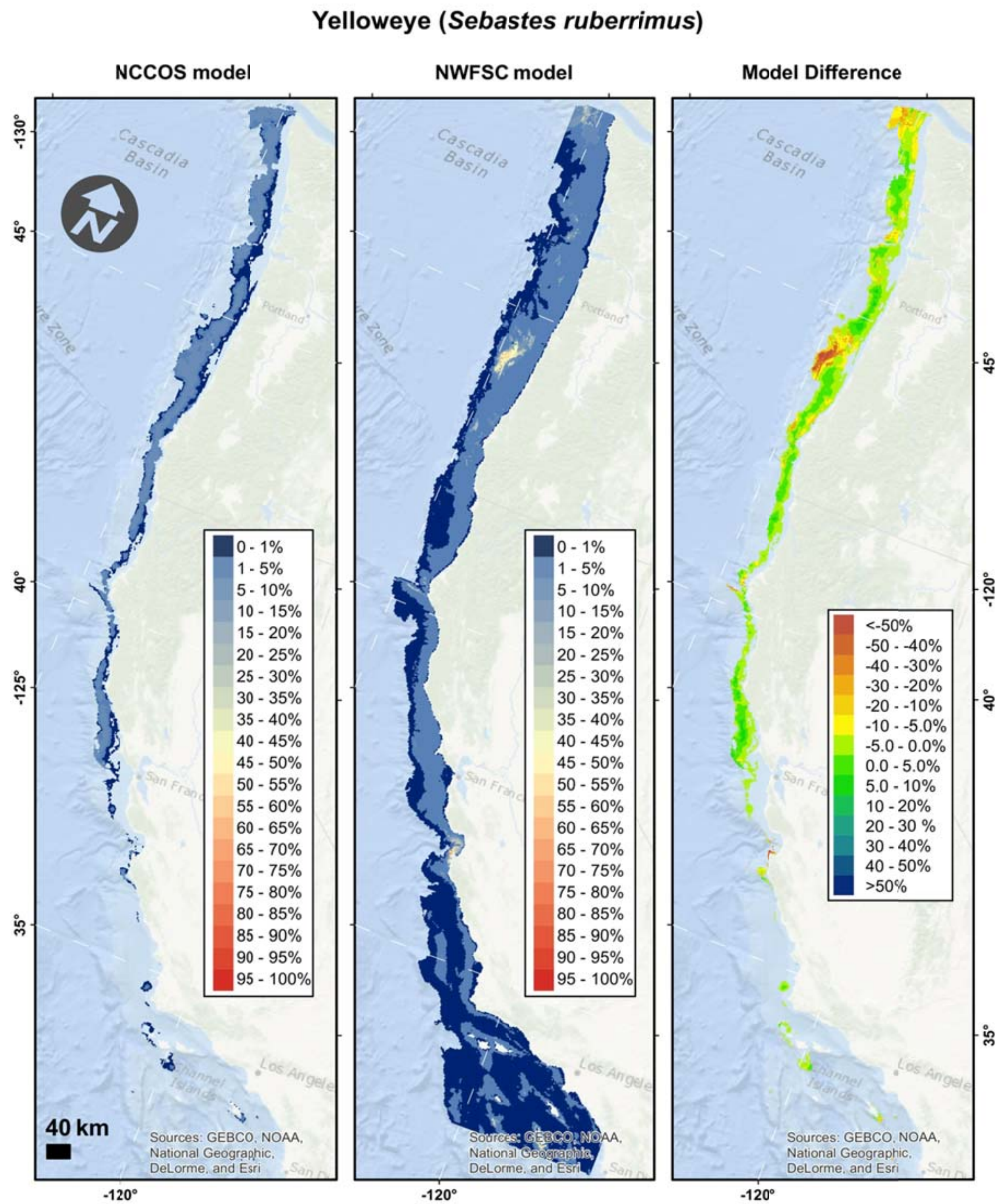

Figure 3.6. Yelloweye rockfish predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

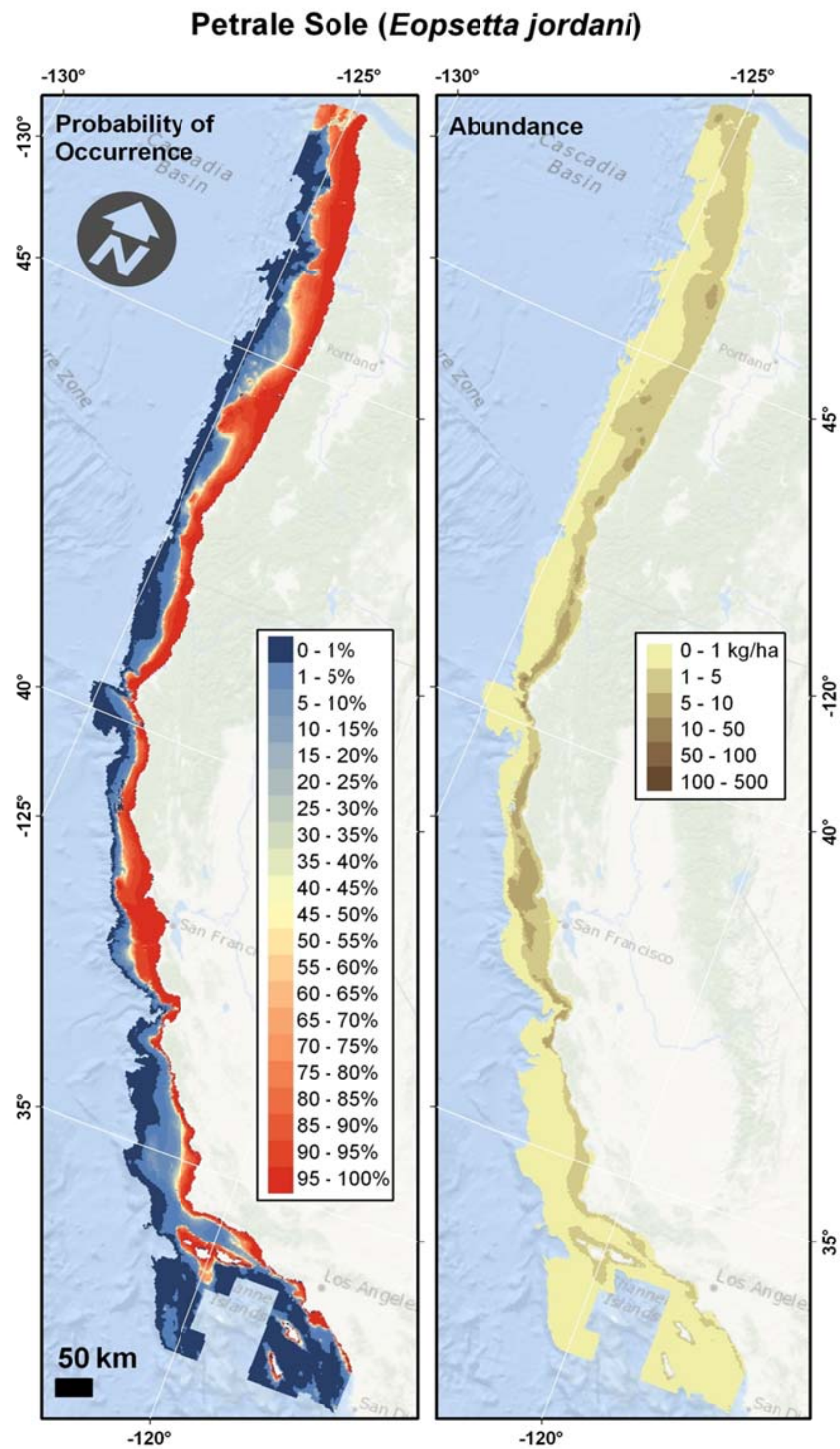

Figure 3.7. Petrale sole mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

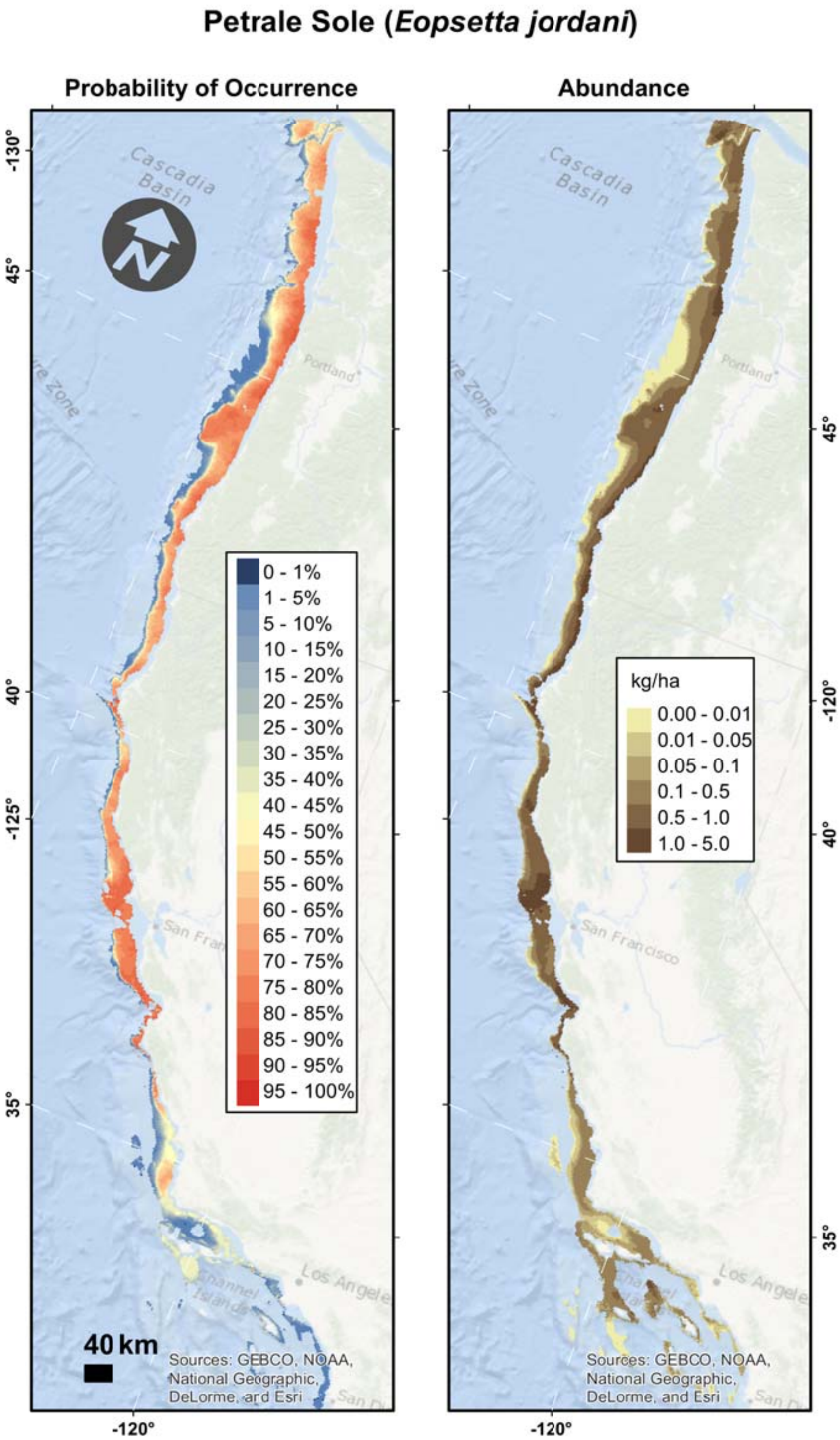

Figure 3.8. Petrale sole predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

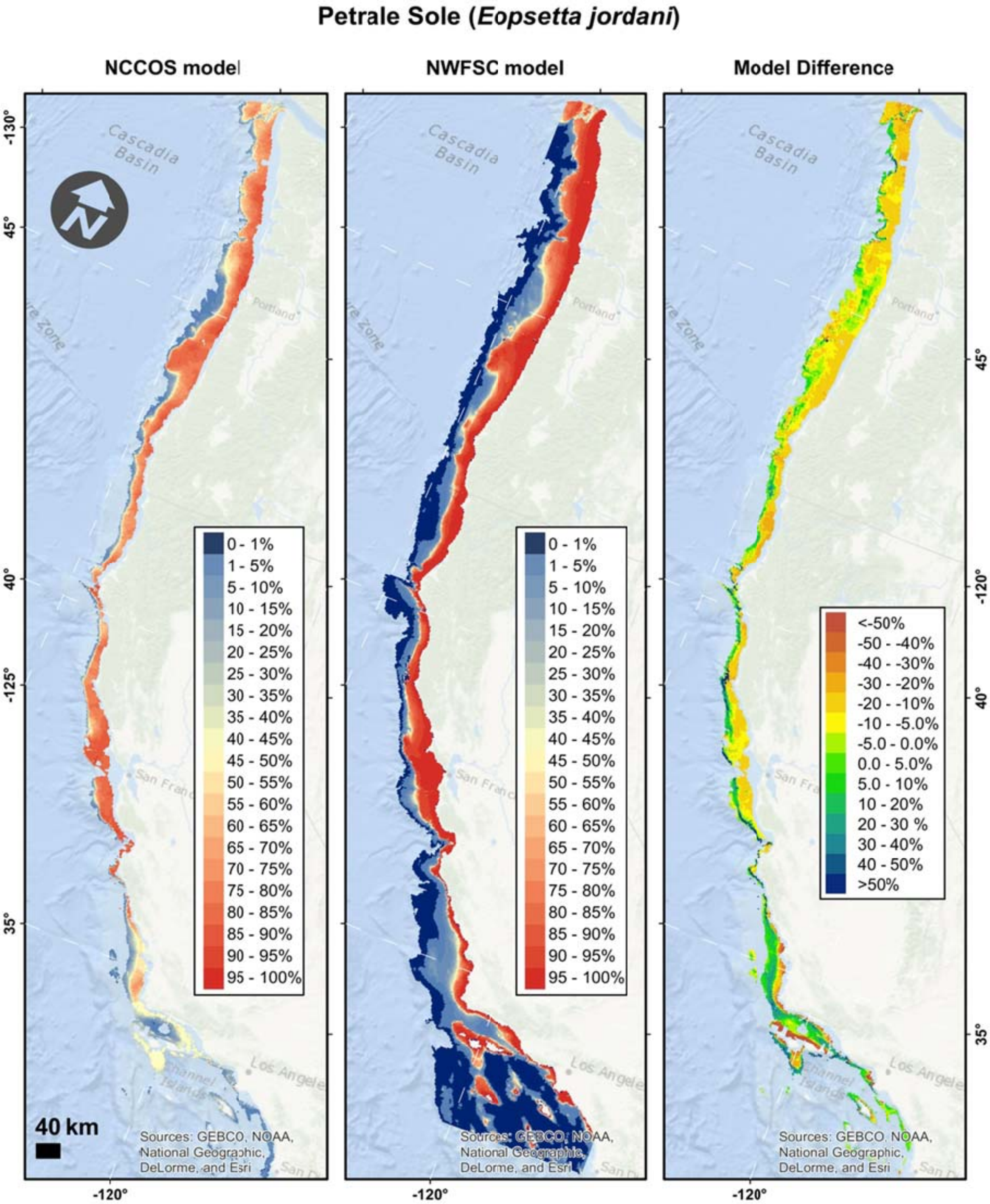

Figure 3.9. Petrale sole predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

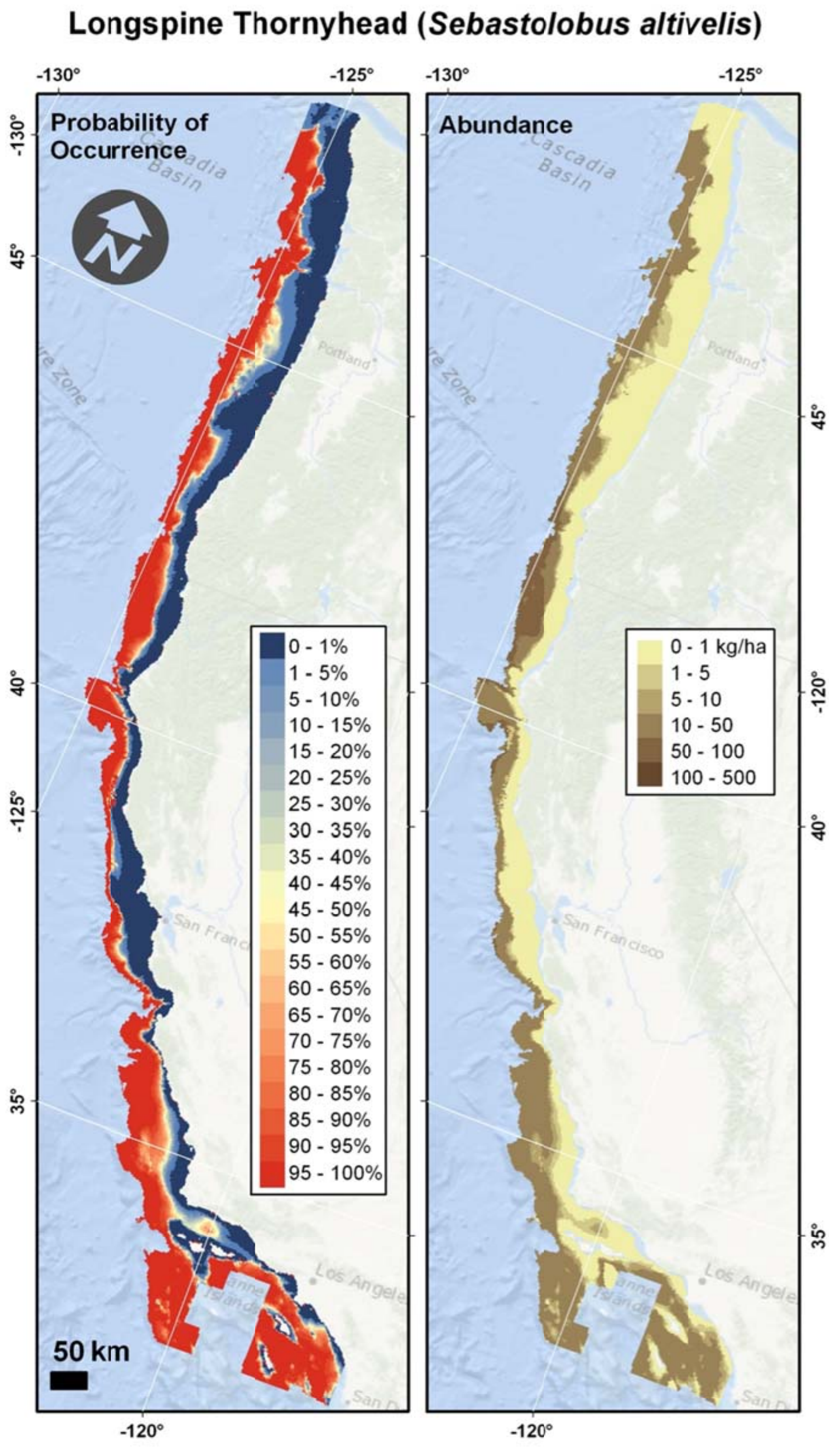

Figure 3.10. Longspine thornyhead mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

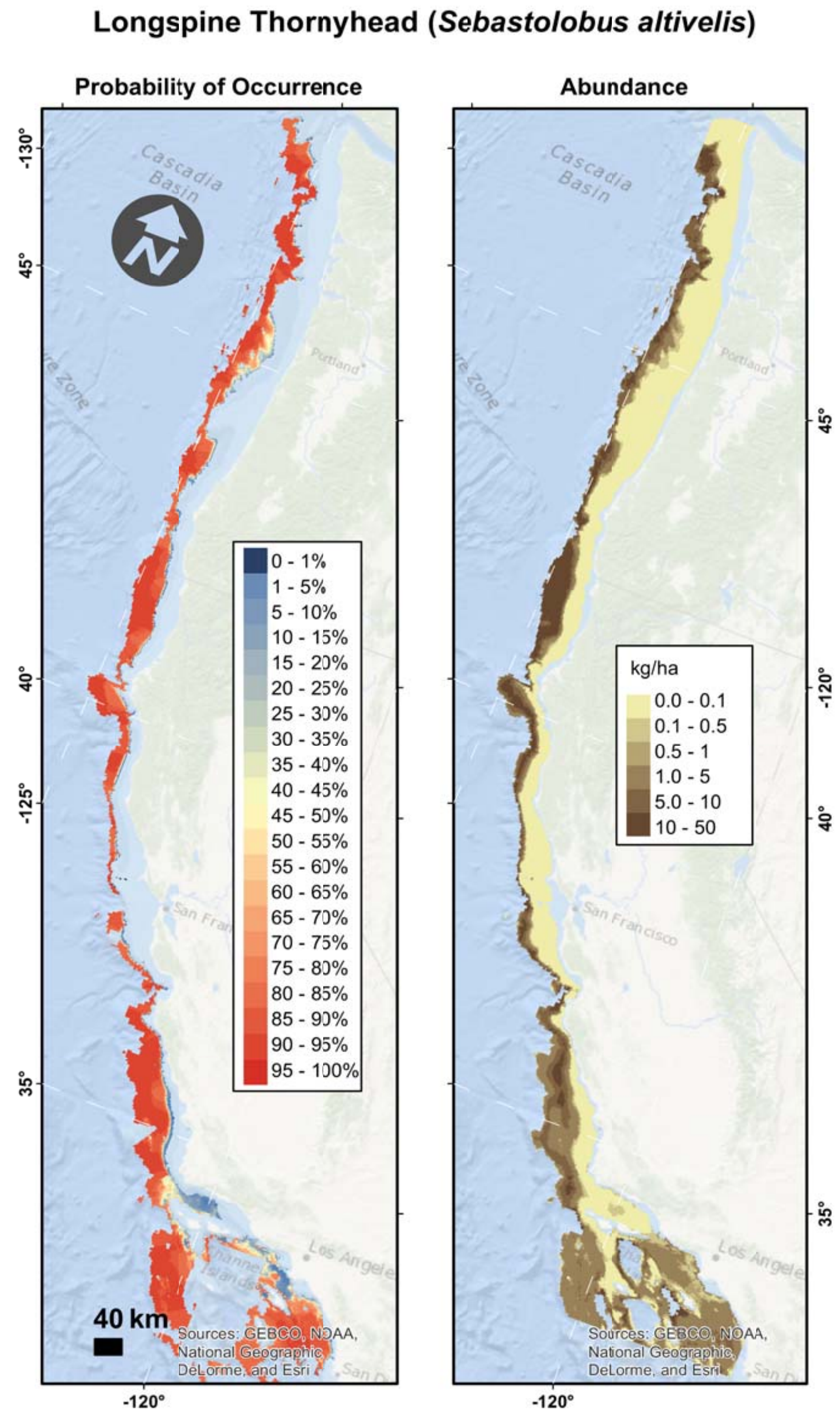

Figure 3.11. Longspine thornyhead predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

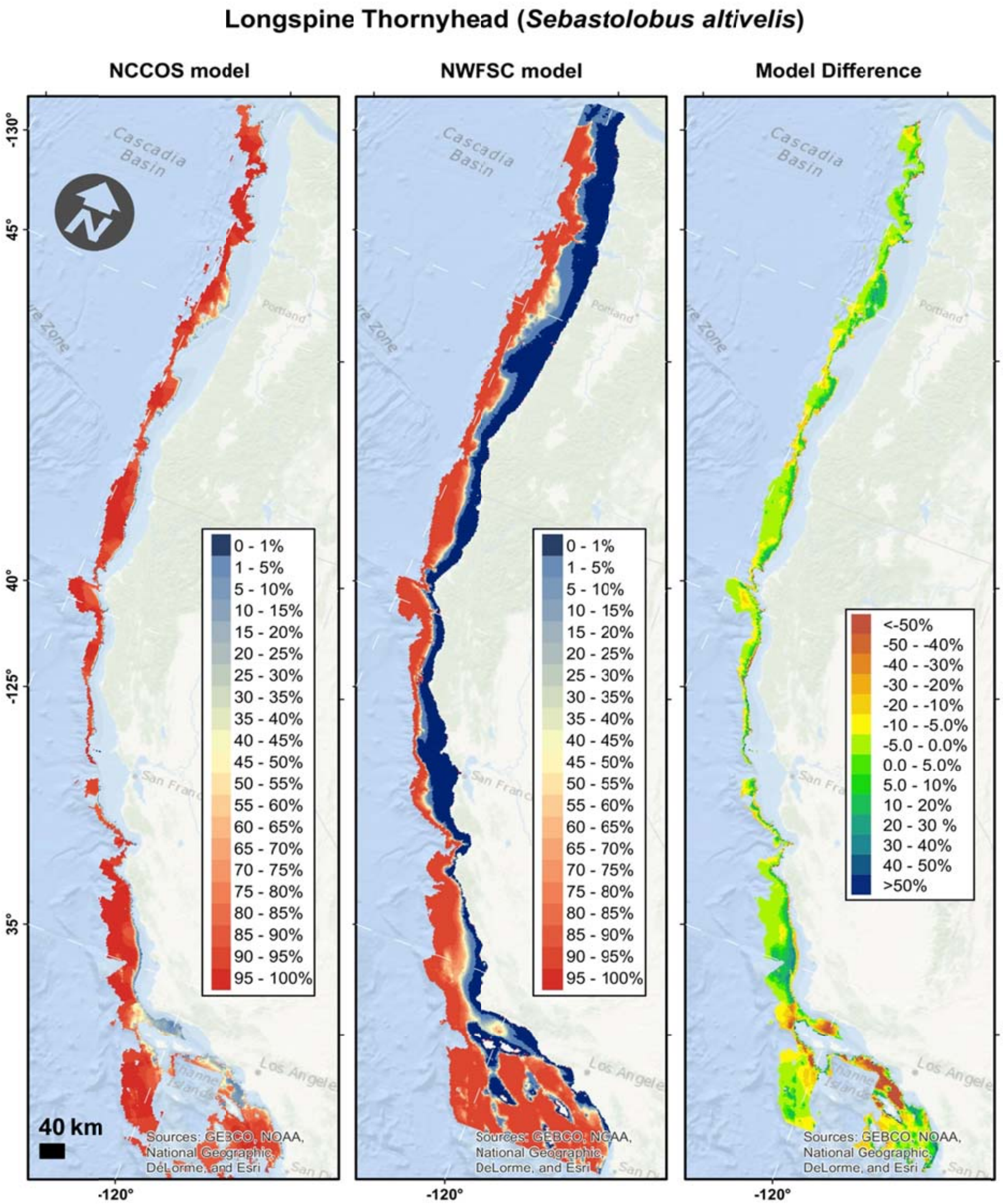

Figure 3.12. Longspine thornyhead predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

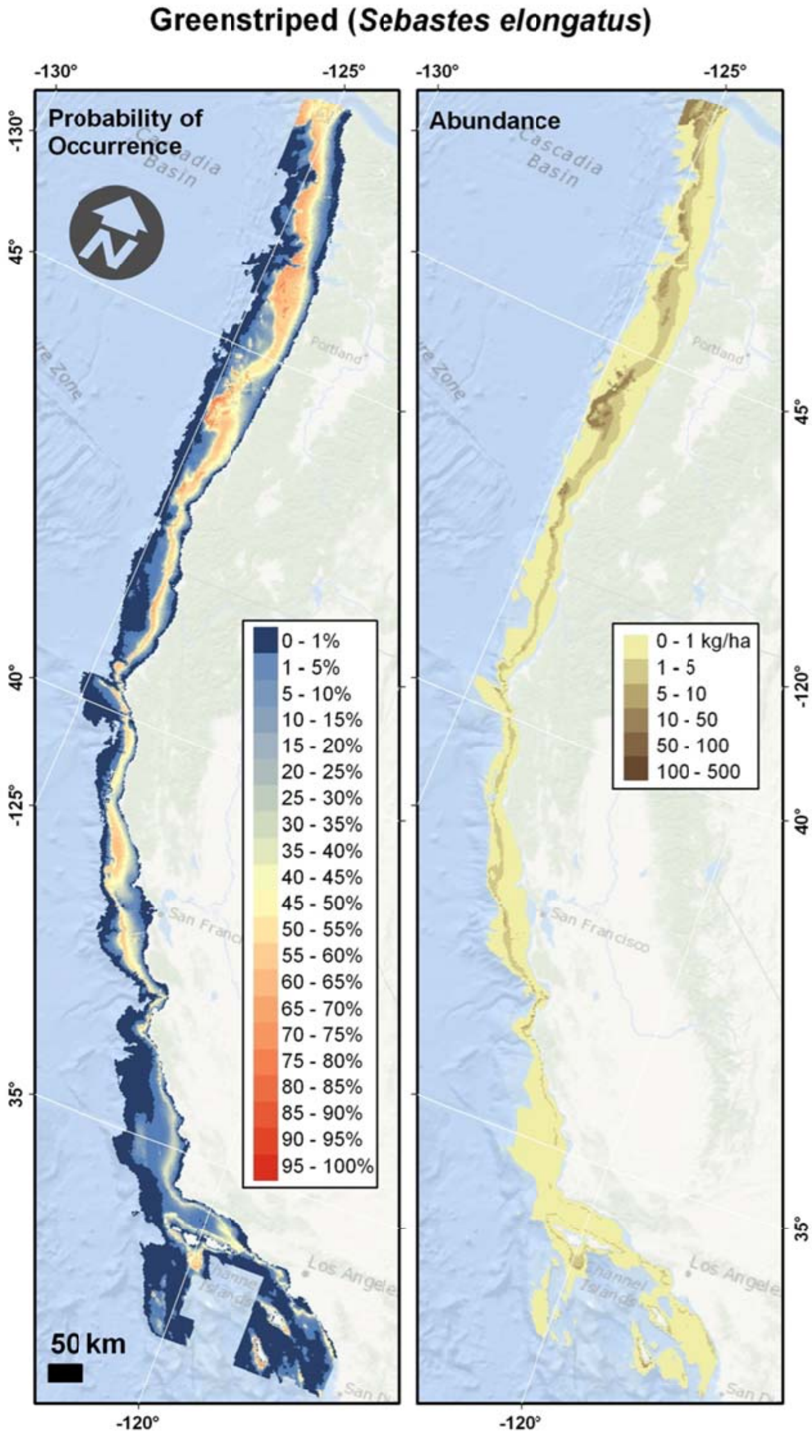

Figure 3.13. Greenstriped mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

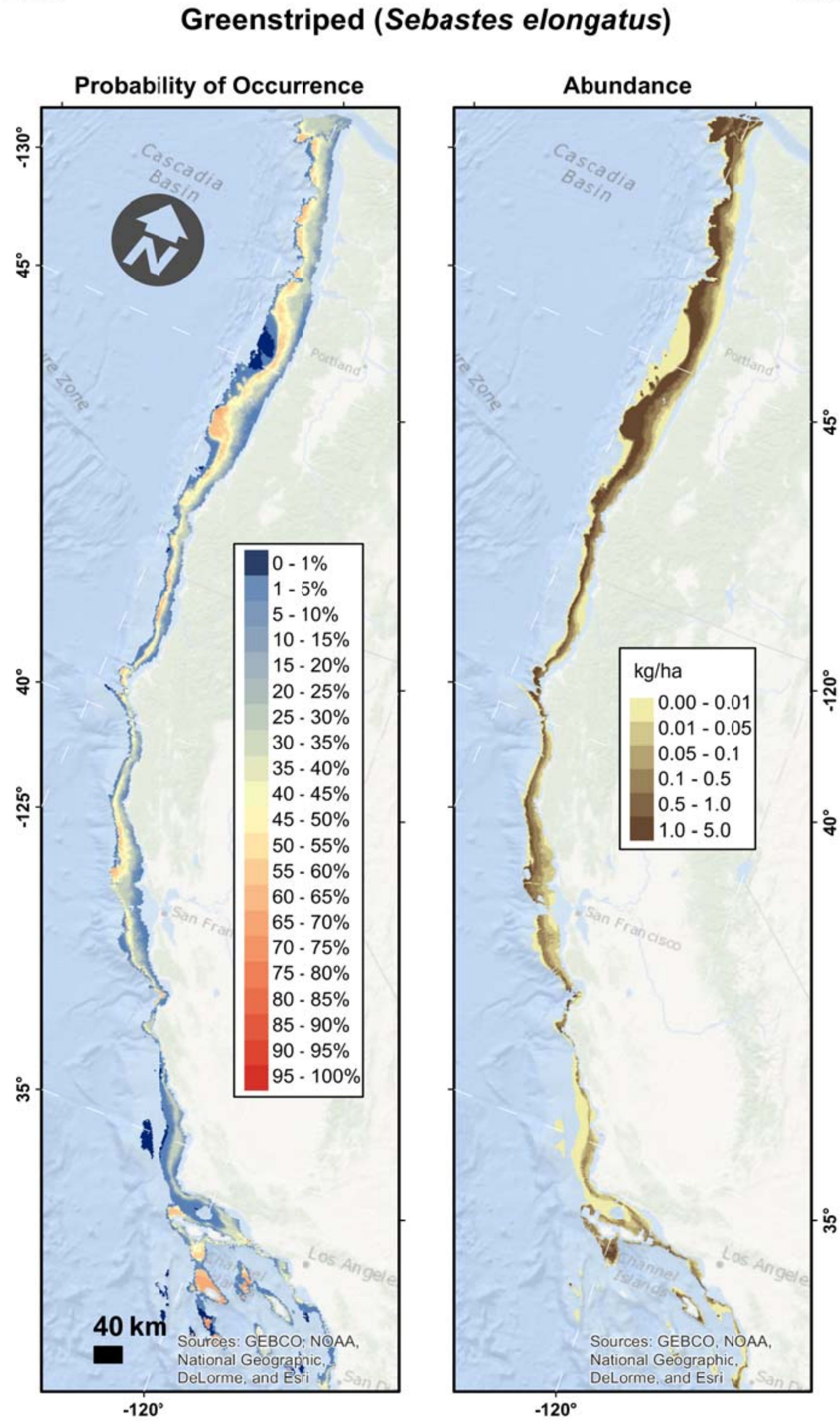

Figure 3.14. Greenstriped predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

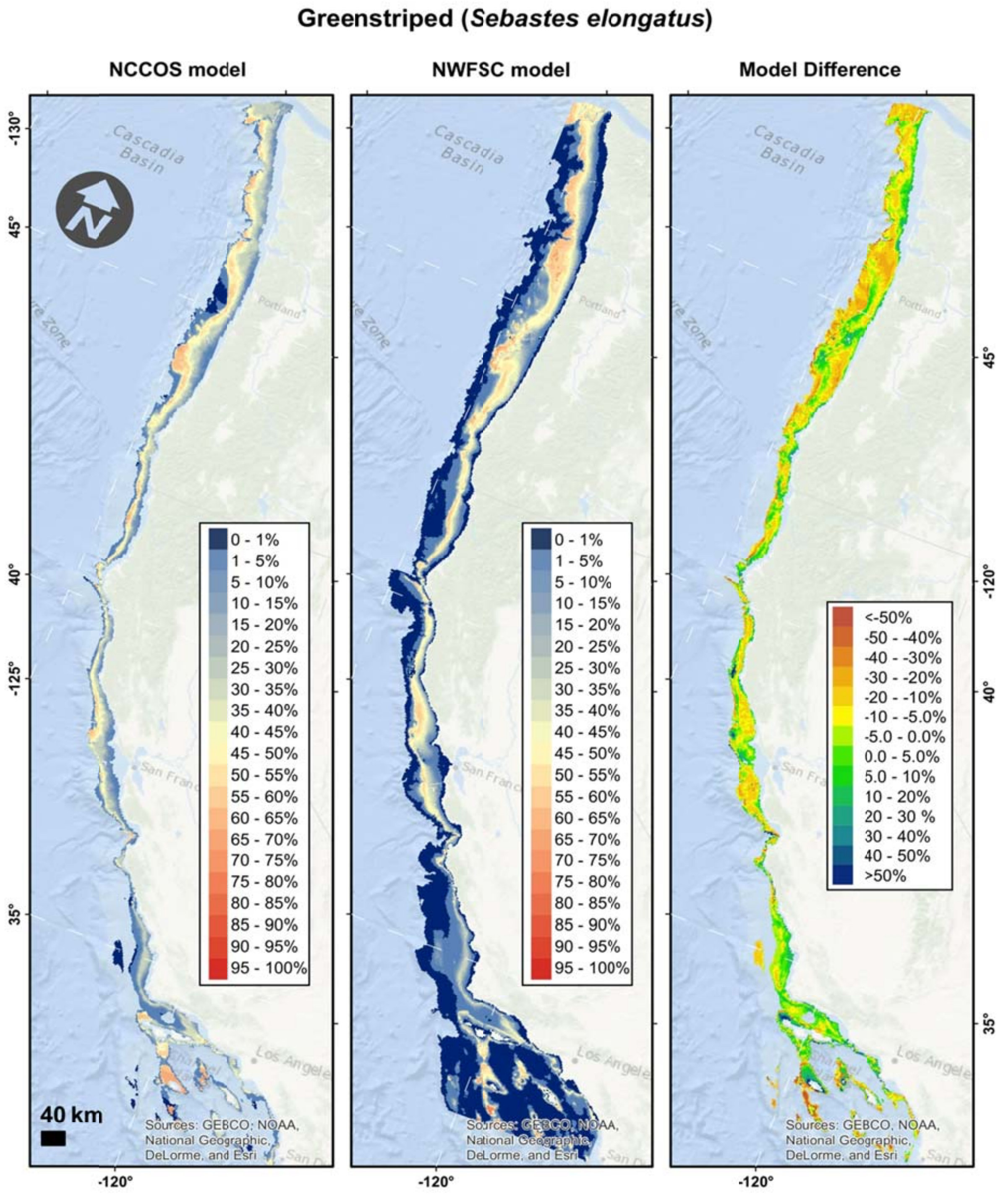

Figure 3.15. Greenstriped predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

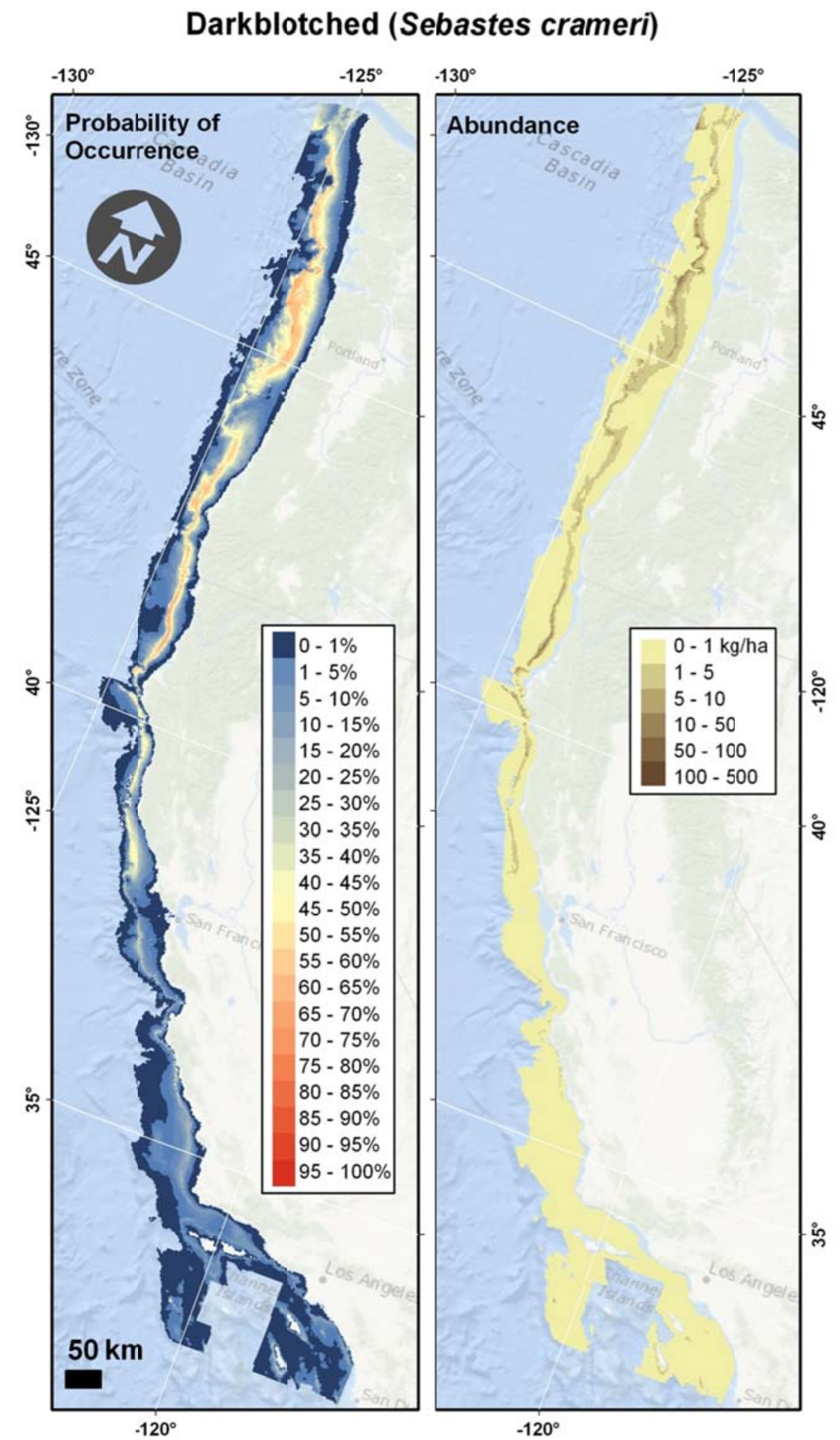

Figure 3.16. Darkblotched mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

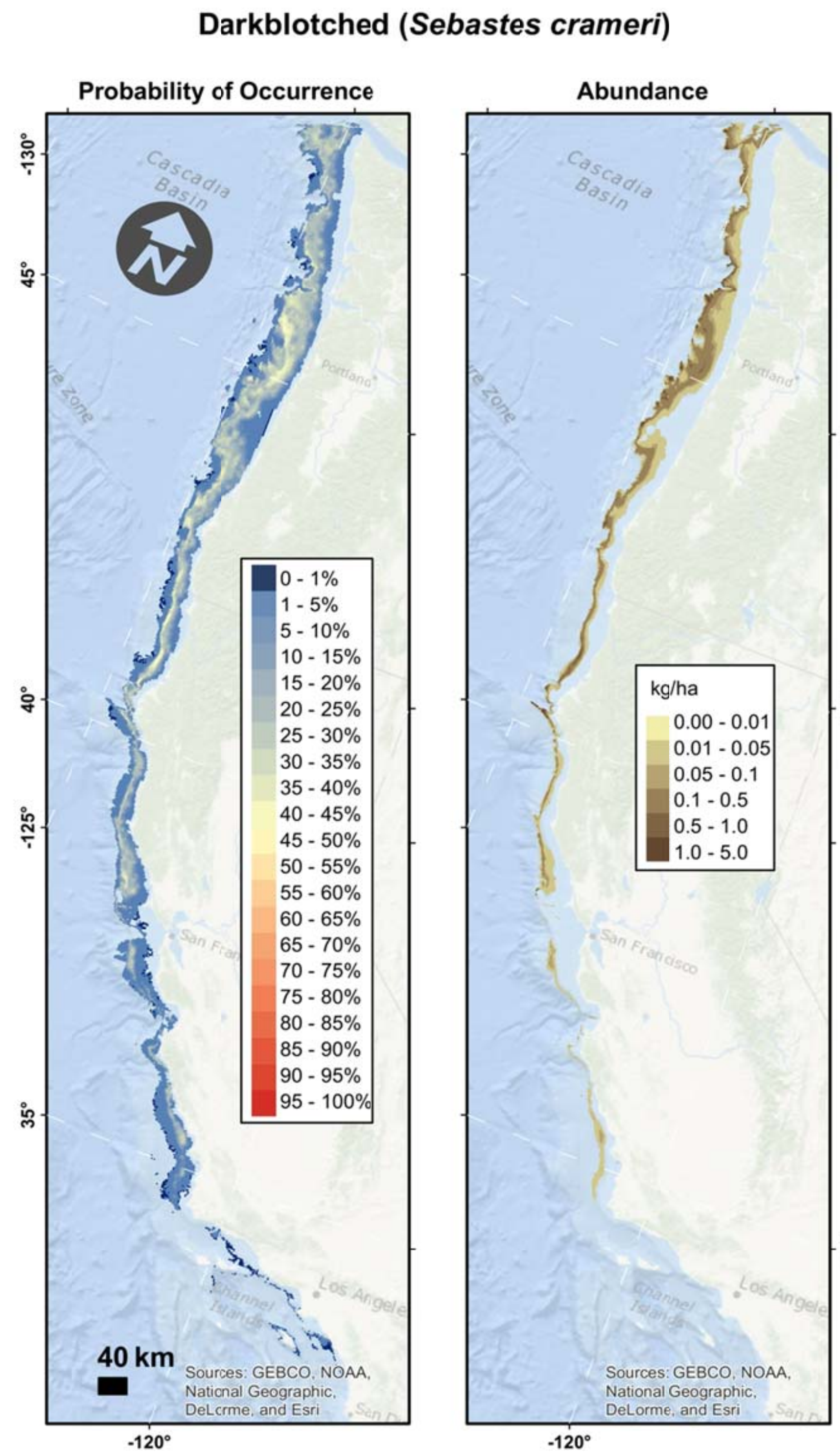

Figure 3.17. Darkblotched rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

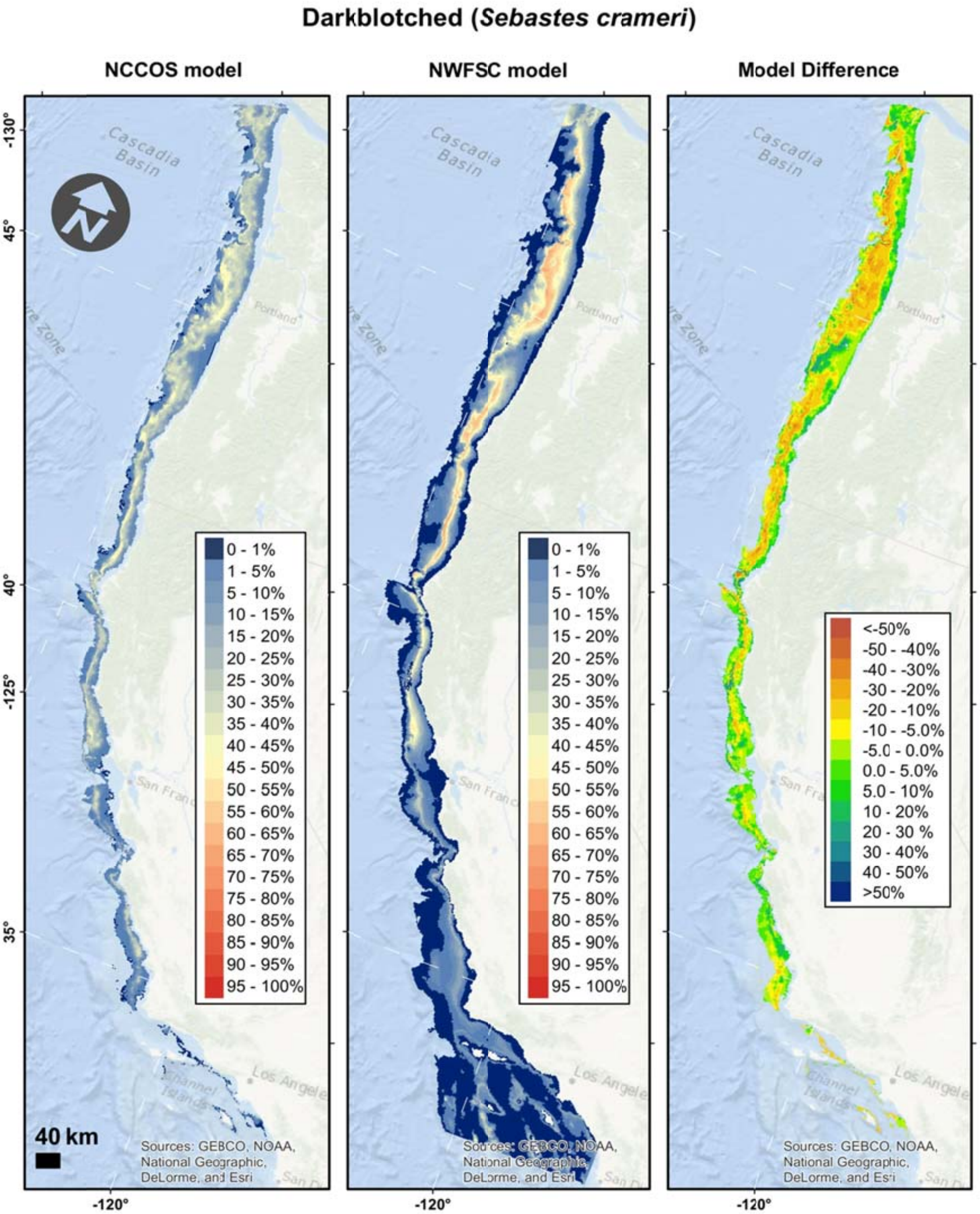

Figure 3.18. Darkblotched rockfish mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

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4.0 STRESSORS

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Overview:

- We compiled new and existing information on U.S. West Coast fisheries, including the federal limited entry groundfish bottom trawl fishery, midwater trawl fishery, and observed fixed gear effort in the groundfish fishery, with a focus on before and after EFH closures.
- The majority of each fleet's fishing effort occurred in the northern biogeographic region over the upper slope.
- The majority of bottom trawling effort occurred over soft seafloor habitats on the shelf and upper slope before EFH conservation areas were enacted, but shifted to the upper slope post-2006.
- The majority of observed fixed gear effort occurred over soft seafloor habitat.
- Midwater trawling ranges from 8-31% annually over EFH conservation areas where bottom trawling is prohibited.
- Bottom trawl effort did not appear to occur where bottom contact gear was prohibited either before or after the EFH conservation areas were established. A low level of bottom trawl fishing in these areas is likely attributable to having only start and end points of trawl sets.
- In areas were only fixed gear is allowed, effort has ranged annually from 4 – 18% of the total fixed gear effort.

4.1 FISHERY PRESSURES

In this synthesis, we focused our efforts on commercial fishing effort information in federally-managed groundfish fisheries. This included bottom trawl fishing effort, midwater trawl fishing effort, and observed fixed gear effort.

4.2 GEAR-TYPE-SPECIFIC DISTRIBUTION

Groundfish fishing effort (not surprisingly) is strongly constrained by bottom type. Nearly all bottom trawl fishing effort occurs over the shelf and upper slope in soft habitats. There is also a trend of decreasing effort from north to south, though effort exists in all regions (Table 4a.1). Within depth-area strata, the highest effort relative to hard habitat was in the northern upper slope stratum (10%). Over soft habitat, a clear effort shift to the upper slope has been evident since 2007.

Mid-water trawl fishing is conducted off the Washington and Oregon coasts, in the northern biogeographic region (Table A4a.6.) and does not occur in other regions. (A small effort in the Salish

Sea region is an artifact of the trawl towlines crossing over the entrance to the Strait of Juan de Fuca boundary at Cape Flattery, WA.) Like the bottom trawl, nearly all occurs over soft bottom, on the upper slope and shelf. The majority occurs over the upper slope, secondly over shelf, and lastly over the lower slope. Over time, an increase in effort over the upper slope occurred from 2002 to 2008 (Figure A4a.2.). A drop in fishing effort during 2009 was related to a reduction in Pacific hake quota in the at-sea fishery.

Fixed gear fishing effort in the groundfish fishery is observed in the following subsectors or state fisheries: limited entry sablefish-endorsed primary season (April-October), limited entry non-sablefish-endorsed fixed gear, open access fixed gear, and Oregon and California nearshore fisheries. Annual coverage of fixed gear sectors and fisheries (calculated as the observed proportion of fleet-wide landings) can be found online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm. Since all fishing operations are not observed, neither the maps nor the data can be used to characterize the fishery completely, but provide the current best available knowledge on the spatial aspects of these fleets.

Observed fixed gear fishing was also biased toward the northern biogeographic region over the upper slope in soft sediments (Table 4a.1.). However, in the northern, central, and southern regions, at least 5% of observed fixed gear fishing effort on both the shelf and upper slope occurred over hard habitat (Table A4a.7.). The highest effort relative to hard habitat occurred over the central shelf (23.7%).

4.3 FISHING EFFORT RELATIVE TO SPATIAL MANAGEMENT BOUNDARIES

4.3.1 Fishing effort relative to Amendment 19 MPAs

We examined fishing effort within the 51 Pacific Coast Groundfish Fishery Management Plan (FMP) Amendment 19 conservation areas. Trawl effort and observed fixed gear effort were summarized from either towline models, which depict a line from the gear deployment to retrieval coordinates, or points representing the average of these coordinates. Because these are straight lines or averages, the “edge” of fishing effort can be fuzzy, and some small margin of fishing effort can still be represented within EFH closure areas, even though a prohibition may exist (Table 4a.2.). Also since 2007, fixed gear fishing effort ranges annually from 0.1 – 0.2 % within EFH closures where bottom contact gear is prohibited. In each case, some of this (but not necessarily all) may be due to our mapping methods.

Midwater trawl fishing is permissible within all Amendment 19 EFH conservation areas since it is assumed to have no contact with the seafloor. Midwater trawl effort ranges annually from 7.7 – 30.8% over EFH areas where bottom trawling is prohibited (Table 4a.1.). However, midwater trawl effort does not appear to occur over EFH conservation areas where either bottom contact gear or bottom trawl gear other than demersal seine are prohibited.

Bottom trawl effort has ranged annually from 1.6 – 3.3% (since EFH closures) where bottom trawl gear is prohibited. From 2002 to 2010, bottom trawl effort did not appear to occur within EFH conservation areas where bottom contact gear (including bottom trawl) was prohibited. Thus, the EFH closures did not displace any bottom trawl fishing effort from these areas. This is likely due to the footrope restrictions put in place in 2000 that appears to have altered fishing behavior (Hannah 2003, Bellman et al. 2005). A long term examination of fishing restrictions and fishing behavior, in order to evaluate which restrictions are associated with behavioral changes would be a very useful next step. Some bottom trawl effort does appear within EFH areas where bottom trawl gear is prohibited, which may be partly attributed to methodology, but may also represent enforcement issues. The level of fishing effort within these prohibited areas is fairly consistent both pre- and post- EFH conservation areas.

Fixed gear fishing effort is permissible within Amendment 19 EFH conservation areas prohibiting only bottom trawl gear or bottom trawl gear other than demersal seine. Since 2002, fixed gear effort in both designated areas combined has ranged annually from 4 – 18.2% (Table 4a.1.). In 2006, the year that EFH conservation areas went into effect, the lowest effort occurred within these areas (4%).

Table 4a.2. Distribution of bottom trawl fishing effort (distance, meters) from 2002-2010 by seabed habitat type, and by depth zones both coastwide and in four biogeographic sub-regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The “Salish Sea” only encompasses the shallowest (“shelf”) depth zone. Data source: PacFIN trawl logbooks, based on a towline model which depicts a line from the gear deployment to retrieval coordinates.

		BIOGEOGRAPHIC SUB-REGION								COASTWIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	***Substrate***	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*
Shelf[1]	**Total**	**465,744,267**	**34.5%**	**135,584,061**	**39.4%**	**57,556,112**	**98.2%**	**3,652,788**	**100.0%**	**662,537,227**	**37.7%**
	hard	4,168,770	0.3%	1,103,097	0.3%	281,647	0.5%	5,767	0.2%	5,559,281	0.3%
	mixed	3,730,922	0.3%	89,351	0.0%	238,597	0.4%	9,969	0.3%	4,068,840	0.2%
	soft	457,844,575	33.9%	134,391,612	39.1%	57,035,868	97.4%	3,637,052	99.6%	652,909,107	37.1%
	undefined	0	0.0%	0	0.0%	0	0.0%		0.0%	0	0.0%
Upper Slope[2]	**Total**	**884,755,328**	**65.5%**	**208,141,081**	**60.5%**	**1,026,193**	**1.8%**	**0**	**0.0%**	**1,093,922,602**	**62.2%**
	hard	22,508,956	1.7%	3,738,955	1.1%	14,917	0.0%	0	0.0%	26,262,828	1.5%
	mixed	32,343,926	2.4%	128,515	0.0%	1,393	0.0%	0	0.0%	32,473,835	1.8%
	soft	829,902,445	61.4%	204,273,611	59.4%	1,009,883	1.7%	0	0.0%	1,035,185,939	58.9%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**1,279,842**	**0.1%**	**198,966**	**0.1%**	**4,716**	**0.0%**	**0**	**0.0%**	**1,483,524**	**0.1%**
	hard	118,706	0.0%	1,155	0.0%	4,716	0.0%	0	0.0%	124,577	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	1,161,136	0.1%	197,812	0.1%	0	0.0%	0	0.0%	1,358,947	0.1%
	undefined	0	0.0%	0	0.0%		0.0%	0	0.0%	0	0.0%
Total		**1,351,779,436**	**100.0%**	**343,924,108**	**100.0%**	**58,587,021**	**100.0%**	**3,652,788**	**100.0%**	**1,757,943,353**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

4.3.2 Fishing effort changes in time relative to EFH closures

The overall time periods from before EFH conservation closures (2002-Jun 2006) and after implementation (Jul 2006-2010) were compared for relative fishing intensity, as presented in the Phase 1 report. The majority of large or moderate increases in bottom trawl fishing effort after EFH conservation areas were established are found within fishing grounds over the continental slope. After 2006, there appear to have been large decreases in bottom trawl effort off the northern WA coast Appendix 4: Figure A4a.4, plate A2) and on the Oregon continental shelf (plates B2, C2). There were also decreases in areas on the continental shelf that have traditionally supported the state-permitted California halibut trawl fishery by limited entry groundfish trawl vessels. Large decreases in California state and federal waters south of Point Conception, CA (plates F3, F4) are also part of the state-permitted California halibut trawl fishery fished by open access groundfish vessels, and may be attributed to area-specific closures in the state fishery.

For the midwater trawl fleet, there were large decreases in effort off the northern WA coast (Appendix 4: Figure A4a.5, plates A2) and on the Oregon continental shelf (plates B2, C2). The majority of increases in midwater trawl fishing effort after EFH closures were over the continental slope.

Changes in observed fixed gear fishing after EFH closures were more patchy in distribution than trawl gears (Appendix 4: Figure A4a.6). They were evident on a coast-wide basis but with a smaller spatial extent of change overall. Some areas of increase were in nearshore waters off Oregon in the state-permitted nearshore groundfish fishery (plates B2, C2). Other areas of increase were in deeper waters fished by the limited entry and open access federal fixed gear sectors.

Table 4a.2. Annual distribution of fleet bottom trawl, fleet midwater trawl, and observed fixed gear fishing effort from 2002-2010 by Pacific Coast Groundfish Fishery Management Plan Amendment 19 prohibition type within Essential Fish Habitat Conservation Area closures. Data source: West Coast Groundfish Observer Program (NWFSC), based on either a towline model which depicts a line from the gear deployment to retrieval coordinates (longlines or pot strings), or on points representing the average of gear deployment and retrieval coordinates (other hook-and-line gears or pot/trap gears), depending on gear type.

Fleet Bottom Trawl Effort									
Amendment 19 Prohibition	2002	2003	2004	2005	2006	2007	2008	2009	2010
Outside EFH Cons. Areas	93.5%	94.2%	97.2%	97.3%	97.5%	97.0%	96.1%	97.3%	96.1%
Bottom contact gear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bottom trawl gear	4.8%	4.1%	2.0%	1.9%	1.4%	1.6%	2.6%	2.6%	3.3%
Bottom trawl gear other than demersal seine	1.8%	1.7%	0.8%	0.8%	1.1%	1.4%	1.3%	0.2%	0.6%
Fleet Midwater Trawl Effort									
Amendment 19 Prohibition	2002	2003	2004	2005	2006	2007	2008	2009	2010
Outside EFH Cons. Areas	92.3%	87.2%	91.2%	90.9%	81.2%	69.2%	86.4%	84.0%	86.4%
Bottom contact gear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bottom trawl gear	7.7%	12.8%	8.8%	9.1%	18.8%	30.8%	13.6%	16.0%	13.6%
Bottom trawl gear other than demersal seine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Observed Fixed Gear Effort									
Amendment 19 Prohibition	2002	2003	2004	2005	2006	2007	2008	2009	2010
Outside EFH Cons. Areas	91.5%	81.8%	89.4%	86.7%	96.0%	93.2%	85.9%	87.0%	88.9%
Bottom contact gear	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%	0.0%	0.2%	0.1%
Bottom trawl gear	5.1%	11.1%	3.7%	8.6%	0.8%	3.0%	9.6%	6.6%	3.1%
Bottom trawl gear other than demersal seine	3.5%	7.1%	6.7%	4.8%	3.2%	3.7%	4.5%	6.2%	7.9%

4.3.2.1 Cumulative fishery pressures

Fishing pressures act upon groundfish essential fish habitat collectively and thus quantifying a cumulative pressure index is an important tool in assessing overall fishing impacts. We used a weighted approach by assuming that fishing pressures were additive, but with a weighting scheme applied for the sensitivity of various habitat types to individual fishing gears. The weighting scheme was adapted from information summarized for a report on the effects of fishing gear on habitats developed for the 2005 groundfish EFH Environmental Impact Statement (PSMFC 2004, NMFS 2005). See Section 4 of the Appendix for more details.

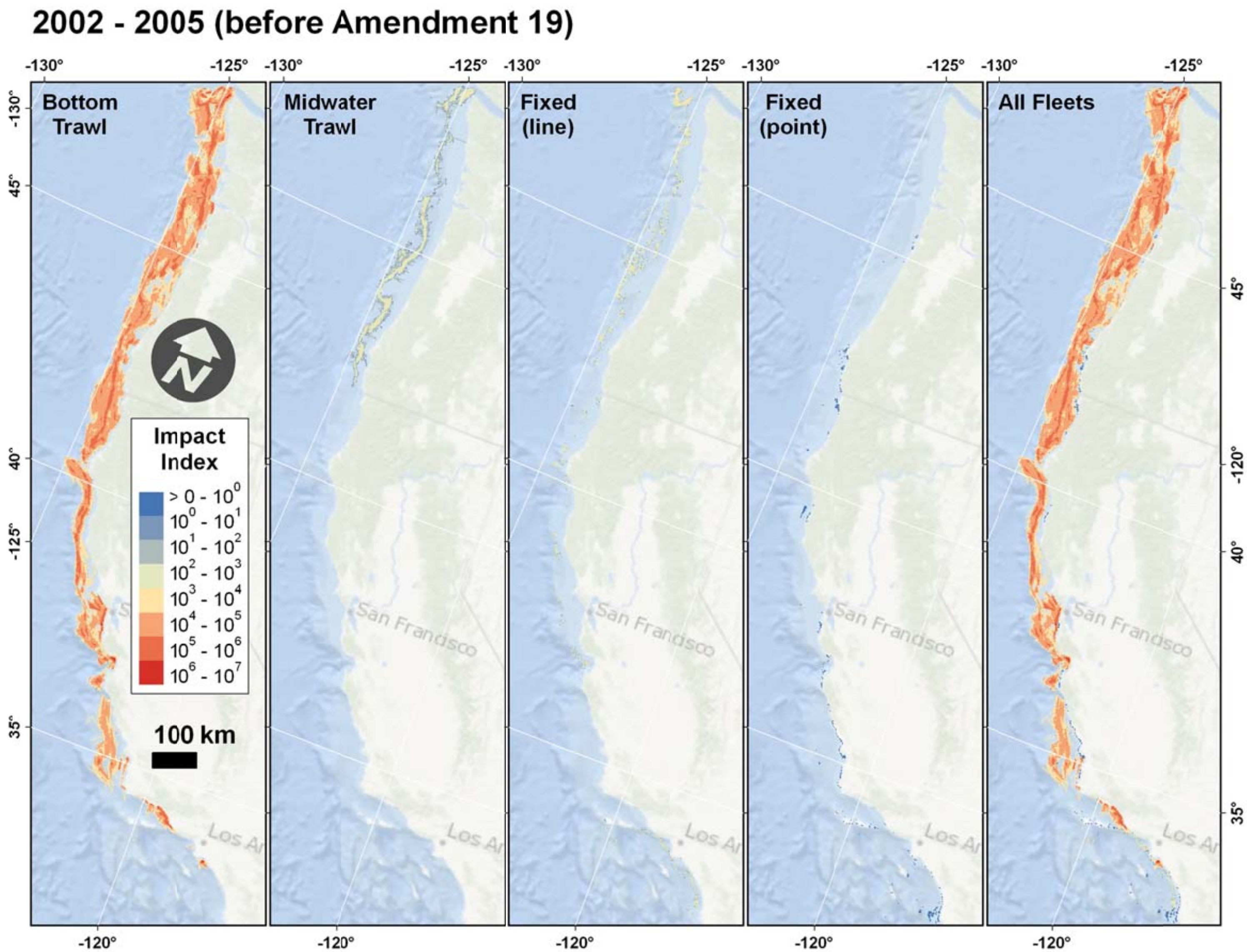

Figure 4a.1. Distribution of cumulative fishing pressure prior to EFH closures (2002-2005) relative to seafloor habitat and depth, based on a summary of bottom trawl, midwater trawl, and observed fixed gear fishing impact layers weighted according to Table A4a.1.

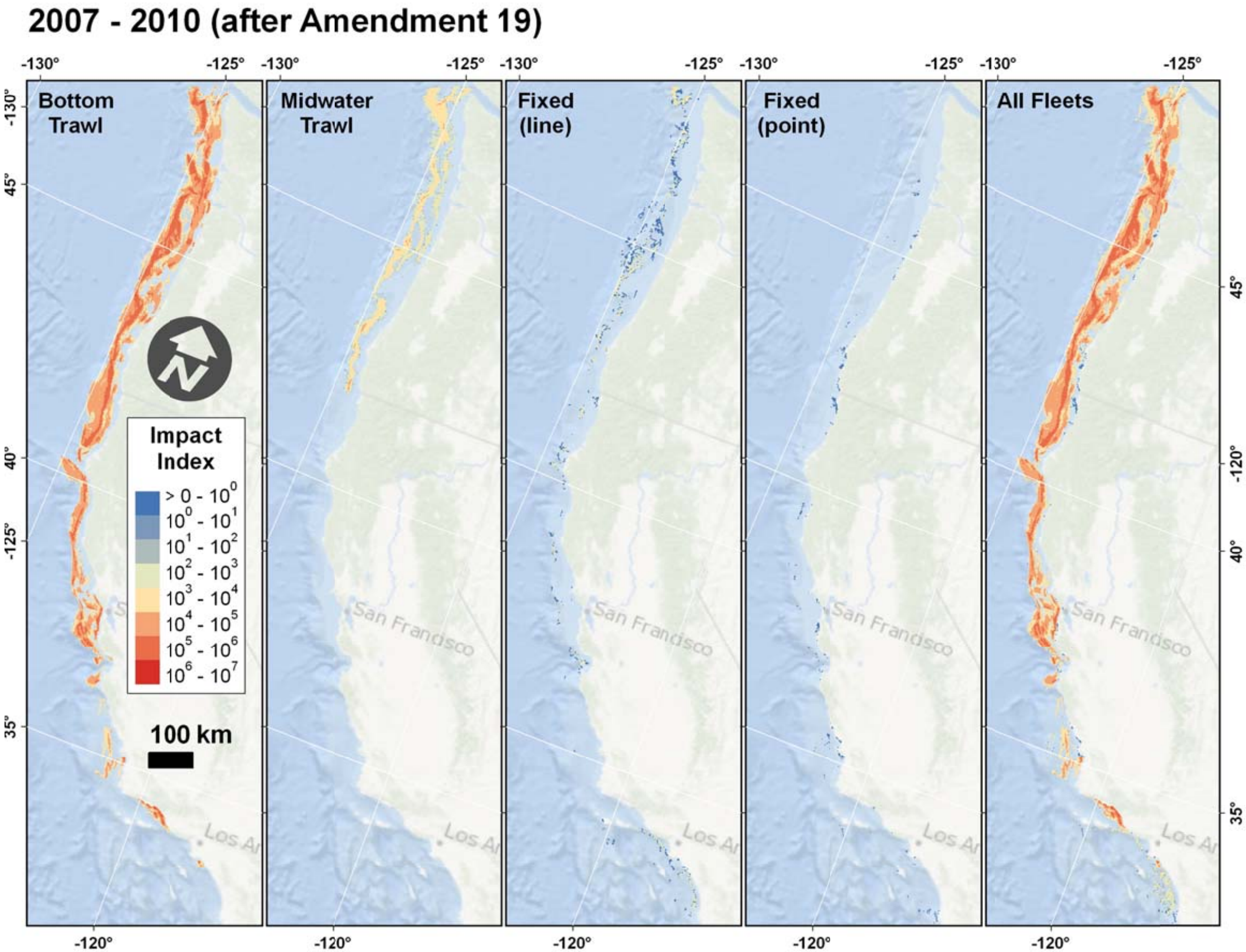

Figure 4a.2. Distribution of cumulative fishing pressure following EFH closures (2007-2010) relative to seafloor habitat and depth, based on a summary of bottom trawl, midwater trawl, and observed fixed gear fishing impact layers weighted according to Table A4a.1.

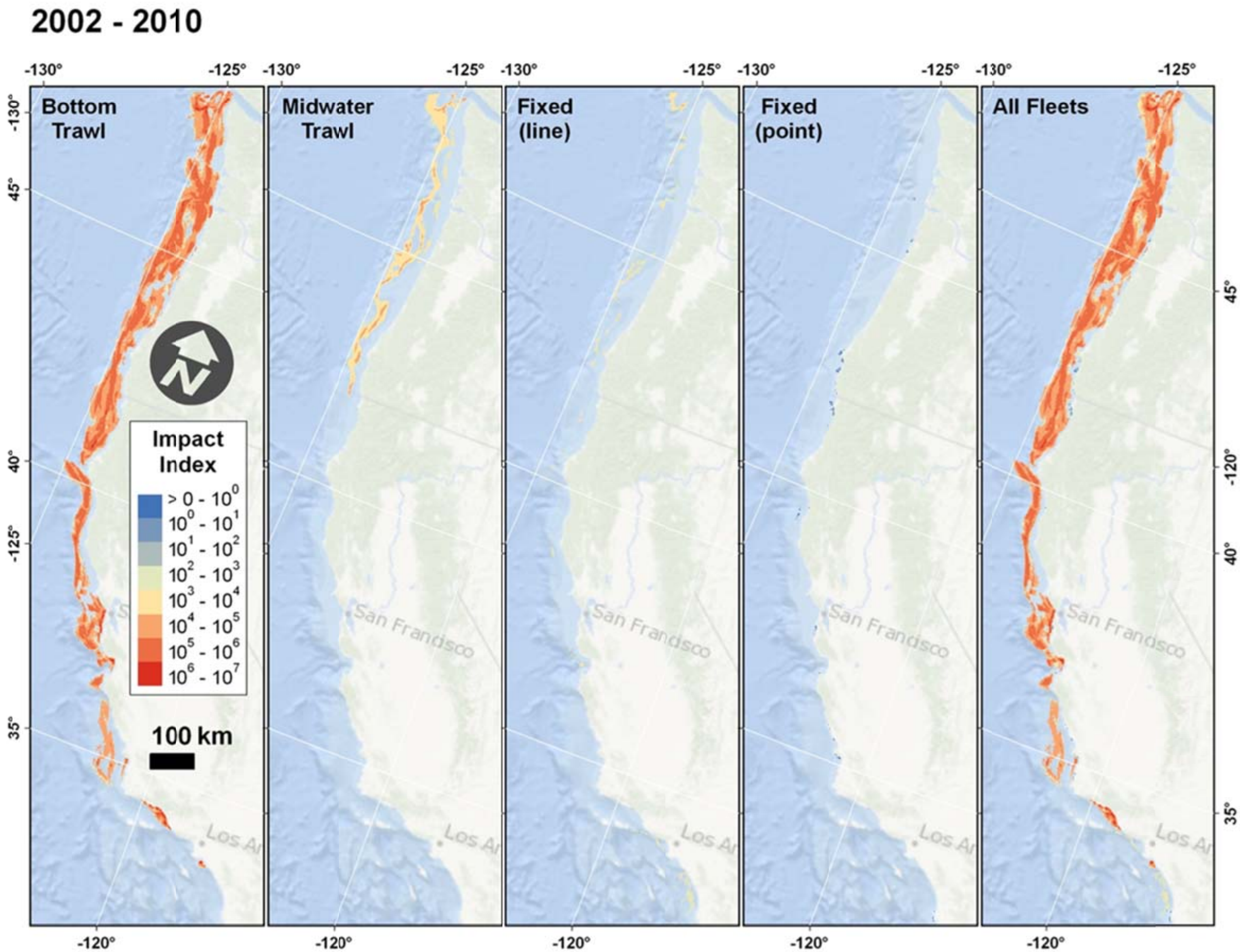

Figure 4a.3. Distribution of cumulative fishing pressure (2002-2010) relative to seafloor habitat and depth, based on a summary of bottom trawl, midwater trawl, and observed fixed gear fishing impact layers weighted according to Table A4a.1.

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4.4 NON-FISHERIES PRESSURES

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4.4.1 Main Findings

- Non-fisheries pressures were greatest in the Salish Sea sub-region, which is entirely]in shelf habitat and is consequently highly exposed to numerous land-derived pressures.
- Among other sub-regions, offshore pressures were more intense in the north, while nearshore pressures were more intense in the south. For example, lower slope habitat was exposed to higher pressure intensity values in the northern sub-region, while shelf and upper slope habitat was exposed to higher pressure intensity values in the southern sub-region.
- There was little variation in the mean intensity of non-fisheries pressures across EFH conservation areas compared to other spatial management regions. This was likely because EFH conservation areas were located offshore and relatively unexposed to land-based pressures.
- Habitat areas of particular concern (HAPCs) were proportionately more exposed to high non-fisheries pressures than other spatial management areas, and this is generally true across other individual pressures.

4.4.2 Introduction

As human population size and demand for marine resources and waterways increases along the coast, numerous human activities in the ocean (e.g., fishing and shipping activity) and on land (e.g., pollutants from industrial activities and runoff from agricultural activities) need to be recognized and incorporated into management of marine resources. There are numerous non-fisheries related pressures acting upon groundfish essential fish habitat (EFH) along the West Coast of the United States (PFMC 2005). We present an example of how some non-fisheries pressures can be analyzed in order to be incorporated into the management framework for West Coast groundfish EFH, and a synthesis of readily available information about threats in these marine areas. This work has been modified from its previous application in the Integrated Ecosystem Assessment (REF).

First, we take advantage of 16 spatially-explicit data layers available from Halpern et al. (2009) to quantify the intensity of non-fisheries pressures among various regions, depth strata, habitat substrate types, and spatial management boundaries related to West Coast groundfish EFH. The pressure data layers were produced from data collected prior to 2007, but represent the most standardized and rigorous analysis of the relative spatial intensity of non-fisheries pressures across the West Coast of the United States. These data layers are currently being updated and will provide estimates for future analyses of non-fisheries pressures on West Coast groundfish EFH.

From the 16 non-fisheries related pressures, we identified seven (Table 4b.1) that were most relevant to West Coast groundfish EFH and which had enough data to be useful for a coastwide analysis. We report on these pressures along with two climate change pressures individually in *Appendix 4*. In order to summarize the distribution of non-fisheries pressures, we combined all 16 non-fisheries pressures into a "combined" pressures data layer and report on the findings below. Each pressure data layer was normalized to values between 0 and 1 so they could be compared and combined into a cumulative impact layer for the Halpern et al. (2009) project; thus, the data layers were easily combined for our purposes.

For specific methods related to each pressure, see the *"Methods for Non-fisheries Pressures"* in Section 4 of the Appendix, but briefly, we used GIS data layers developed in *"Section 1: Habitat"* to delineate sub-regions, depth strata, habitat substrate type, and management boundaries. We then overlaid pressure layers and calculated the mean value for each non-fisheries pressure among all the combinations of sub-regions, depth strata, habitat substrate, and management boundaries.

Table 4b.1. Non-fisheries pressures data layers from Halpern et al. (2009).

NON-FISHERIES PRESSURES DATA LAYERS	
Pressures reported individually	Brief description of data used to create data layer
Atmospheric pollution	Deposition of sulfates derived from the National Atmospheric Deposition Program.
Inorganic pollution	Point source pollution from factories and mines and non-point source pollution that scales with the amount of impervious surface area.
Organic pollution	Input of pesticides.
Ocean-based pollution	Combination of "Commercial shipping activity" and "Invasive species" below.
Nutrient input	Nitrogen input from farming and atmospheric deposition.
Sediment decrease	Sediment input from watersheds with dams.
Sediment increase	Sediment input from watersheds without dams.
Combined pressures	Sum of all 16 pressures.
Additional pressures for calculating "Combined Pressures"	
Coastal trash	Amount of trash collected from beach clean-up efforts in CA.
Recreational beach use	Beach attendance.
Power plants	Locations of coastal power plants.
Light pollution	Stable lights at night database (National Geophysical Data Center).
Coastal engineering	Location of hardened shorelines.
Commercial shipping activity	Vessel track lines from the World Meteorological Organization Voluntary Observing Ships Scheme and ferries.
Oil rig platforms	Locations of offshore oil rigs.
Aquaculture – fish net-pens	Locations of fish net-pens.
Species invasions	Based on annual tonnage of goods passing through each port.

4.4.3 Distribution of non-fisheries pressures

Importantly, pressures do not act upon groundfish essential fish habitat (EFH) individually, but collectively. Pressures from terrestrial-based pollution, shipping, offshore energy development, fisheries and coastal development exert cumulative effects on the ecosystem and should be managed in a holistic way (Vinebrooke et al. 2004, Crain et al. 2008, Halpern et al. 2008, Curtin and Prellezo 2010, Stelzenmüller et al. 2010). However, quantifying the cumulative effects of these pressures is a difficult task primarily because our understanding of whether effects among multiple pressures are additive, synergistic, or antagonistic is relatively poor (Darling and Côté 2008, Hoegh-Guldberg and Bruno 2010).

Instead of trying to calculate the cumulative effects of non-fisheries pressures on groundfish EFH, we used a simplified approach by assuming that pressures were additive and each had equal weight. Thus, we simply summed the pressure intensity values across all 16 non-fisheries pressures (Table 4b.1) for each 1 km^2 cell within the U.S. economic exclusive zone (EEZ) to calculate a "combined pressures" data layer.

The distribution of combined pressures showed the distinct influence of land-based pollution pressures in nearshore habitats and the exposure of offshore habitats to ocean-based pollution and commercial shipping activity (Figure 4b.1). Overall, mean intensity values were highest in the Salish Sea biogeographic sub-region and in the shelf depth strata (Figure 4b.2a). The Salish Sea was most exposed because the vast majority of the region is exposed to highly populated areas and is completely locked within the shelf habitat, which is the most exposed depth stratum. The northern sub-region was the next most-greatly exposed region, but this varied among depth strata (Table 4b.2). For example, pressure intensity values were highest in lower slope habitat in the north, but pressures were higher in the southern sub-region in shelf and upper slope habitat. High values in the lower slope of the northern sub-region were most likely the result of high atmospheric pollution values (see *'Atmospheric pollution'* in Section 4 of the Appendix, whereas multiple land-based pressures (see *Individual pressures* in Section 4 of the Appendix) were responsible for high values in the shelf and upper-slope in the southern sub-region. Within each depth stratum, pressure intensity values varied across habitat types, but showed no clear trend.

We used EFH conservation areas (EFH CA), rockfish conservation areas, and state territorial sea restrictions to define management areas that were prohibited, restricted, or had no restrictions on fishing. Identifying differences in pressure intensity values among management boundaries were more difficult to determine, but pressure intensity values seemed to be higher in areas where commercial and recreational fishing was prohibited (Figure 4b.2b). This was likely because many prohibited areas were located nearshore or inside bays where pressure intensity values were relatively high because of numerous land-based pressures. We also found there was relatively little variation in non-fisheries pressures in EFH CA compared to nearly all other habitat or management regions (Figure 4b.2). This was likely because EFH CA are located offshore and are not exposed to most land-based pressures along the coast (Figure 4b.1). It should be noted that mean intensity values were simply calculated using all cell values (units were ~1km^2 cells across the entire U.S. EEZ) within the habitat or management boundaries; this analysis does not take spatial autocorrelation into account. Future work will account for spatial autocorrelation and make explicit statistical comparisons among habitats and management boundaries.

We also calculated what proportion of various management areas were exposed to the highest pressure intensity values (i.e. the "high" values in Figure 4b.1 represent the top 20% of all pressure intensity values coastwide). EFH CA and non-EFH CA were equally exposed to the highest combined non-fisheries pressures, but this pattern varied among individual pressures (Figure 4b.3). Habitat areas of particular concern (HAPC) were most exposed to the highest non-fisheries pressures with nearly 40% of all area within HAPC boundaries exposed to the highest combined pressures intensity values (Figure 4b.3). This was most distinct across land-based pressures as most HAPCs are located in nearshore habitats. However, differences observed coastwide among management areas varied among sub-regions (Table 4b.3). For example, in the northern sub-region, the proportion of EFH CA exposed to the highest combined pressures (23%) was less than the proportion of areas with no commercial fishing restrictions exposed to high pressures (58%), whereas in the central and southern sub-regions we found that EFH CA and areas with no commercial fishing restrictions were equally exposed.

Overall, we found four main findings from non-fisheries pressures that may potentially affect management of West Coast groundfish EFH. First, non-fisheries pressures were greatest in the Salish Sea, because the entire region is in shelf habitat and is highly exposed to numerous land-derived pressures. Second, among other sub-regions, pressure intensity values varied across depth strata. Lower slope habitat was exposed to higher pressure intensity values in the northern sub-region (offshore pressures), while shelf and upper-slope habitat was exposed to higher pressure intensity values in the southern sub-region (nearshore pressures). Third, we found little variation in mean intensity values for non-fisheries pressures across EFH conservation areas compared to other spatial management regions. This was likely because EFH conservation areas were located offshore and relatively unexposed to land-based pressures. Fourth, we found that HAPCs were proportionately more exposed to high non-fisheries pressures than other spatial management areas, and this is generally true across other individual pressures.

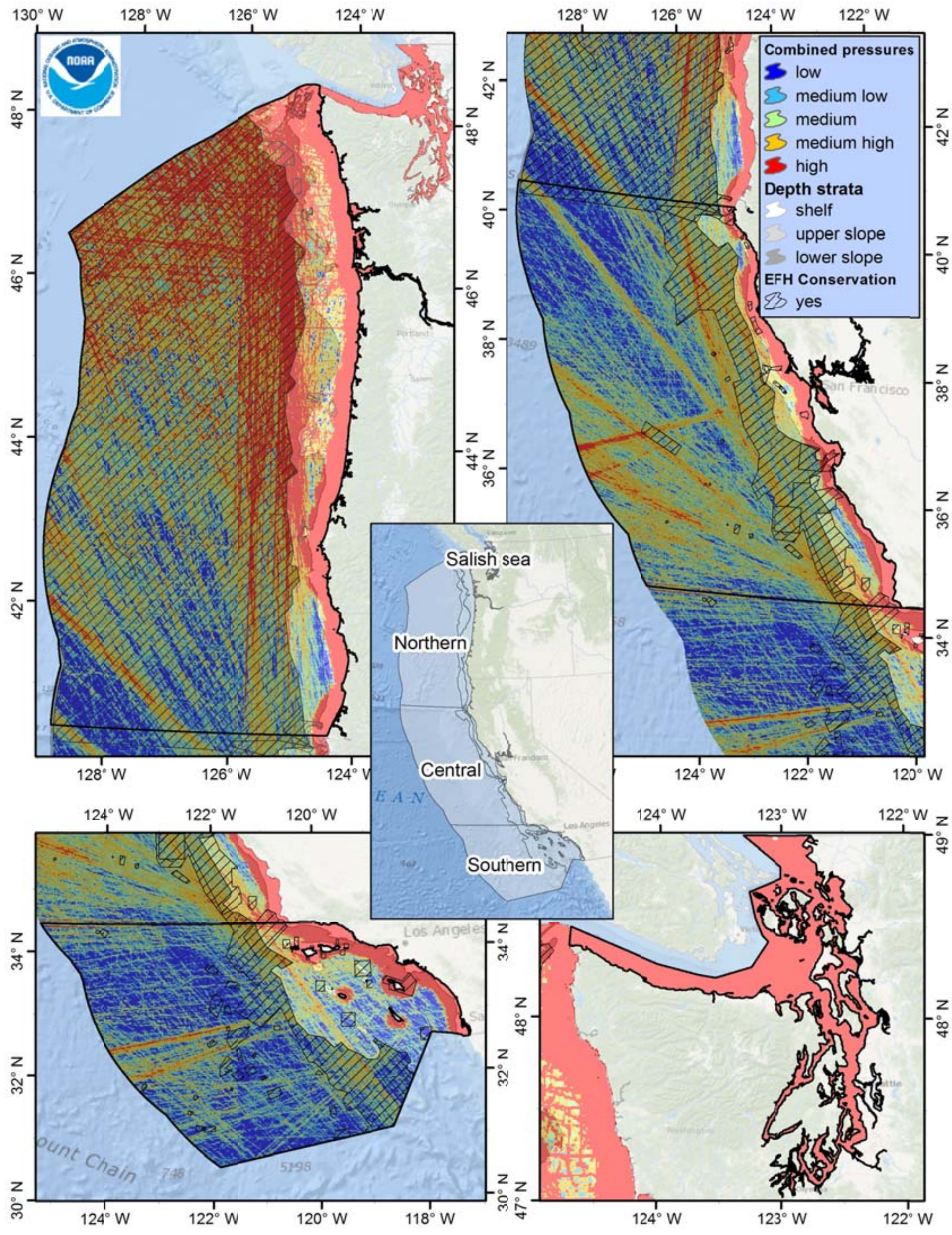

Figure 4b.1. Distribution of combined pressures intensity values among biogeographic sub-regions, depth strata and essential fish habitat (EFH) conservation areas. Combined pressures data is the sum of 16 non-fisheries pressures identified in Table 4b.1. Data for each pressure comes from Halpern et al. 2009. “Streaks” result from vessel shipping lanes.

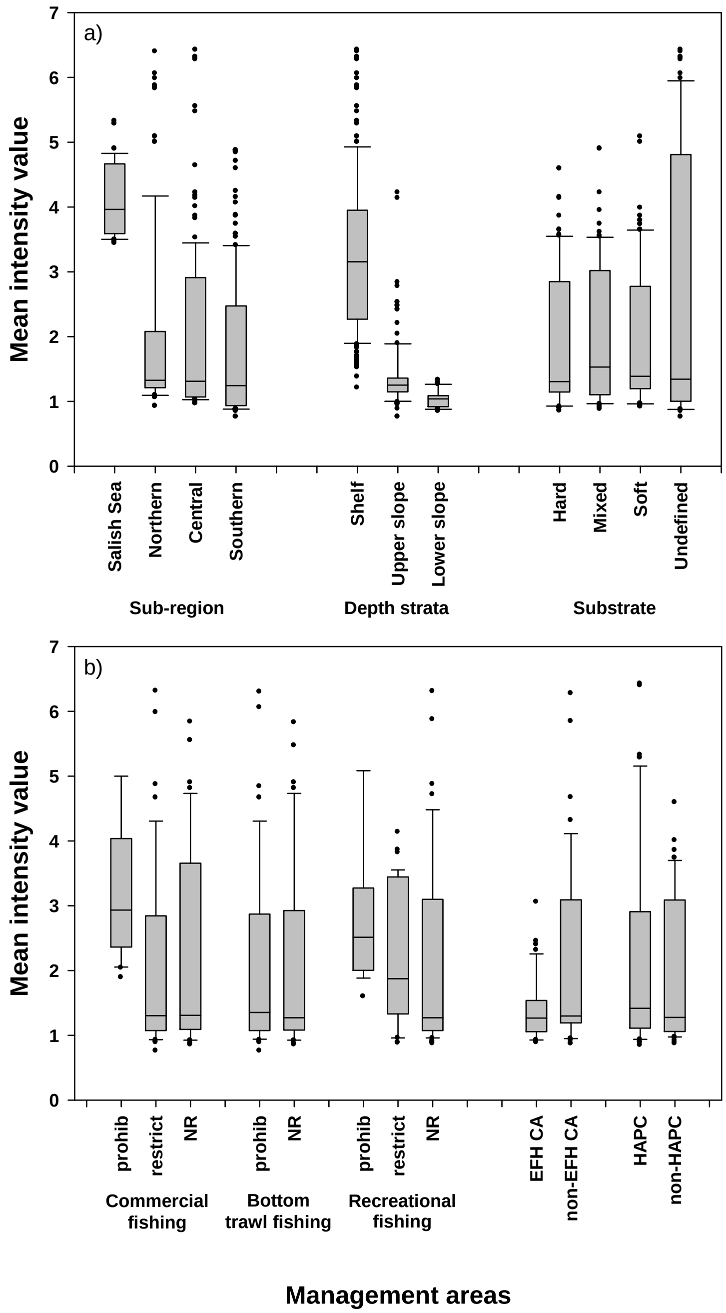

Figure 4b.2. Mean intensity values of combined pressures across a) sub-regions, depth strata, substrate, and b) management areas. The shaded box indicates the 25th to 75th percentile, the line within the box marks the median, the whiskers indicate the 10th and 90th percentiles, and the dots indicate all outliers. prohib: type of fishing is prohibited; restrict: type of fishing is restricted; NR: type of fishing has no restrictions; EFH CA: essential fish habitat conservation areas for West Coast groundfish; HAPC: habitat areas of particular concern. Fishing restrictions include areas within EFH CA, rockfish conservation areas (RCAs), and state territorial sea restrictions.

Overall, we found three main findings from non-fisheries pressures that may potentially affect management of West Coast groundfish EFH. First, non-fisheries pressures were greatest in the Salish Sea, but this is because the entire region is in shelf habitat and is highly exposed to numerous land-derived pressures. Second, among other sub-regions, pressure intensity values varied across depth strata. Lower slope habitat was exposed to higher pressure intensity values in the northern sub-region (offshore pressures), while shelf and upper-slope habitat was exposed to higher pressure intensity values in the southern sub-region (nearshore pressures). Third, we found that EFH was proportionately more exposed to high non-fisheries pressures than other spatial management areas, and this is generally true across other individual pressures.

Table 4b.2. Mean intensity values for combined non-fisheries pressures by depth zones and seabed habitat types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from the sums of 16 pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

Combined pressures						
Depth Zone	*Habitat*	Northern	Central	Southern	Salish Sea	Coastwide
Shelf[1]	All	2.20	2.71	2.92	4.31	2.63
	hard	1.76	3.00	2.57	3.57	2.30
	mixed	1.98	3.04	2.41	3.55	2.31
	soft	2.18	2.45	2.93	3.64	2.40
	undefined	5.85	6.27	4.71	4.67	5.03
Upper Slope[2]	All	1.22	1.22	1.28	NA	1.25
	hard	1.28	1.15	1.17	NA	1.18
	mixed	1.34	1.37	0.98	NA	1.29
	soft	1.21	1.23	1.29	NA	1.25
	undefined	NA	1.05	1.00	NA	1.03
Lower Slope[3]	All	1.08	0.98	0.88	NA	1.00
	hard	1.26	1.05	0.90	NA	1.03
	mixed	1.10	1.09	0.91	NA	0.99
	soft	1.26	1.06	0.95	NA	1.10
	undefined	1.06	0.97	0.87	NA	0.98
Grand mean	All	1.22	1.10	1.04	4.31	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

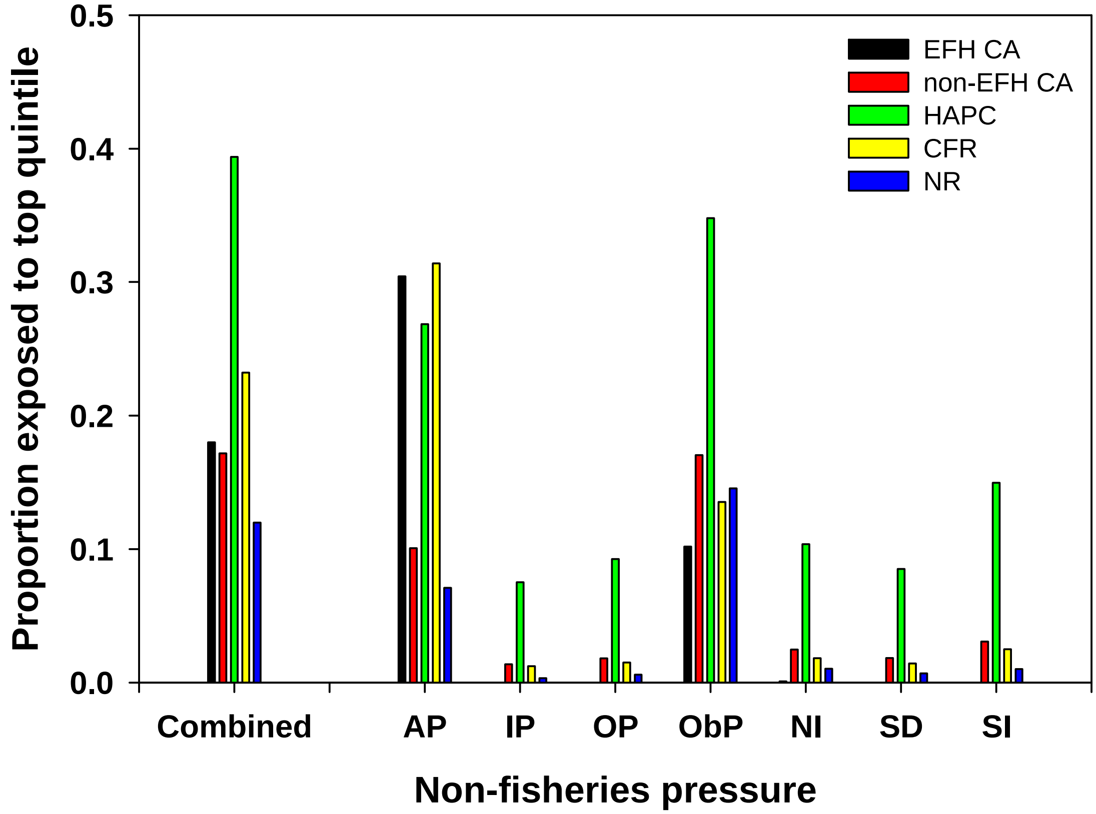

Figure 4b.3. Proportion of coastwide habitat in each management area exposed to the highest intensity values (top 20% - "high" values in Figure 3b.1) for each pressure. EFH CA: essential fish habitat conservation areas; HAPC: habitat areas of particular concern; CFR: all commercial fishing restricted areas, including EFH CA, Rockfish Conservation Areas and state territorial sea restrictions; NR: areas with no commercial fishing restrictions. Combined: sum of 16 pressures; AP: atmospheric pollution, IP: inorganic pollution; OP: organic pollution; ObP: ocean-based pollution; NI: nutrient input; SD: sediment decrease; SI: sediment increase.

Table 4b.3. Proportion of habitat within management boundaries exposed to the top quintile (20%) of intensity values for each pressure within each biogeographic sub-region and across the entire U.S. West Coast. EFH: designated essential fish habitat; CFR: commercial fishing restricted areas; NR: no commercial fishing restrictions; NA: no habitat in this category.

	BIOGEOGRAPHIC SUB-REGIONs														
	Northern			Central			Southern			Salish Sea			Coastwide		
Pressures	EFH CA	CFR	NR	EFH CA	CFR	NR	EFH CA	CFR	NR	EFH CA	CFR	NR	EFH CA	CFR	NR
Atmospheric pollution	0.44	0.46	0.64	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.98	N/A	0.30	0.31	0.07
Inorganic pollution	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.02	0.00	N/A	0.23	N/A	0.00	0.01	0.00
Organic pollution	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.02	0.00	N/A	0.29	N/A	0.00	0.01	0.01
Ocean-based pollution	0.03	0.05	0.27	0.36	0.38	0.19	0.09	0.11	0.05	N/A	0.96	N/A	0.10	0.14	0.15
Nutrient input	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.03	0.01	N/A	0.32	N/A	0.00	0.02	0.01
Sediment decrease	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.02	0.01	N/A	0.27	N/A	0.00	0.01	0.01
Sediment increase	0.00	0.01	0.06	0.00	0.05	0.01	0.00	0.02	0.00	N/A	0.51	N/A	0.00	0.02	0.01
Combined pressures	0.23	0.26	0.58	0.06	0.14	0.06	0.06	0.14	0.06	N/A	0.98	N/A	0.18	0.23	0.12

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5.0 PROBABILITY OF OCCURRENCE, EXPOSURE TO FISHING PRESSURE, AND SPATIAL MANAGEMENT

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Overview:

- EFH conservation areas protect some groundfish species from fishing more than others**.**
- The proportion of habitat where there is a high probability of occurrence for one of six representative groundfish species that is also included within an EFH conservation area varies widely among species. Those species that occur in rocky or deeper areas (yelloweye rockfish, sablefish, and longspine thornyhead) have a relatively higher proportion of their 'high probability' habitat included within the EFH conservation areas than fish that are generally found in shallower or softer habitats (petrale sole, greenstriped rockfish, darkblotched rockfish).
- Fishing pressure was high in high-probability habitat for adults of some groundfish species but not others. Species vary in the coincidence of habitat suitability and fishing pressure from the groundfish fishery. Sablefish has the highest proportion of areas that are heavily targeted by the fishery and also have a high probability of occurrence. Petrale sole has high probability of occurrence and high fishing pressure near the mouth of the Columbia River (Washington/Oregon border) and near San Francisco, California, but areas of lower fishery pressure (from federally observed fisheries) near shore. The estimated threat to yelloweye rockfish is generally low since yelloweye have a high probability of occurrence only in areas with a low exposure to bottom trawl fishing.

5.1 INTRODUCTION

Determining where there is a coincidence of highly suitable habitat and high (or low) pressures (fishing or otherwise) is a key element of determining important areas for changes in restrictions, if any. Here we provide a summary of how the change in exposure to fishing impacts has interacted with species occupancy patterns over the past decade. We divide our analyses into two parts. First, we summarize the interaction of fishing effort and species occurrence over the entire time series and then address how this interaction responded to a major shift in spatial management in 2006. We examine changes in fishing effort relative to the occurrence of the six focal species identified in Section 3. Here, we restrict our discussion to three of the six species (sablefish, petrale sole, and yelloweye rockfish), which show the most notable patterns. See Section 5 of the Appendix for results for all six species.

For each species, we provide two visualizations of the intersection of fishing effort and species occupancy. First, we provide a series of three maps that show the probability of occurrence, the cumulative fishing effort from 2002-2010, and the intersection of the probability of occurrence and the cumulative fishing effort (e.g. Figure 5.1 for sablefish). We refer to the intersection of occurrence and fishing effort as "pressure" for the remainder of this section. For the purpose of this analysis we assume that the probability of occurrence for each species is a proxy for the quality of the habitat at a given location. We acknowledge that the probability of occurrence is an imperfect proxy for habitat quality. Since each species has a distinct probability of occurrence distribution, the areas considered high quality will vary among species (see Section 3 or Appendix, Section 2); this number implicitly incorporates the contribution of habitat variables (e.g. depth, bottom temperature, etc.) to the occurrence of each species. Fishing effort and the probability of occurrence are summarized in 2x2km grid cells along the coast. In these plots cumulative fishing effort includes all gear types (bottom trawl, midwater trawl, and fixed gear) and is expressed in linear km of fishing gear deployed (see Section 3). In this section, we weight the impact from each fishing gear equally, so the cumulative fishing effort is the linear length of gear deployed summed across bottom trawl, midwater trawl, and fixed gear. Thus, the data in these plots will differ slightly from some of plots of cumulative impact that weight the impacts from each gear type (see Section 4 or Appendix, Section 3). For the predicted probability of occurrence, we used the across year mean prediction from the NWFSC model (see Section 3 or Appendix, Section 2 for details).

Second, we provide a non-spatial summary of the intersection of probability of occurrence from the NWFSC model and cumulative fishing effort. This allows us to determine how different levels of fishing effort coincide with areas of high quality for each species. For this comparison we restrict our analysis to bottom trawl effort and also evaluate the changes in fishing pressure that occurred in response to spatial gear restrictions implemented in 2006. We divided our data into two time periods - before spatial gear restrictions were enacted in 2006 (years 2002-2005) and after 2006 (years 2007-2010) – and classified grid cells as containing or not containing bottom contact restrictions. Since management boundaries did not align with the grid cell boundaries used for the predicted probability of occurrence maps, there are individual grid cells that contain both areas open to fishing and areas closed to fishing. For simplicity, if any portion of the grid cell had fishing restrictions in it, we classified the cell as having fishing restrictions. Of the 38,600 grid cells for which we have a predicted probability of occurrence and fishing effort data, the majority (~85%) had no fishing restrictions while the remainder (~15%) have some variety of gear restrictions. The NWFSC model extent does not overlap with the large 700-ftm bottom trawl closure. We refer interested readers to Section 4 and to Appendix, Section 3, for a full description of the various gear types and management implementation of fishing restrictions. We exclude fishing effort in 2006 due to the fact that the management regime was implemented in June of that year.

Each panel in Figures 5.1 to 5.3 takes on the same basic form: the colors on each plot indicate the density of points with red indicating that many grid cells occur in that vicinity. A high density of points in the upper right of the panel indicates there are many areas that have both a high probability of occurrence and experience high fishing effort. A high density of points in the upper left of the plot indicates area that experience high fishing effort but a low probability of occurrence while points in the lower right of the plot indicate the converse. Finally, an area of high density near the plot origin indicates both low fishing effort and low probability of occurrence.

5.2 RESULTS

Sablefish, petrale sole, and yelloweye rockfish (Figures 5.1, 5.2, and 5.3, respectively) show distinct patterns of fishing pressure. Areas of coincidence between fishing effort and species occurrence are highest for sablefish and concentrated in deep water offshore areas (Figure 5.1). Lower than those for sablefish, the pressures on Petrale are focused in shallow waters with particularly high effort located near the mouth of the Columbia River and near San Francisco (Figure 5.2). In contrast, yelloweye rockfish have a relatively low cumulative pressure throughout their range (Figure 5.3). This low overall value is a function both of the limited impact trawl gear has on the rocky high relief habitat utilized by yelloweye and the overall low probability of occurrence of yelloweye. We caution that pressure posed by any one fishing gear category may differ significantly from their cumulative effects. We also note that due to confidentiality rules, some grid cells with low fishing participation are omitted from the maps and appear as clear cells in the figures (as do cells with zero effort).

Overall exploitation patterns varied among species. Sablefish are a species targeted by bottom trawling and consequently, a large proportion of high trawl effort locations coincide with areas of high probability of occurrence (Figure 5.4a). Petrale sole show a bimodal distribution, with many areas of high abundance experiencing substantial trawl effort, but also many areas of low probability of occurrence seeing high trawl effort (Figure 5.5a). In contrast, nearly all trawl effort falls on locations where yelloweye are predicted to be absent (Figure 5.6a) (although obviously, yelloweye are caught in some trawls. It is important to note that all three species have areas with relatively high probability of abundance that are subject to low or no bottom trawl threat.

Examination of the non-spatial summaries provides a method for contrasting the intersection of occurrence and bottom trawl effort before and after EFH conservation areas were implemented in 2006 (Figures 5.4, 5.5 and 5.6). For each figure, comparing panels *A* and *B* provides a way to examine the distribution of fishing effort and probability of occurrence prior to Amendment 19. The most notable aspect of this comparison is that the level of fishing effort is much lower in the areas designated for gear restrictions in 2006 (e.g. Figure 5.4b for sablefish) than in grid cells not designated for gear restrictions (e.g. Figure 5.4a for sablefish). This indicates that the locations protected in 2006 tended to be areas that were not experiencing high fishing pressure. This is true for all species examined (Figures 5.4, 5.5, 5.6; see also Appendix, Section 4). This is likely to be related to the footrope restrictions put in place in 2000, which may have displaced effort before these areas were more permanently protected.

A comparison of panels *A* and *C* informs how the intersection of fishing and probability of occurrence in unrestricted areas differs before and after Amendment 19. In all species, panels *A* and *C* are very similar, indicating minimal aggregate changes in fishing effort outside EFH conservation areas. Also note that even outside conservation areas (panels *A* and *C*), there are many areas that are predicted to have high probability of occurrence but limited (near zero) fishing pressure (see Figures 5.4a and 5.4c for sablefish, Figures 5.5a and 5.5c for petrale sole, and Figures 5.6a and 5.6c for yelloweye rockfish).

The final contrast of interest compares panels *B* and *D*. This comparison shows how bottom trawl effort has changed inside conservation areas. Panels *B* and *D* describe only the EFH conservation areas before and after their implementation, respectively. In all cases and as expected, there is decidedly lower fishing effort post Amendment 19; a larger portion of the probability density is concentrated along the x-axis. However, the qualitative pattern of fishing effort is very similar between the two time periods[1]. These figures suggest that when aggregated across the entire range of the fleet, the spatial management implemented as part of Amendment 19 has done relatively little to change the overall bottom trawl effort with respect to the occurrence of the six focal species. Areas that were heavily exploited from 2002-2005 tend to remain heavily exploited while areas that experience minimal fishing pressure in 2002-2005 tend to remain lightly exploited in 2007-2010. Again, these results hold for a coast-wide summary of trawl effort. Section 4 and Appendix 3 provide figures that illustrate how local changes in fishing effort have occurred within this larger background of consistent overall fishing effort. Again, other changes in regulations may have changed the pattern of fishing effort prior to the implementation of Amendment. 19.

[1] A reasonable question is: why there are any grid cells with non-zero effort in panel *D?* Recall that panels *B* and *D* include grid cells that are partially open to bottom trawl effort, so trawling along the edges of closed area will appear in these panels.

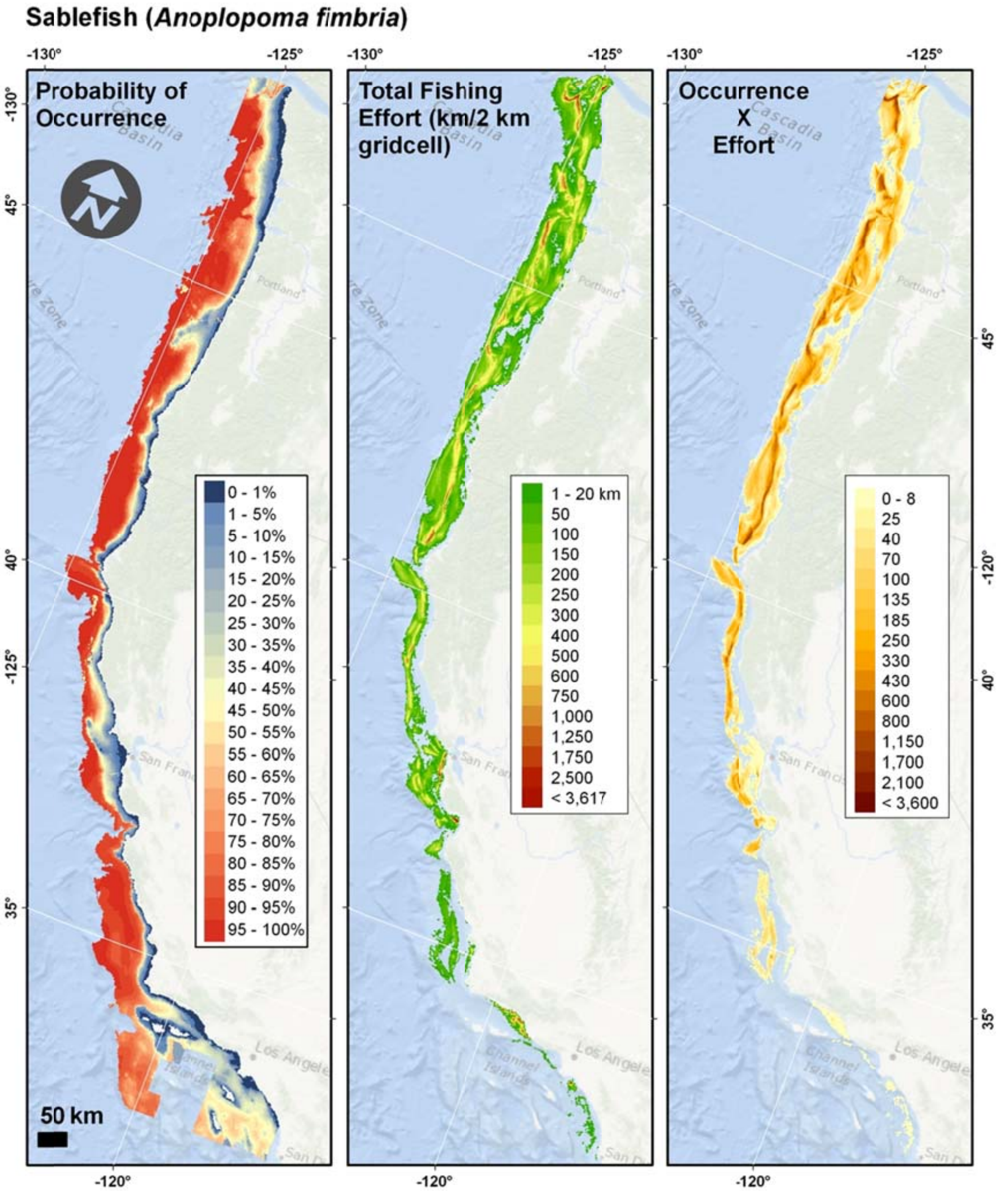

Figure 5.1. Sablefish. A comparison of the predicted probability of occurrence from the NWFSC model (*left panel*), the cumulative fishing effort (*middle; units = km*) and the intersection of probability of occurrence and cumulative effort for sablefish (*right*; units = km * probability of occurrence). Cumulative fishing effort includes bottom trawl, midwater trawl, and fixed gear.

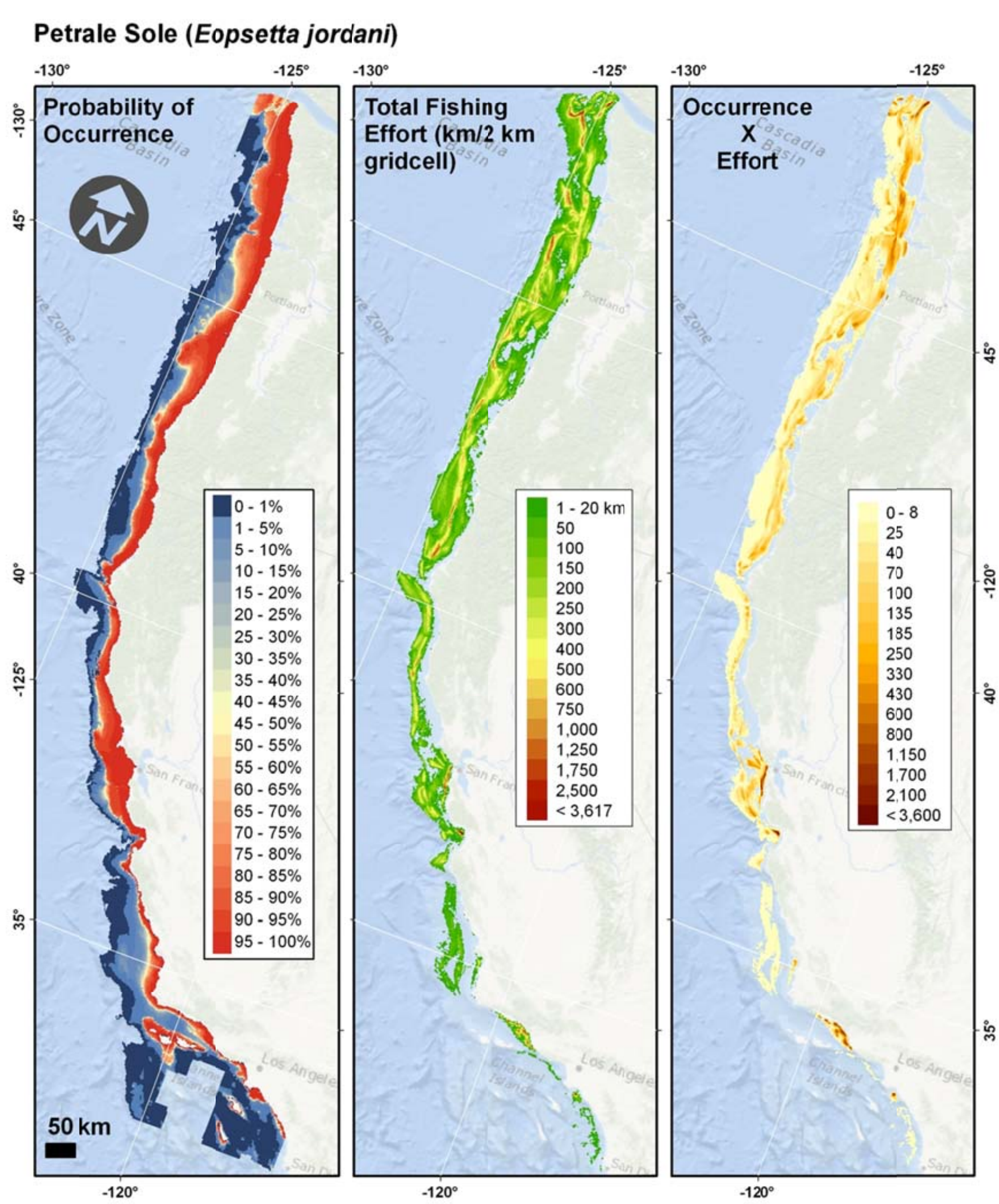

Figure 5.2. Petrale sole. A comparison of the predicted probability of occurrence from the NWFSC model (left panel), the cumulative fishing effort (middle; units = km) and the intersection of probability of occurrence and cumulative effort for petrale sole (*right*; *units = km * probability of occurrence*). Cumulative fishing effort includes bottom trawl, midwater trawl, and fixed gear.

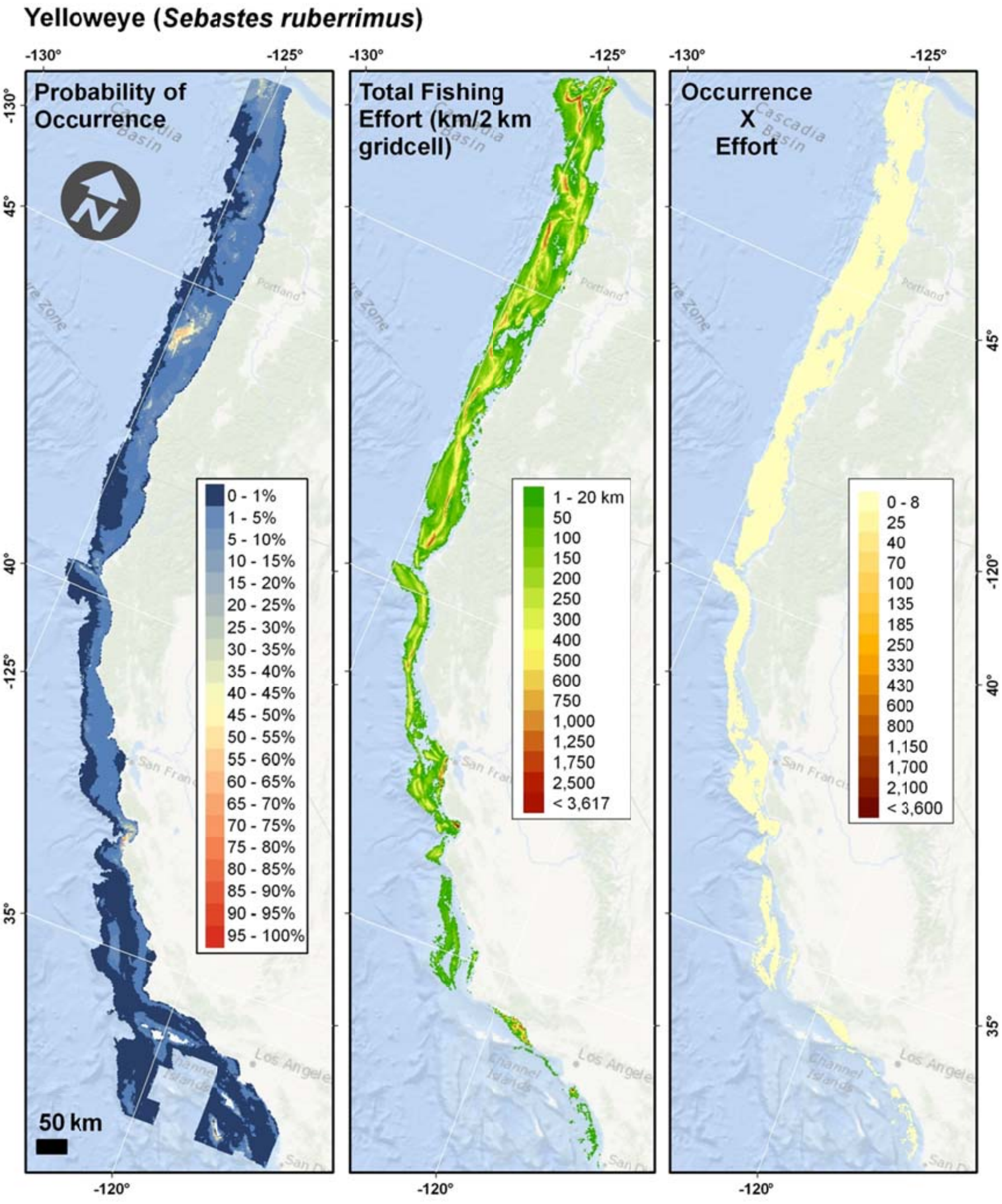

Figure 5.3. Yelloweye rockfish. A comparison of the predicted probability of occurrence from the NWFSC model (*left panel*), the cumulative fishing effort (*middle; units = km*) and the intersection of probability of occurrence and cumulative effort for yelloweye (*right*; units = km * probability of occurrence). Cumulative fishing effort includes bottom trawl, midwater trawl, and fixed gear.

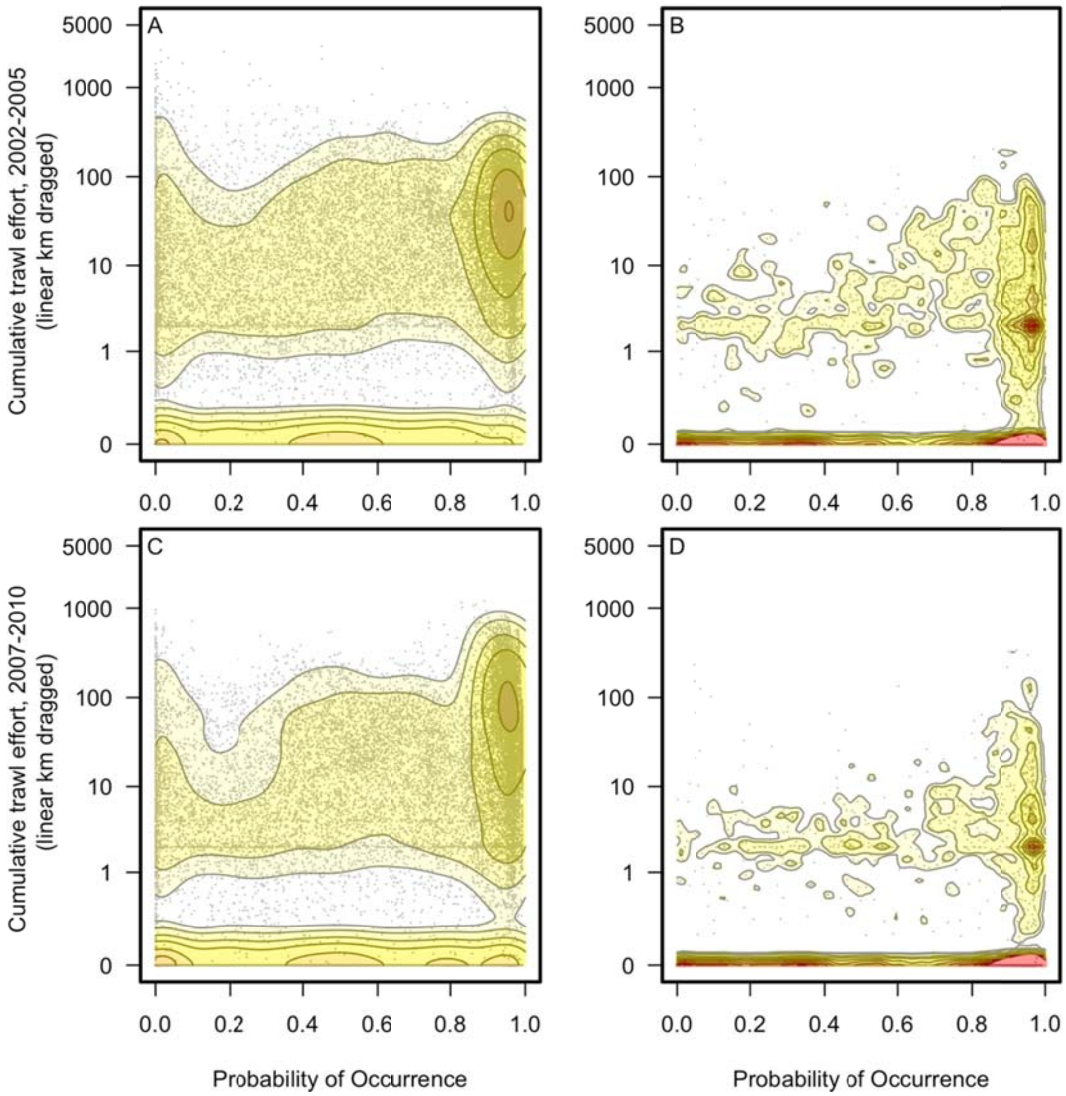

Figure 5.4. Sablefish. A comparison of the predicted probability of occurrence for sablefish (NWFSC model) and the cumulative bottom trawl effort with respect to fishing restrictions imposed by Amendment 19 in 2006. In each panel a point indicates the cumulative trawl effort and predicted probability of occurrence for a 2km x 2km grid cell on the West Coast. Contour lines and shading are derived from a bivariate normal kernel density estimate; white indicates probability density near zero and colors change from white to yellow to red as density increases. All panels have identical color scales. The two panels on the left side (*A* and *C)* represent grid cells with no gear restrictions from 2002-2010. *A)* Cumulative effort from 2002-2005 and *C)* Cumulative fishing effort from 2007-2010. Panels on the right side (*B* and *D)* show areas for which fishing restrictions were imposed in 2006. *B)* Cumulative fishing effort for these grid cells before restrictions were imposed (2002-2005). *D)* Cumulative effort after restrictions were imposed (2007-2010).

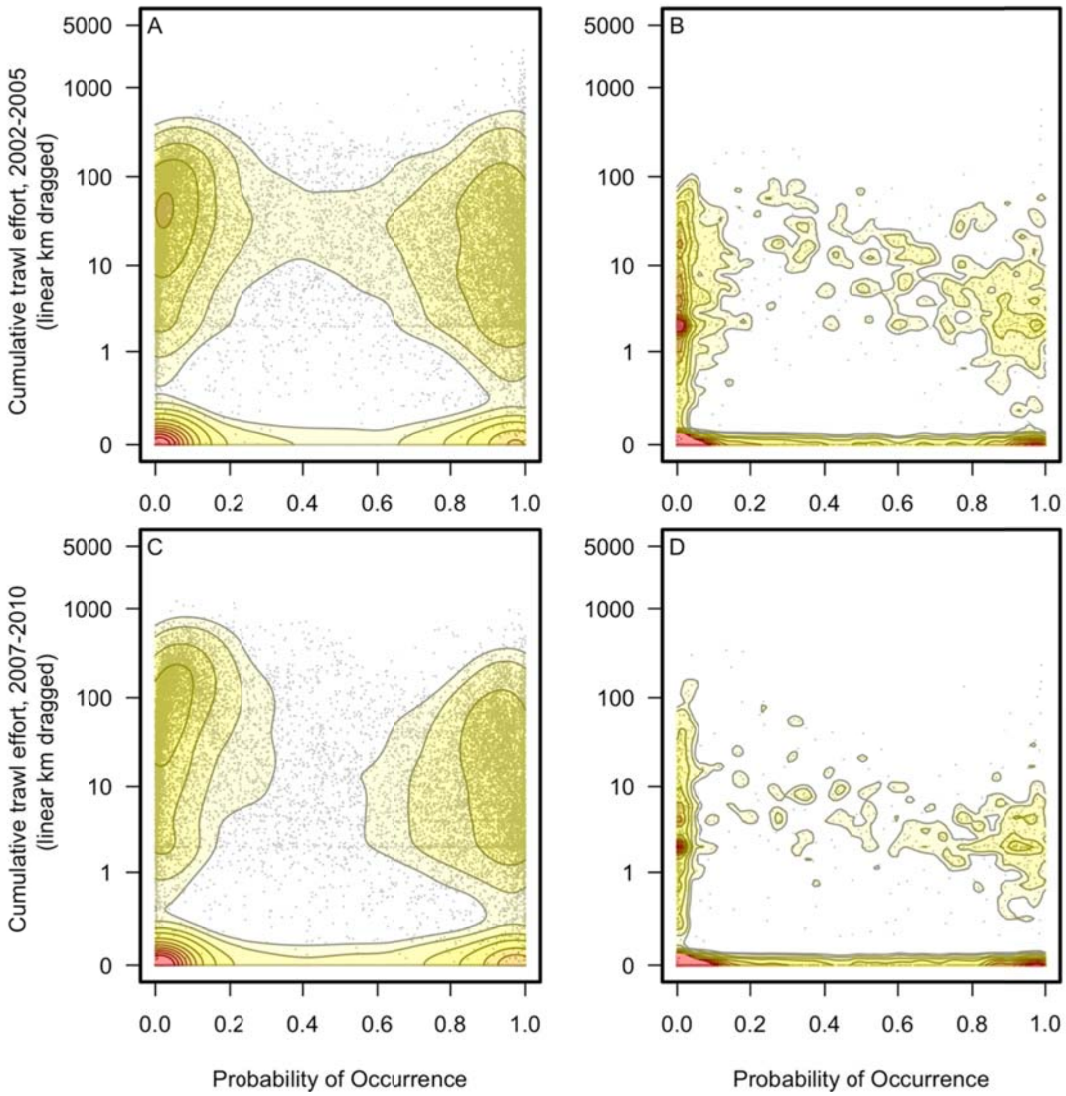

Figure 5.5. Petrale sole. A comparison of the predicted probability of occurrence for petrale sole (NWFSC model) and the cumulative bottom trawl effort with respect to fishing restrictions imposed by Amendment 19 in 2006. In each panel a point indicates the cumulative trawl effort and predicted probability of occurrence for a 2km x 2km grid cell on the West Coast. Contour lines and shading are derived from a bivariate normal kernel density estimate; white indicates probability density near zero and colors change from white to yellow to red as density increases. All panels have identical color scales. The two panels on the left side (*A* and *C)* represent grid cells with no gear restrictions from 2002-2010. *A)* Cumulative effort from 2002-2005 and *C)* Cumulative fishing effort from 2007-2010. Panels on the right side (*B* and *D)* show areas for which fishing restrictions were imposed in 2006. *B)* Cumulative fishing effort for these grid cells before restrictions were imposed (2002-2005). *D)* Cumulative effort after restrictions were imposed (2007-2010).

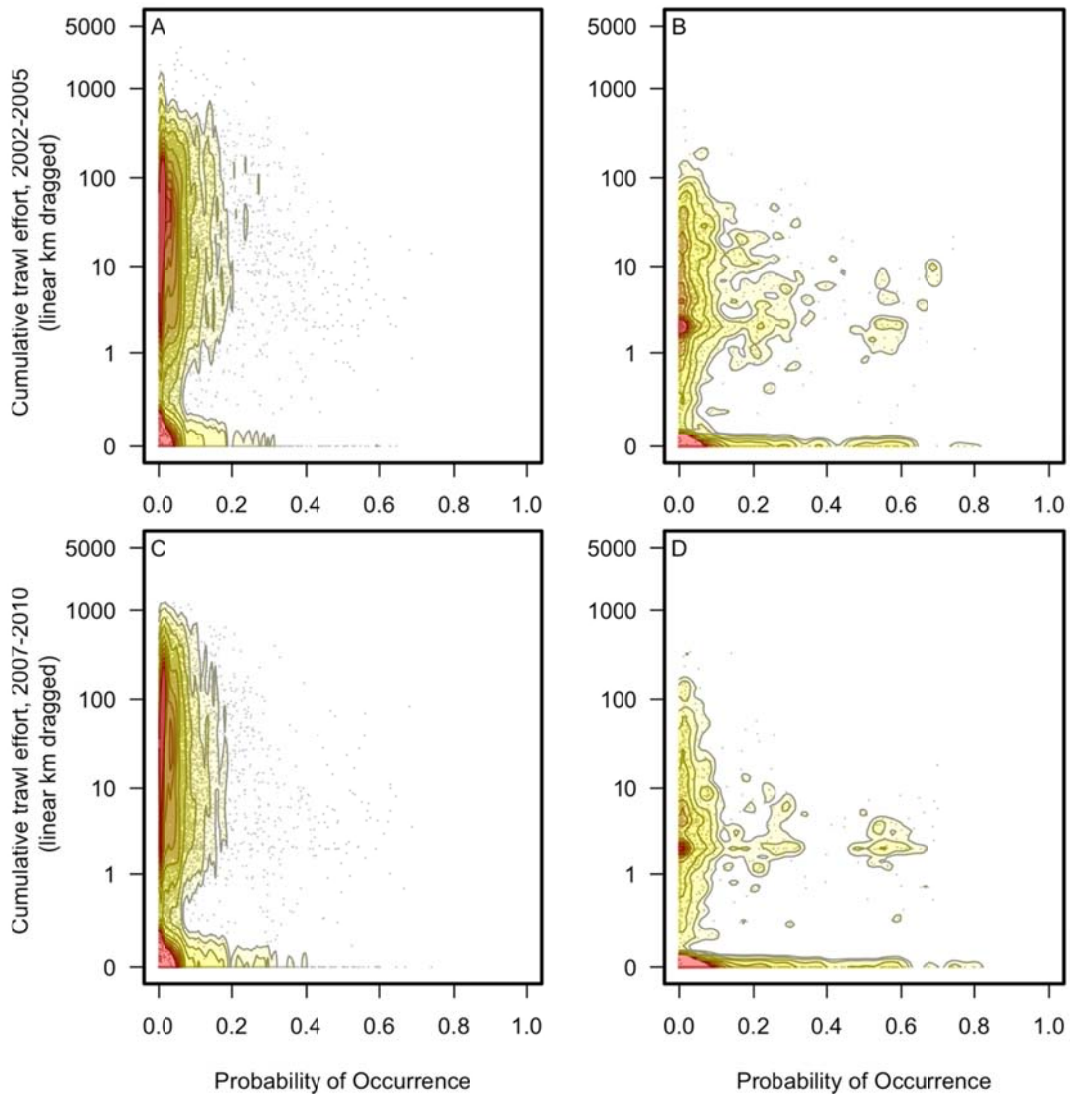

Figure 5.6. Yelloweye rockfish. A comparison of the predicted probability of occurrence for yelloweye (NWFSC model) and the cumulative bottom trawl effort with respect to fishing restrictions imposed by Amendment 19 in 2006. In each panel a point indicates the cumulative trawl effort and predicted probability of occurrence for a 2km x 2km grid cell on the West Coast. Contour lines and shading are derived from a bivariate normal kernel density; white indicates probability density near zero and colors change from white to yellow to red as density increases. All panels have identical color scales. The two panels on the left side (*A* and *C)* represent grid cells with no gear restrictions from 2002-2010. *A)* Cumulative effort from 2002-2005 and *C)* Cumulative fishing effort from 2007-2010. Panels on the right side (*B* and *D)* show areas for which fishing restrictions were imposed in 2006. *B)* Cumulative fishing effort for these grid cells before restrictions were imposed (2002-2005). *D)* Cumulative effort after restrictions were imposed (2007-2010).

6.0 PREY SPECIES OF WEST COAST GROUNDFISH

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Overview:

- Prey is a component of fish habitat and is being considered in the 5-year review of Pacific Coast Groundfish EFH. We improved the level of taxonomic diversity of a diet matrix presented in Phase 1, at the Council's request. Additional research is needed to determine habitat associations for important prey species.
- Diet composition, at a high level of prey specificity, is reported for 11 of the 91 FMP groundfish species. These 11 had medium-to-high amounts of diet information, and represent various habitat guilds on the continental shelf and slope of the West Coast.
- The breadth of the diets of some species was narrow and included just a few prey taxa (e.g., polychaete worms dominated the diet of Dover sole), whereas other groundfishes consumed a diverse array of prey types.
- In general, the dominant prey groups were crustaceans (e.g., copepods, euphausiids, shrimps, and crabs) and fishes (e.g., sand lance, flatfishes, sculpins, herring, anchovy, and smelts). Sardines had no trophic significance in the diets of these 11 groundfish species.
- Ontogenetic differences in diet were evident for sablefish, darkblotched rockfish, lingcod, and Pacific hake. Juveniles of these species consumed more small pelagic organisms (e.g., euphausiids, copepods, jellyfish) than the older life stages, which became increasingly piscivorous.
- Diet composition differed substantially among these groundfish species, and therefore such information should not be combined among species for subsequent analysis.
- Quantitative information on diet composition is limited for most of the other 80 species in the groundfish FMP. Additional studies are needed to establish trophic linkages for these species throughout the California Current system.

6.1 DIET COMPOSITION OF SELECT GROUNDFISH SPECIES

The prey of groundfishes are being considered in this 5-year review of Pacific Coast Groundfish EFH. Quantifying major prey is dependent on the availability of appropriate data on diet composition. The primary goal of this project was to provide more taxonomic specificity to supplement the prey reports in the Phase 1 EFH reports by quantifying prey in the diets of groundfish species based on available literature. The key goal here is to identify prey species appropriately. As additional information about the habitat requirements for key prey species is developed, managers can consider prey species' needs in the design and implementation of spatial management regulations.

We prioritized 11 species of groundfishes based on data availability and ecological diversity: petrale sole, Dover sole, sablefish, lingcod, greenstriped, rosethorn, sharpchin, darkblotched, and yelloweye rockfishes, longspine thornyhead, and Pacific hake (Table 6.1). These species represent various habitat guilds that have been described based on seafloor substratum (e.g., low relief mud; cobble fields; complex rock outcrops) and water depth of the continental shelf and slope (Allen et al. 2006).

Table 6.1. Species and life stages of Pacific coast groundfishes evaluated for diet composition. *n* = number of studies; N = number of stomach samples with prey.

COMMON NAME	SCIENTIFIC NAME	SPECIES GROUP	Life Stage	*n*	N
Petrale sole	*Eopsetta jordani*	Flatfishes	Juvenile - Adult	2	43
Dover sole	*Microstomus pacificus*	Flatfishes	Juvenile - Adult	6	1,446
Sablefish	*Anoplopoma fimbria*	Other Groundfish	Juvenile	2	40
Sablefish	*Anoplopoma fimbria*	Other Groundfish	Juvenile - Adult	5	3,153
Lingcod	*Ophiodon elongatus*	Other Groundfish	Juvenile	2	24
Lingcod	*Ophiodon elongatus*	Other Groundfish	Juvenile - Adult	3	457
Greenstriped rockfish	*Sebastes elongatus*	Other Rockfish	Juvenile - Adult	3	110
Rosethorn rockfish	*Sebastes helvomaculatus*	Other Rockfish	Juvenile - Adult	2	68
Sharpchin rockfish	*Sebastes zacentrus*	Other Rockfish	Juvenile - Adult	2	44
Darkblotched rockfish	*Sebastes crameri*	Rockfishes	Juvenile	1	18
Darkblotched rockfish	*Sebastes crameri*	Rockfishes	Juvenile - Adult	1	20
Yelloweye rockfish	*Sebastes ruberrimus*	Rockfishes	Juvenile - Adult	2	37
Longspine thornyhead	*Sebastolobus altivelis*	Rockfishes	Juvenile - Adult	2	1,240
Pacific hake	*Merluccius productus*	Other Groundfish	Juvenile	5	1,526
Pacific hake	*Merluccius productus*	Other Groundfish	Juvenile - Adult	7	4,031
Pacific hake	*Merluccius productus*	Other Groundfish	Adult	4	778
Total:					13,035

We conducted a literature review (Section 4 of Appendix) using summarized life history information in three recent publications (McCann et al. 2005; Love 2011; PFMC 2012), and from a thorough search of Aquatic Science and Fisheries Abstracts, Biosis, Web of Science, and Zoological Record databases. The geographic range of this analysis was restricted to the waters off the continental U.S. West Coast; literature on groundfish diets specifically from other regions was not considered. However, studies that included some fish samples from Canada or Mexico were included when data only from U.S. waters could not be discerned. Details for each study are in Appendix I. Only studies that reported quantitative estimates of weight or volume were included in our analysis because these metrics generally track energetic importance of the prey taxa (Hyslop 1980; Cailliet et al. 1986). By contrast, frequency metrics (e.g., percent frequency of occurrence and relative number of a prey taxon) are typically a proxy for feeding behavior, but do not necessarily represent the relative importance of each prey type in the fish's diet

(Hyslop 1980; Cailliet et al. 1986). Compound measures that incorporate weight or volume (such as Index of Relative Importance [IRI]) were considered only if volume or weight were not individually reported.

Volume or weight of each prey category, as originally designated in a study, was converted to a percentage and then reclassified among 47 prey categories (Table 6.2) to standardize our evaluation. When possible, diet composition data were calculated by life stage (i.e., juvenile or adult). If maturity stage or size of the fish was not reported, diet was analyzed from juvenile and adult life stages together. A weighting scheme was applied to the final diet composition data when more than one diet study was available for a species or life-stage; that is, if the number of samples = 1, data were weighted by 1; 2-10 samples (weight of 2), 11-25 samples (weight of 4); 26-50 samples (weight of 8); 51-100 samples (weight of 16); > 100 samples (weight of 32).

Quantitative information on diet composition was limited for most species. Notable exceptions were juvenile, adult, and juvenile-adult Pacific hake, and juvenile-adult Dover sole and sablefish, which were each represented by several studies and large sample sizes (Table 6.1). There were 1-3 suitable diet studies from which to draw for the other species, and of these only lingcod, greenstriped rockfish, and longspine thornyhead had aggregate sample sizes > 100 stomachs (Table 1). By comparison, a vastly larger amount of comparable information is available in other US regions, such as the Northwestern Atlantic, Gulf of Alaska, and Bering Sea, where diet sampling has been conducted routinely for many years. Overall, 23 suitable publications were used in our study (Section 4 of the Appendix), some of which provided data for multiple groundfish species. The lack of replicate studies and generally low sample sizes result in estimates of diet composition that may not accurately reflect either historical, seasonal, or geographic prey spectrums for some of these species. In addition, the majority of the studies did not characterize diet by life stage. Even when data on fish lengths were available, life stages often spanned size ranges that encompassed juveniles and adults and therefore could not be segregated.

Although diet composition data were limited for most species, the identification of important prey taxa emerged from our analyses. Diets comprised a wide range of prey taxa from polychaete worms to finfish (Table 3). The breadth of the diets of some groundfish species was very narrow and included just a few prey taxa. Other groundfish species consumed a diverse array of prey taxa. The diet of Dover sole was dominated by infaunal polychaetes and echinoderms and differed considerably from that of the other groundfish species, including the other flatfish (petrale sole) that consumed small flatfishes and crustaceans. Other groundfish species with diets largely comprising fishes included juvenile and juvenile-adult lingcod (61 and 92%, respectively), juvenile-adult sablefish (64%) and yelloweye rockfish (63%), and adult Pacific hake (71%). Fish prey for lingcod, sablefish, and yelloweye mostly included small benthic fishes (e.g., sand lance, flatfishes, sculpins) and a relatively small amount of pelagic forage fishes (herring, anchovy, and smelts). These small pelagic species comprised 47% of the diet of adult Pacific hake. Sardines had no trophic significance in the diets of these 11 groundfish species. Diets of juvenile hake, darkblotched rockfish, sablefish, and lingcod differed considerably from those of their combined juvenile-adult life stages, although the low sample sizes for juveniles (other than hake) may be cause for some misinterpretation. The prey spectrum of juvenile darkblotched rockfish included jellies and other small midwater organisms in contrast to the juvenile-adult darkblotched that mostly ate euphausiids (76%) and sand lance (12%). Crustaceans, a group that includes copepods to crabs, were dominant in the diets of juvenile-adult hake (58%) and rosethorn (91%), darkblotched (88%), greenstriped (80%), and sharpchin (62%) rockfishes, and of juvenile hake (69%), darkblotched rockfish (69%), and sablefish (56%). Euphausiids and shrimps generally were the main crustaceans preyed upon by these species; juvenile hake also consumed a considerable proportion of copepods (19%). Cephalopods, bivalves, and gastropods made relatively small contributions to (or were absent altogether from) the diets of most of these 11 groundfish species. However, loligonid squid (largely the market squid, *Doryteuthis opalescens*) was 8% of juvenile sablefish and 12% of juvenile-adult greenstriped rockfish diets.

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Table 6.2. Prey categories, abbreviations, and color codes used in the analysis of diets of Pacific coast groundfish species. Colors organize prey categories into broad taxonomic or functional groups.

Prey Category	Abbreviation	Color Code
Invertebrates, unidentified	INV	
Jellyfishes and other unidentified gelatinous zooplankton	JELL	
Polychaetes (annelid worms)	POLY	
Other marine worms (e.g., Nematoda, Sipuncula)	WORM	
Echinoderms (sand dollars, sea urchins, stars, cucumbers)	ECHINO	
Bivalves (clams, oysters, mussels, scallops)	BIVAL	
Gastropods (snails)	GAST	
Bivalves or gastropods, unidentified	MOLL	
Cuttlefishes	CUTT	
Loligonid squids	LOLI	
Squids (Oegopsina)	OEGO	
Squids, unidentified	SQUID	
Octopi	OCTO	
Cephalopods (squids and octopi, unidentified)	CEPH	
Copepods	COPE	
Amphipods	AMPH	
Isopods	ISO	
Mysids	MYSID	
Euphausiids (krill)	EUPH	
Penaeid and sergestid shrimps	SHRIMP PS	
Caridean shrimps	SHRIMP C	
Shrimps, unidentified	SHRIMP	
Thalassinidea (ghost shrimp, mud shrimp)	THALA	
Anomuran crabs	CRAB A	
Brachyuran crabs	CRAB B	
Crabs, unidentified	CRAB	
Other decapods	DECA	
Other and unidentified crustaceans	CRUST	
Tunicates (sea squirts)	TUN	
Agnathan fishes (lampreys, hagfishes)	AGNATH	
Chondrichthyan fishes (sharks, skates, rays, ratfishes)	CHOND	
Herrings	HERR	
Sardines	SARD	
Clupeidae (herrings, unidentified)	CLUP	
Engraulidae (anchovies)	ENGR	
Osmeriformes (smelts)	OSMER	
Myctophidae (lanternfishes)	MYCT	
Gadiformes (grenadiers, hake, cods)	CODS	
Zoarcidae (eelpouts)	ZOAR	
Poachers	AGON	
Sculpins	SCULP	
Hexagrammidae (greenlings)	HEX	
Rockfishes and thornyheads	ROCK	
Ammodytidae (sand lance)	AMMO	
Scorpaeniformes, other and unidentified	SCORP	
Pleuronectiformes (flatfishes)	FLAT	
Other and unidentified fishes	TELE	

Table 6.3. Diet composition (%) of Pacific coast groundfish species. Prey categories and color codes as in Table 2. J=juvenile and A=adult life stage of fish species.

COMMON NAME	INV	JELL	POLY	WORM	ECHINO	BIVAL	GAST	MOLL	CUTT	LOLI	OEGO	SQUID
Petrale sole (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0
Dover sole (J-A)	0.0	0.5	53.2	0.5	30.1	1.7	0.7	3.6	0.0	0.0	0.0	0.3
Sablefish (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0
Sablefish (J-A)	0.0	0.3	1.2	0.1	0.3	0.1	0.9	0.0	0.0	0.9	0.6	3.1
Lingcod (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lingcod (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Greenstriped rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0
Rosethorn rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Sharpchin rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Darkblotched rockfish (J)	0.0	31.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Darkblotched rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yelloweye rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Longspine thornyhead (J-A)	6.5	0.0	9.4	0.0	6.2	0.7	0.1	0.0	0.0	0.0	4.2	2.0
Pacific hake (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Pacific hake (J-A)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8
Pacific hake (A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Table 6.3 (continued)

COMMON NAME	OCTO	CEPH	COPE	AMPH	ISO	MYSID	EUPH	SHRIMP PS	SHRIMP C	SHRIMP	THALA	CRAB A
Petrale sole (J-A)	0.0	0.0	0.0	0.0	0.0	8.0	2.8	0.0	11.3	0.0	0.0	0.0
Dover sole (J-A)	0.0	0.0	0.0	0.8	0.3	0.0	0.4	0.3	0.2	0.0	0.1	0.9
Sablefish (J)	2.1	1.1	0.0	0.0	0.0	0.0	44.9	0.0	0.0	0.0	0.0	0.0
Sablefish (J-A)	1.7	4.0	0.0	2.8	0.1	0.1	8.0	0.0	0.8	1.1	0.1	0.2
Lingcod (J)	0.0	0.0	19.1	0.0	0.0	0.0	19.3	0.0	0.0	0.0	0.0	0.0
Lingcod (J-A)	3.7	0.5	0.0	0.0	0.0	0.0	0.1	0.0	4.0	1.0	0.0	0.0
Greenstriped rockfish (J-A)	0.0	0.8	0.4	0.1	0.3	0.2	13.7	30.7	27.2	3.0	0.0	3.1
Rosethorn rockfish (J-A)	0.0	0.0	1.1	0.3	0.3	0.0	9.4	5.3	29.6	3.7	0.0	35.6
Sharpchin rockfish (J-A)	0.0	0.0	1.7	0.0	0.0	0.0	34.3	3.9	3.2	3.7	0.0	5.0
Darkblotched rockfish (J)	0.0	0.0	9.3	19.7	0.0	0.0	15.3	0.0	0.0	0.0	0.0	0.0
Darkblotched rockfish (J-A)	0.0	0.0	4.1	5.7	0.0	0.0	75.5	3.0	0.0	0.0	0.0	0.0
Yelloweye rockfish (J-A)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.3	0.0	0.0
Longspine thornyhead (J-A)	0.0	0.7	0.0	2.5	1.1	0.2	0.1	0.7	5.6	9.5	8.5	0.0
Pacific hake (J)	0.0	0.0	19.2	0.0	0.0	0.1	63.8	0.0	0.0	4.6	0.0	0.0
Pacific hake (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	45.1	1.6	2.0	7.6	0.0	0.0
Pacific hake (A)	0.0	0.0	0.0	0.0	0.0	0.0	19.4	0.0	2.4	2.8	3.3	0.0

Table 6.3. (continued)

COMMON NAME	CRAB B	CRAB	DECA	CRUST	TUN	AGNATH	CHOND	HERR	SARD	CLUP	ENGR	OSMER
Petrale sole (J-A)	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0
Dover sole (J-A)	0.0	0.0	0.2	5.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sablefish (J)	9.1	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	12.6	0.0
Sablefish (J-A)	2.4	0.4	0.1	1.6	5.3	2.4	0.7	0.0	0.0	5.7	2.6	0.3
Lingcod (J)	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lingcod (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	12.1	0.1	1.2
Greenstriped rockfish (J-A)	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rosethorn rockfish (J-A)	2.1	0.0	0.0	3.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sharpchin rockfish (J-A)	0.0	0.0	0.0	10.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Darkblotched rockfish (J)	0.0	0.0	0.0	24.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Darkblotched rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yelloweye rockfish (J-A)	26.6	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	2.2	0.0	0.3
Longspine thornyhead (J-A)	13.4	0.1	0.7	2.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	7.5
Pacific hake (J)	0.0	0.0	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Pacific hake (J-A)	0.2	0.1	0.0	1.0	0.0	0.0	0.0	6.0	0.0	1.2	9.0	2.4
Pacific hake (A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	0.0	11.5	10.3	7.4

Table 6.3 (continued)

COMMON NAME	MYCT	CODS	ZOAR	AGON	SCULP	HEX	ROCK	AMMO	SCORP	FLAT	TELE
Petrale sole (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	43.0	17.3
Dover sole (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Sablefish (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3
Sablefish (J-A)	0.3	6.0	0.4	0.1	0.0	0.0	12.3	0.0	7.5	5.4	20.1
Lingcod (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.7	0.0	0.0	4.3
Lingcod (J-A)	0.4	8.6	0.0	0.0	16.2	14.5	0.5	3.5	14.7	6.2	9.3
Greenstriped rockfish (J-A)	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1
Rosethorn rockfish (J-A)	1.9	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	6.3
Sharpchin rockfish (J-A)	25.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7
Darkblotched rockfish (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Darkblotched rockfish (J-A)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	0.0	0.0	0.0
Yelloweye rockfish (J-A)	0.0	0.0	0.0	0.0	21.8	4.3	11.2	0.0	0.0	11.9	0.6
Longspine thornyhead (J-A)	3.7	0.3	1.4	0.0	0.0	0.0	2.6	0.0	0.0	0.0	8.7
Pacific hake (J)	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
Pacific hake (J-A)	0.6	8.1	0.0	0.0	0.0	0.0	0.8	0.0	0.2	0.8	11.3
Pacific hake (A)	0.0	7.4	0.0	0.2	0.1	0.0	0.5	0.0	1.2	4.7	10.0

Appendix
to
Groundfish Essential Fish Habitat Synthesis:
A Report to the Pacific Fishery Management Council

APRIL 2013

NATIONAL MARINE FISHERIES SERVICE
NOAA

This document should be cited as:
National Marine Fisheries Service (NMFS). 2013. Appendix to Groundfish Essential Fish Habitat Synthesis: A Report to the Pacific Fishery Management Council. NOAA NMFS Northwest Fisheries Science Center, Seattle, WA, April 2013. 378 p.

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1.0 METHODS FOR SYNTHESIS OF HABITAT INFORMATION

1.1 PHYSICAL HABITAT: DATA AND METHODS

Results from the Pacific Coast Groundfish 5-Year Review of Essential Fish Habitat Report to the Pacific Fishery Management Council Phase 1: New Information (PFMC, 2012), provided access to 261 new sources of seabed habitat type for US west coast EEZ waters including the Puget Sound/Salish Sea inland waters. Seabed habitat maps from these sources update large regions of the "Version 1" regional habitat maps used during the 2005 EFH Review. However, owing to the wide range of map sources and mapping programs from which this new set has been collected, the mapping methods and interpretive schemes are not standardized under any single classification scheme like the Coastal and Marine Ecological Classification Standard (FGDC, 2012) or the Classification Scheme for Deep Seafloor Habitats (Greene, 1999).

Regionally, the coast-wide Surficial Geologic Habitat Maps for Oregon and Washington, covering outer coast continental shelf and slope areas from Cape Flattery, WA south to the Oregon-California border, have been upgraded periodically since 2005's Version 1 to today's Version 3.6. California's coast-wide habitat map remains unchanged since 2005. However, in all 3 states new mapping at local scales modifies and improves the regional maps by refining our knowledge of rocky outcrop, mixed seabed types, and sediment distribution locally. The aerial extent of this new information may be examined graphically in a set of map plates from the EFH Phase 1 Report, Appendix C-2. Full resolution (Adobe PDF) copies of this map set and GIS data are available at:

http://efh-catalog.coas.oregonstate.edu/overview/

To support the synthesis goals of characterizing the spatial distribution of hard, soft, and mixed seabed habitat types and characterizing groundfish species-habitat relationships (report sections 1 and 2, respectively), several data preparation steps were necessary.

1. The complete set of shapefile and raster habitat maps, new local maps overlying 2005 or updated regional maps, was reduced to a unified raster format GIS layer under the common Phase 1 Report categorical classification scheme of probable: Hard Seabed, Mixed Seabed, and Soft Seabed.
2. A continuous seabed sediment grain size surface, derived from the USGS usSEABED database, was adopted to further describe the soft seabed habitat type.
3. A conceptual framework for understanding the variable thematic map accuracy of the integrated habitat map was developed and implemented in a map product.

1.1.1 Habitat Map Integration

A raster format habitat map was developed unifying EFH Review datasets under the categorical classification scheme: Probable Hard Seabed, Probable Mixed Seabed, and Probable Soft Seabed (see: EFH Phase I report, Appendix C, Bathymetry and Seafloor Habitat Maps). A fourth class, Predicted or Inferred Rock, has been mapped in Oregon and is treated as Probable Hard Seabed in this synthesis. To develop this data layer individual habitat map data sets from the Phase 1 Report set were converted from polygon to raster format at 25m by 25m cell size. For cells where multiple habitat types were present within the 25m by 25m neighborhood, the combined habitat type feature with the largest area determined the final value of the cell. Seabed habitat map layers of native raster format and resolutions less than the target were resampled to 25m x 25m cell size. Resultant raster layers were mosaicked in the same layer order that the EFH Report presents, such that the most modern and descriptive data took precedence over underlying regional data (Figure A1.1.1).

1.1.2 Sediment Grain Size

The unified raster map of seabed habitat type provides a broad categorical representation of habitats in three principal types. The modeling team sought a more descriptive and continuous seabed environmental covariate for their characterization work. Several methods for transforming the categorical types were considered including; using acoustic reflectivity or backscatter as a proxy for hardness, calculating % cover for each habitat within a moving window, or simply assigning a mean sediment grain size to each class. Each of these initial transformation methods was rejected in favor of using a continuous surface of sediment grain size interpolated from regional sample data. An interpolated grain size image covering the study area at 100m by 100m grid resolution area was identified from previous unpublished work (Active Tectonics and Seafloor Mapping Lab) providing a better alternative than assigning ideal mean grain size values to seabed classes (Figure A1.1.2).

The sediment grain size data layer is available for download at the PaCOOS West Coast Habitat Server (http://pacoos.coas.oregonstate.edu/archive/woc_sgh_grsz2.zip) and was derived from an interpolation of USGS usSEABED (Reid, 2006) and OSU (unpublished) sediment seabed sample databases. While the sample data inputs to this interpolation are not uniformly distributed spatially or temporally, the compilation is understood to be comprehensive, totaling 16,997 sample points and drawing from academic and agency sources.

1.1.3 Thematic Habitat Map Confidence

Estimating the thematic map accuracy of the final integrated habitat map was not possible without either reserving a portion of the input data or developing a program of sampling for this purpose. Instead, a first principles approach to understanding the likely thematic map accuracy or map confidence was developed. The assumption that guides this framework is simple; that high quality remotely sensed data backed up with local reference information produce maps that describe the distribution of seabed habitat types more confidently than maps that extrapolate information and knowledge into un-surveyed areas. This framework is an adaptation of Tobler's first law of geography, "Everything is related to everything else, but near things are more related than distant things." The framework described in Table A1.1 provided a simple means to score individual seabed habitat map data layers. Data layers were scored then mosaicked in a 25m by 25m raster map (Figure A1.1.3) companion to the integrated seabed habitat map.

1.2 BIOGENIC HABITAT: DATA AND METHODS

1.2.1 Observations of Deep-Sea Corals and Sponges

Much of what is known about the overall spatial distribution of corals and sponges in the region has been compiled by NOAA's Deep-Sea Coral Research & Technology Program (NOAA, 2013). The data set contains almost 174,000 records of corals and sponges collected between 1888 and 2012 off the west coast, with a large majority (99.5%) collected since 1989 (Figure A1.2.1). These records originate from a number of federal agencies, academic institutions and non-governmental organizations (Table A1.2). Roughly 95% of these records are direct, visual observations of corals and sponges in situ, while most of the remaining records (5%) are from surveys using benthic trawls, dredges, or grabs. With these records, we created two summary data products: one summarizing presence only data within contiguous 1x1 km cells, and the other summarizing relative observed abundance within contiguous 2x2 km cells.

Differences in how data were collected make it challenging to estimate relative abundance or density of corals and sponges. For example, some studies summarized counts over individual photo or video frames, while others summarized over the course of entire dive. Furthermore and in contrast to information available for physical seabed habitats, no map of continuous areas of biogenic habitats exists for the region. In order to compare the distributions in a standardized manner, coral-sponge presence was summarized within 1x1 km contiguous grid cells (Figure A1.2.2). If any observation, represented by a point with geographic coordinates (e.g., latitude, longitude), was located within a 1x1 km cell, the entire cell was categorized as having presence. This summarization technique facilitated the analysis of presence information in the context of various protected areas (see Tables A1.3.6a-b – A1.3.8a-b) similar to what was done for the physical habitat information.

Due to the lack of density values or available information on survey effort, we developed a metric of relative observed abundance defined as mean counts of corals and sponges observed per km. Records representing direct observations of corals and sponges in situ using either submersibles, ROVs or AUVs were categorized by dive and 1 km intervals. For records from dives of length <1 km or records where observations were summarized over an entire dive, counts of corals and sponges were used as the metric of relative abundance. If a dive transect was greater than 1 km in length, counts were apportioned into 1 km increments (Figure A1.2.2). Individual count values were summarized within 2x2 km cells (similar to other data themes [e.g., fishing and non-fishing stressors]) and mean values per cell were calculated. For 2x2 km cells with only one count value, the mean value was equal to the count, with a variance of 0. Because effort varied widely between cells, mean values rather than sum of counts were used as the metric in order to standardize the abundance values per cell. The resulting metric of relative abundance (mean counts per km) is depicted in Figure A1.3.17 map plates.

1.3 HABITAT: ADDITIONAL SUMMARY TABLES AND FIGURES

An extensive series of tables with complementary charts and maps were developed to compare and contrast the spatial distribution of physical and biogenic seabed habitat types within sub-regions and depths zones, and in relation to current commercial fishing prohibitions and restrictions. A subset of those tables and figures was presented in the report, but the full complement is included in this appendix. For the purposes of this synthesis, areas of commercial fishing prohibitions or restrictions were categorized in three different ways. The first category includes the 51 EFH conservation areas implemented as part of Amendment 19 of the groundfish FMP, including areas with four gear specific prohibitions. The second category includes MPAs prohibiting one of three main commercial gear types: bottom trawl, mid-water (pelagic) trawls, and fixed gears. The third category includes marine protected areas (MPA) where commercial fishing is either "prohibited" or "restricted", based on the definition and classification system developed by the NOAA's National MPA Center (NMPAC, 2012).

References

FGDC (Federal Geographic Data Committee). 2012. Coastal and Marine Ecological Classification Standard (June 2012). FGDC-STD-018-2012. Federal Geographic Data Committee. Washington, D.C.

Greene, H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, J.E. McRea Jr., and G.M. Cailliet. 1999. A classification scheme for deep seafloor habitats. Oceanol. Acta 22(6): 663-678.

NMPAC (National Marine Protected Areas Center). 2011. Definition & Classification System for U.S. Marine Protected Areas. May 2011. http://www.mpa.gov/pdf/helpful-resources/factsheets/mpa_classification_may2011.pdf

NOAA Deep Sea Coral Research and Technology Program. Deep Sea Coral National Geodatabase. [4 Feb 2013] Dan.Dorfman@noaa.gov

PFMC (Pacific Fishery Management Council). 2012. Pacific coast groundfish 5-year review of essential fish habitat Phase 1: New information. Final Report to Pacific Fishery Management Council, September 2012. Portland, OR. 416 p.

Reid, J.A., Reid, J.M., Jenkins, C.J., Zimmermann, M., Williams, S.J., and Field, M.E., 2006, usSEABED: Pacific Coast (California, Oregon, Washington) offshore surficial-sediment data release: U.S. Geological Survey Data Series 182, version 1.0. Online at http://pubs.usgs.gov/ds/2006/182/

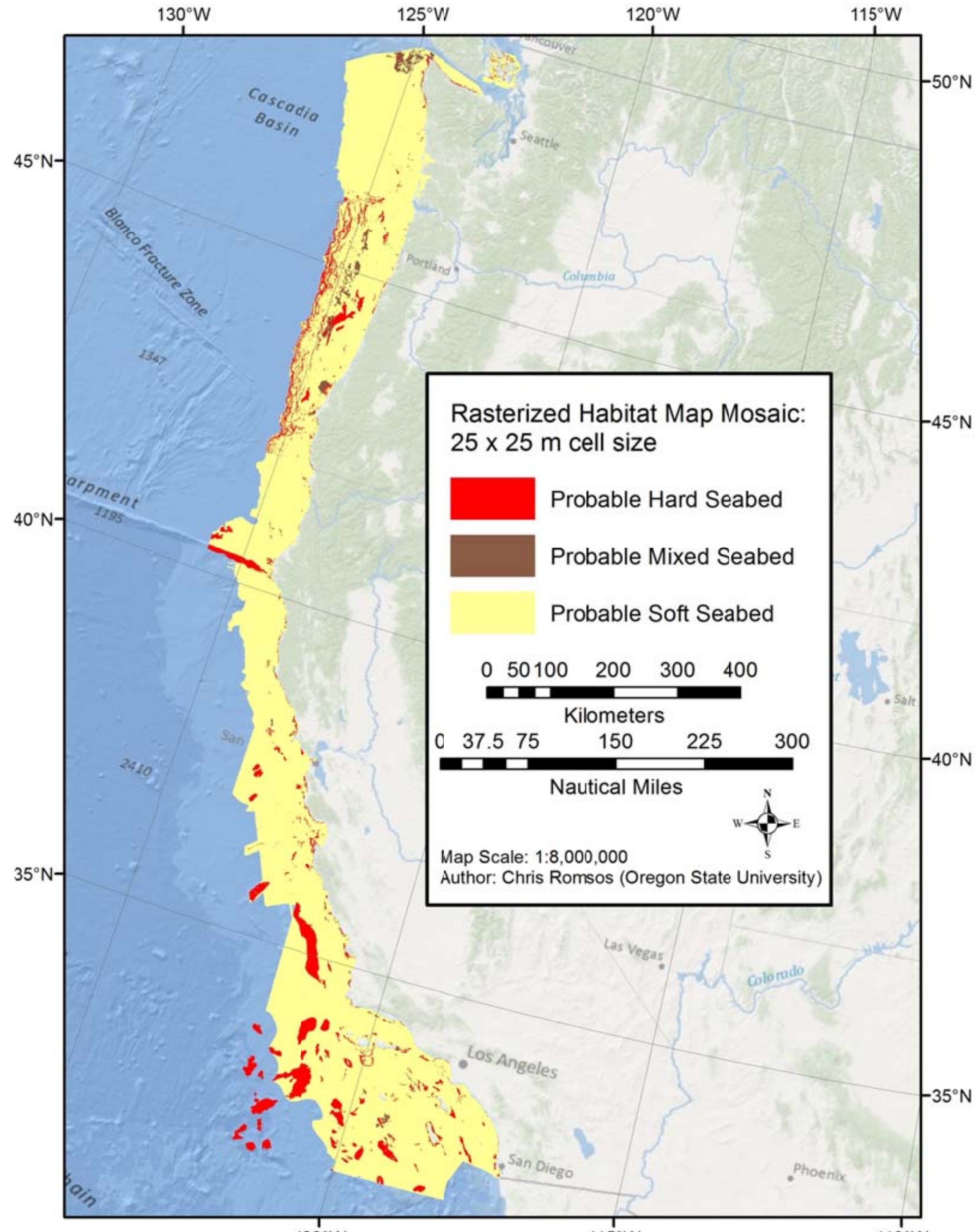


Figure A1.1.1. Each individual habitat map from the Phase 1 Report set was converted from polygon to raster format at 20m by 20m cell size. For cells with more than one habitat type present, the combined feature with the largest area determined the value of the cell. Maps of native raster format were resampled to 20m x 20m cell size. Resultant raster layers were mosaicked such that the most modern data took precedence.

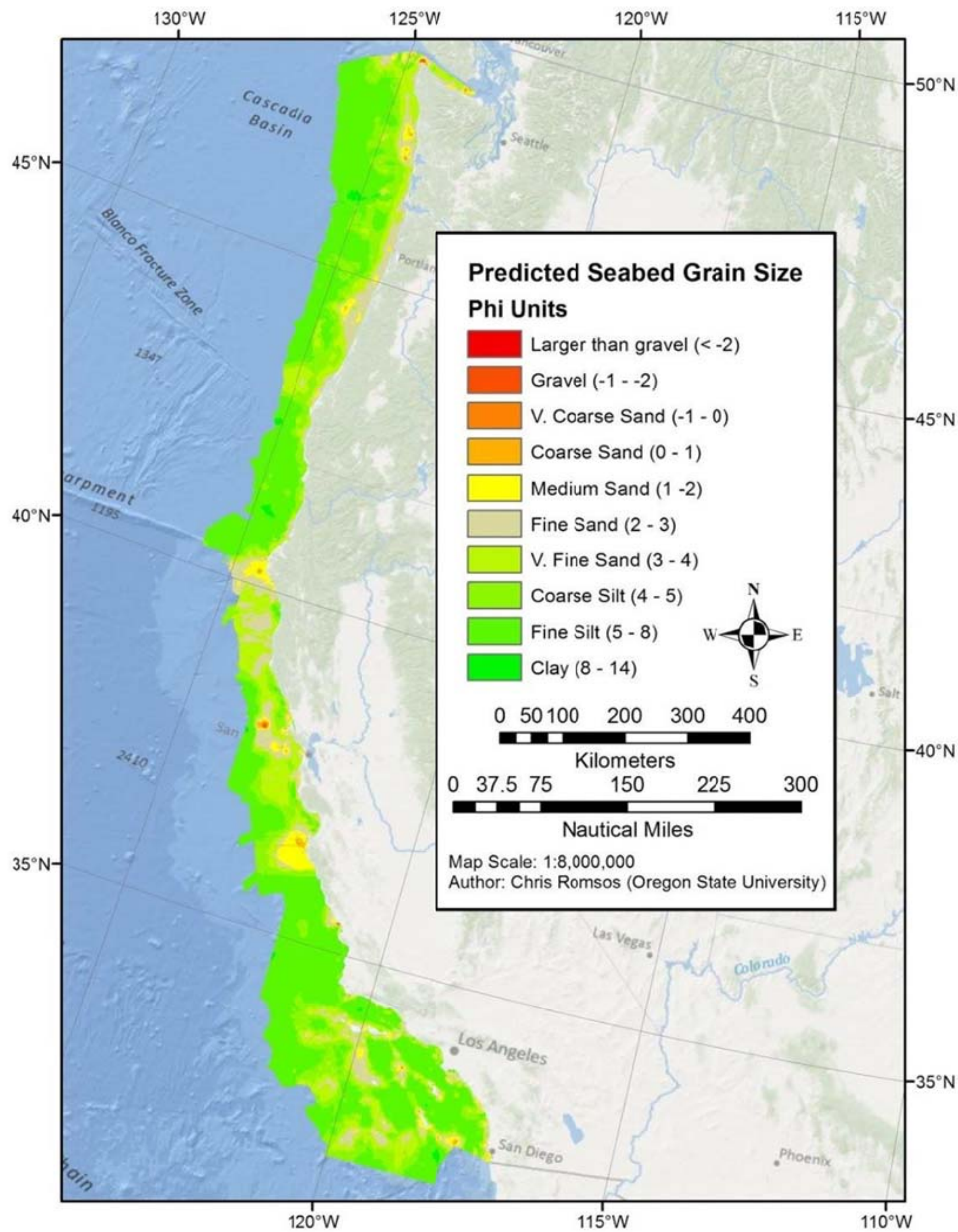


Figure A1.1.2. Grain size distribution predicted from usSEABED and Oregon State University databases. This map product was developed under funding from the Cooperative Institute for Marine Resources Studies at OSU (http://pacoos.coas.oregonstate.edu/archive/woc_sgh_grsz2.zip).

Table A1.1. A thematic seabed habitat map confidence framework is built upon the principle that habitat map confidence increases with increasing quality inputs. Maps of highest confidence are developed where high-resolution data inputs and reference datasets (groundtruth) are applied. Maps developed through interpretation of sparse or extrapolated data are more abundant than targeted high-resolution mapping studies, are necessary and useful, and may indeed be of excellent quality. However, it is reasonable to expect that thematic map confidence decreases with decreasing input data abundance, resolution, and reference control.

Confidence Level	Definition	Rationale/Criteria	Examples
Higher (3)	Lowest chance of omission (missing a habitat patch) and comission (mis-identifying a habitat patch) errors.	Automated or interpretive classifications made from high resolution acoustic imagery with support from groundtruth observations used as reference during mapping process.	OCNMS Habitat Maps, CA (USGS) and OR (OSU) State Waters maps, USGS and Center for Habitat Studies Puget Sound/Salish Sea maps
Medium (2)	Moderate chance of omission and comission errors.	Automated or interpretive classification of high resolution acoustic imagery without groundtruth reference.	CA Territorial Sea "predictive" maps of Smooth and Rough bottom, Oregon Predicted Rock Outcrop, OR and WA Smooth Sheet Maps, and some areas of the Version 1 -> 3.6.1 SGH Maps for WA and OR.
Lower (1)	Highest chance of omission and comission errors.	Interpretive maps, generally of regional scale, made from sparse or extrapolated data. Mapping generally applies localized knowledge over broad regions.	Version 1 -> 3.6 SGH Maps for WA, OR, and CA

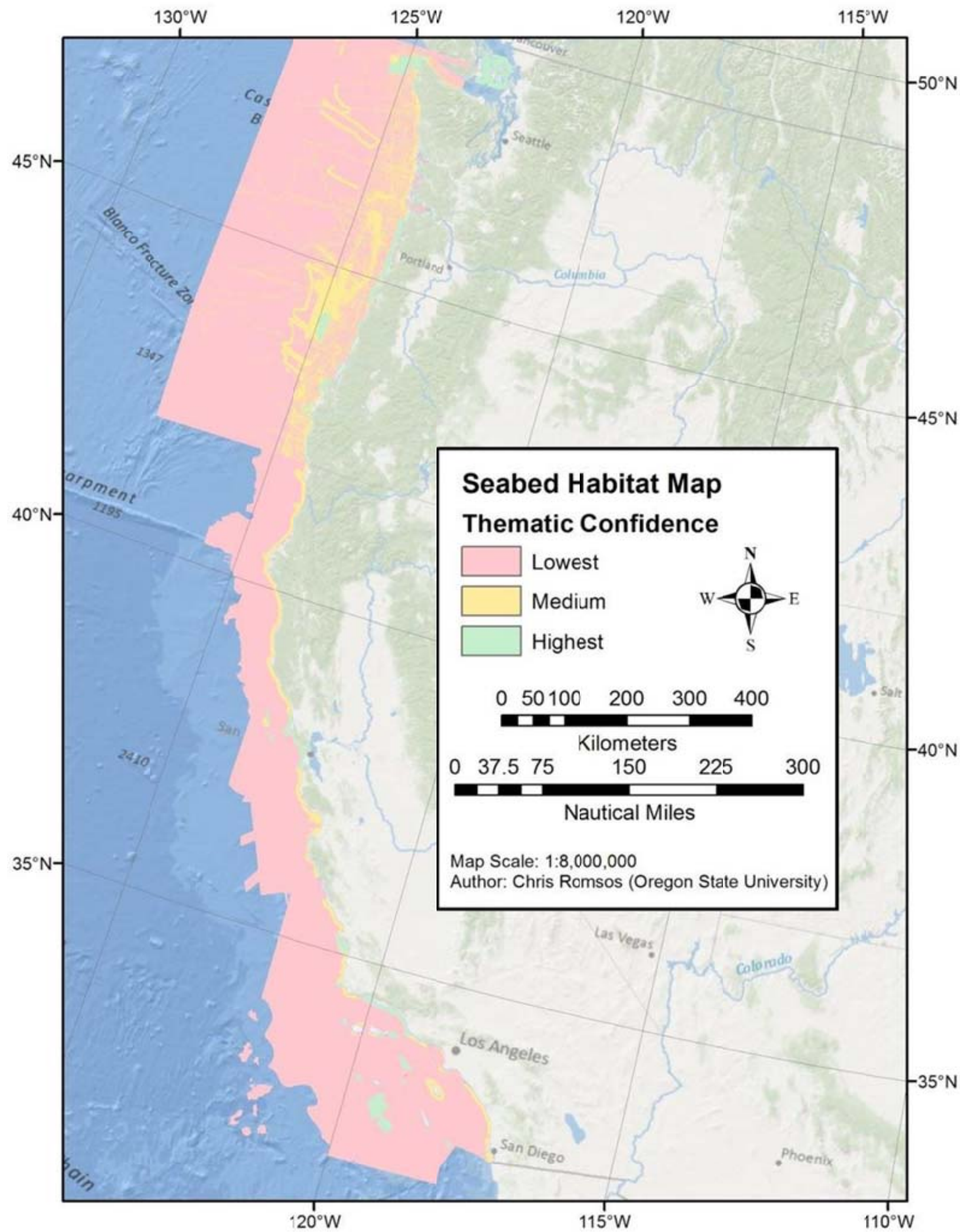


Figure A1.1.3**.** Thematic confidence for the integrated seabed habitat map. Individual habitat map raster data layers from the integration phase were reclassified and assigned a thematic confidence score according to the outlined framework. Scored data layers were mosaicked in the same order as the integrated habitat map processing where modern data (or highest quality) took precedence.

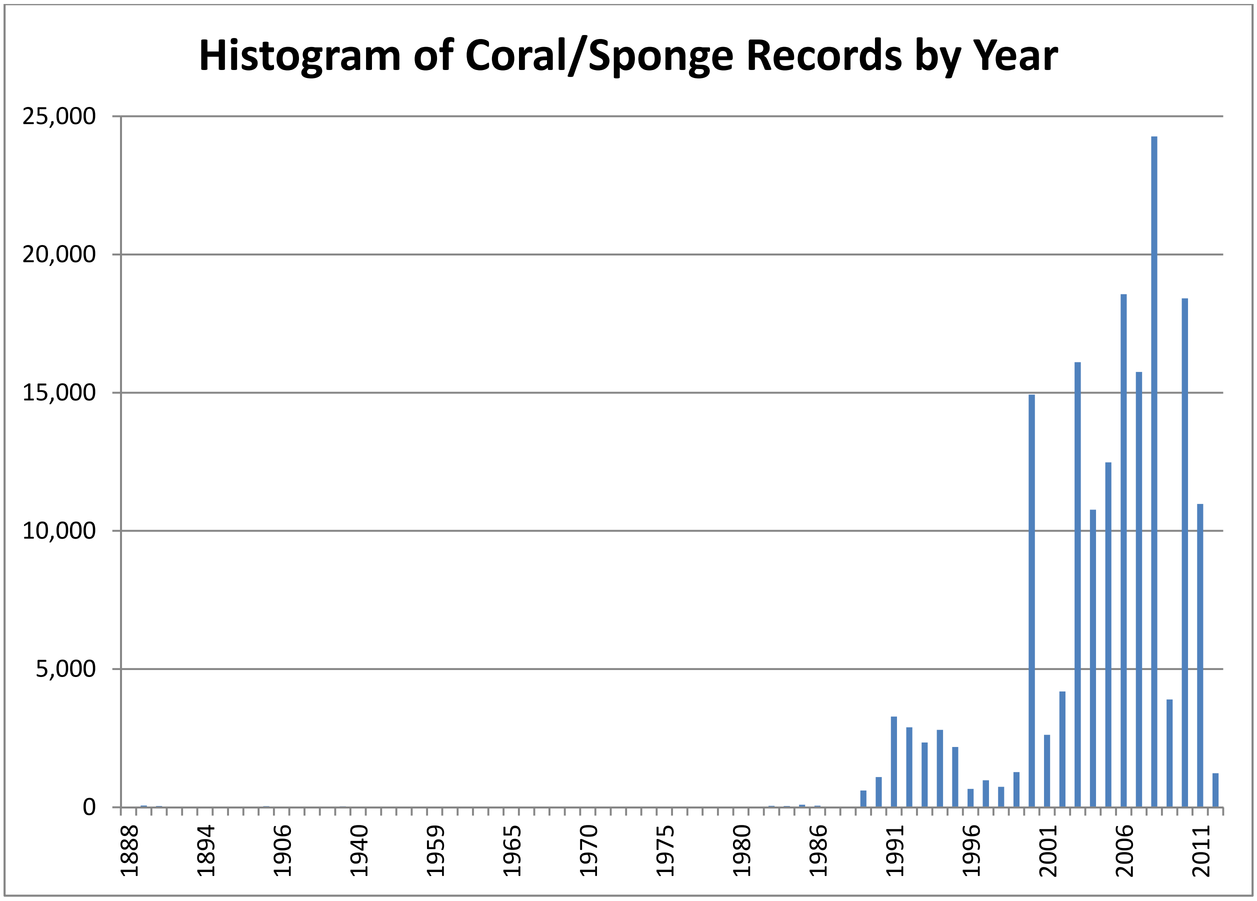


Figure A1.2.1. Distribution of coral and sponge records by year for observations collected from areas within the U.S. exclusive economic zone off the U.S. West Coast. Data source: NOAA's Deep Sea Coral Research and Technology Program (see Table A1.2).

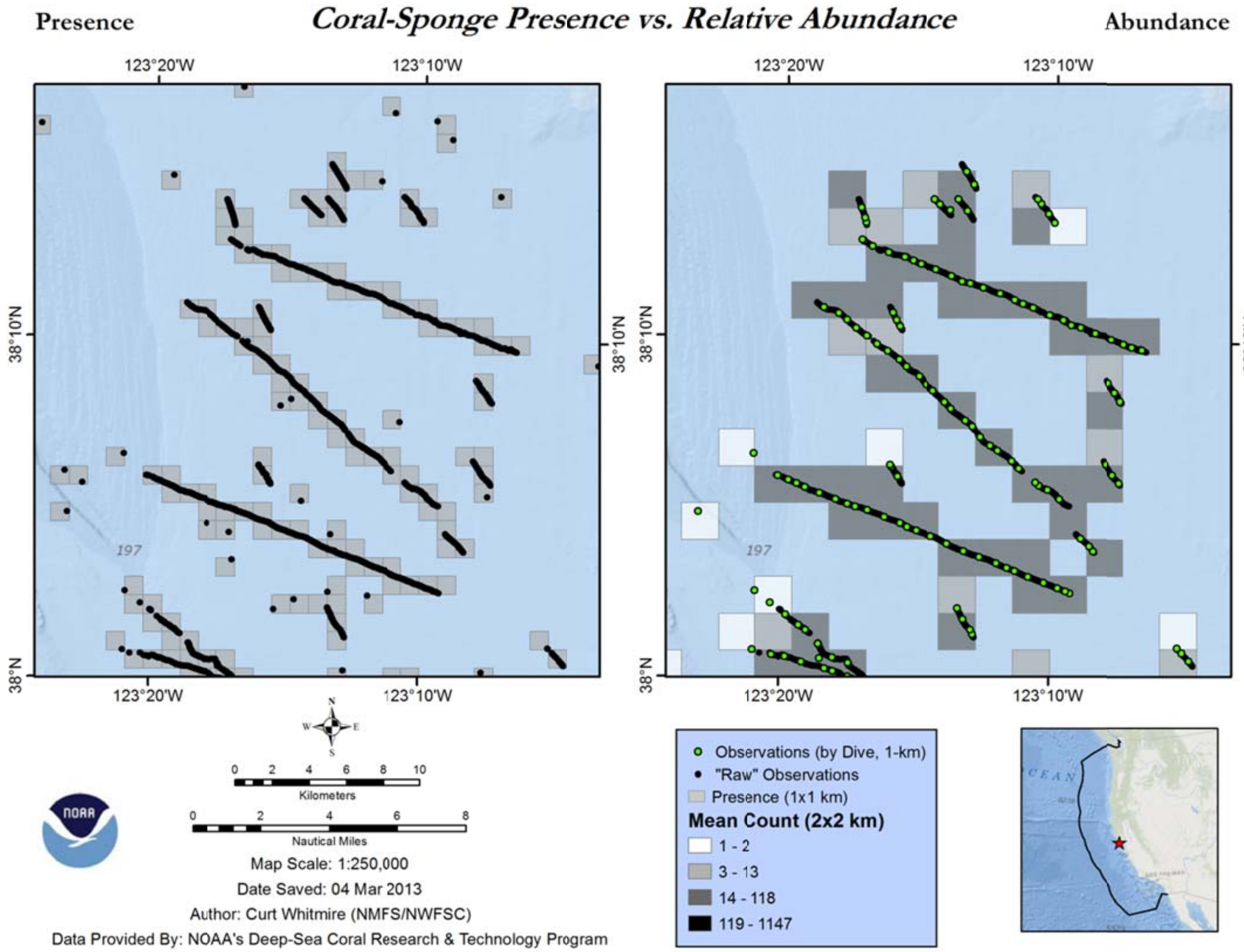


Figure A1.2.2. Map showing spatial summarization of presence (left) and relative observed abundance (right) of coral and sponge. Presence was summarized within 1x1 km cells, while relative observed abundance (i.e., mean count per dive or transect) was summarized within 2x2 km cells.

Table A1.2. Sources of data of direct observations* of corals and sponges recorded off the U.S. West Coast between 1989 and 2012. Source information includes the organization, point of contact for the data source and any relevant citation. Main data source: NOAA's Deep Sea Coral Research and Technology Program.

DATA SOURCE: (Organization\Contact\Citation)	# Records
Center for Coastal Environmental Health and Biomolecular Research, NOAA	**3,973**
Peter Etnoyer	**3,973**
Etnoyer et al. In prep.	3,785
Stierhoff et al 2011, NOAA Tech Memo NOS NCCOS 138	188
Channel Islands National Marine Sanctuary, NOAA	**55**
Danielle Lipski	**55**
Various	55
Cordell Bank National Marine Sanctuary, NOAA	**4,896**
Kaitlin Graiff	**4,896**
Etherington, L., P. van der Leeden, K. Graiff, B. Nickel. 2011. Deep-sea coral patterns and habitat modeling results from Cordell Bank, CA. Report to NOAA Deep-Sea Coral Research and Technology Program, pp. 24.	1,115
Graiff, K., D. Roberts, D. Howard, P. Etnoyer, G. Cochrane, J. Hyland and J. Roletto. 2011. A characterization of deep-sea coral and sponge communities on the continental slope west of Cordell Bank, using a remotely operated vehicle. Report to NOAA Deep-Sea Coral Research and Technology Program, pp. 24.	195
Various	3,586
Gulf of the Farallones National Marine Sanctuary, NOAA	**1,223**
Jan Roletto	**1,223**
NOAA. 2013. Deep-sea Coral Cruise within the Gulf of the Farallones National Marine Sanctuary, Preliminary Data, 1-12 October 2012. Prepared for National Oceanic and Atmospheric Administration, San Francisco, CA.	1,223
Monterey Bay Aquarium Research Institute	**120,478**
Lonny Lundsten	**120,478**
Various	120,478
Northwest Fisheries Science Center, NOAA	**9,307**
Elizabeth Clarke	**9,307**
Various	9,307
Oceana	**176**
Ben Enticknap	**80**

DATA SOURCE: (Organization\Contact\Citation)	# Records
Enticknap, B., G. Shester, M. Gorny, and M. Kelley. 2012. Important Ecological Areas off the Southern Oregon Coast: Fish and Seafloor Habitat Characterization Using a Remotely Operated Vehicle. Oceana.	80
Geoff Shester	**96**
Shester G., Donlou N., and Gorny M. 2012. Important Ecological Areas: Seafloor Habitat Expedition, Monterey Bay, California. 95 pp.	96
Olympic Coast National Marine Sanctuary, NOAA	**22,477**
Ed Bowlby	**22,477**
Various	22,477
Oregon State University	**54**
Chris Goldfinger	**54**
Strom, N.A. 2006. Structure-forming benthic invertebrates: habitat distributions on the continental margin of Oregon and Washington. MS Thesis, Oregon State University, Corvallis, OR.	54
Southwest Fisheries Science Center, NOAA	**2,731**
Mary Yoklavich	**2,731**
Various	2,731
Washington State University	**239**
Brian Tissot	**239**
Bianchi, C. 2011. Abundance and distribution of megafaunal invertebrates in NE Pacific submarine canyons and their ecological association with fishes. M.S., thesis. Washington State Univ., Washington State University. Vancouver, WA	108
Bright, J.L. 2007. Abundance and distribution of structure-forming invertebrates and their association with fishes at the Channel Islands ôFootprintö Off the Southern Coast of California. M.S., thesis. Washington State Univ., Vancouver, WA.	80
Pirtle, J.L. 2005. Habitat-based assessment of structure-forming megafaunal invertebrates and fishes on Cordell Bank, California. M.S., thesis. Washington State Univ., Vancouver, WA.	51
TOTAL	**165,609**

* Additional records of corals and sponges include 8,227 records of specimens collected either by submersible, remotely-operated vehicle, trawl, dredge or grab. Most (99%) of these specimens (trawl, dredge, grab) were not observed in situ.

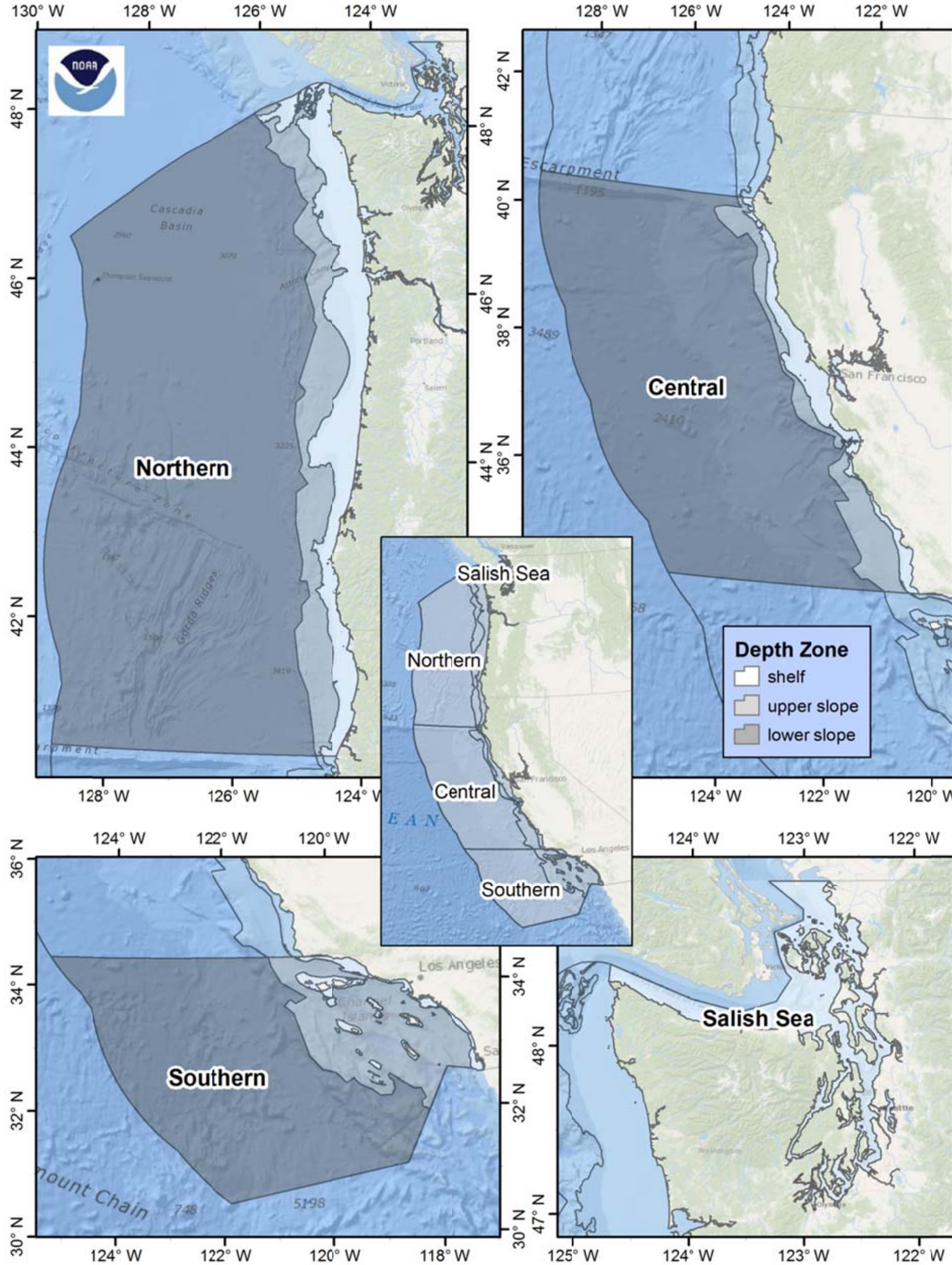


Figure A1.3.1. Map showing the spatial stratification, including four biogeographic sub-regions and three depth zones.

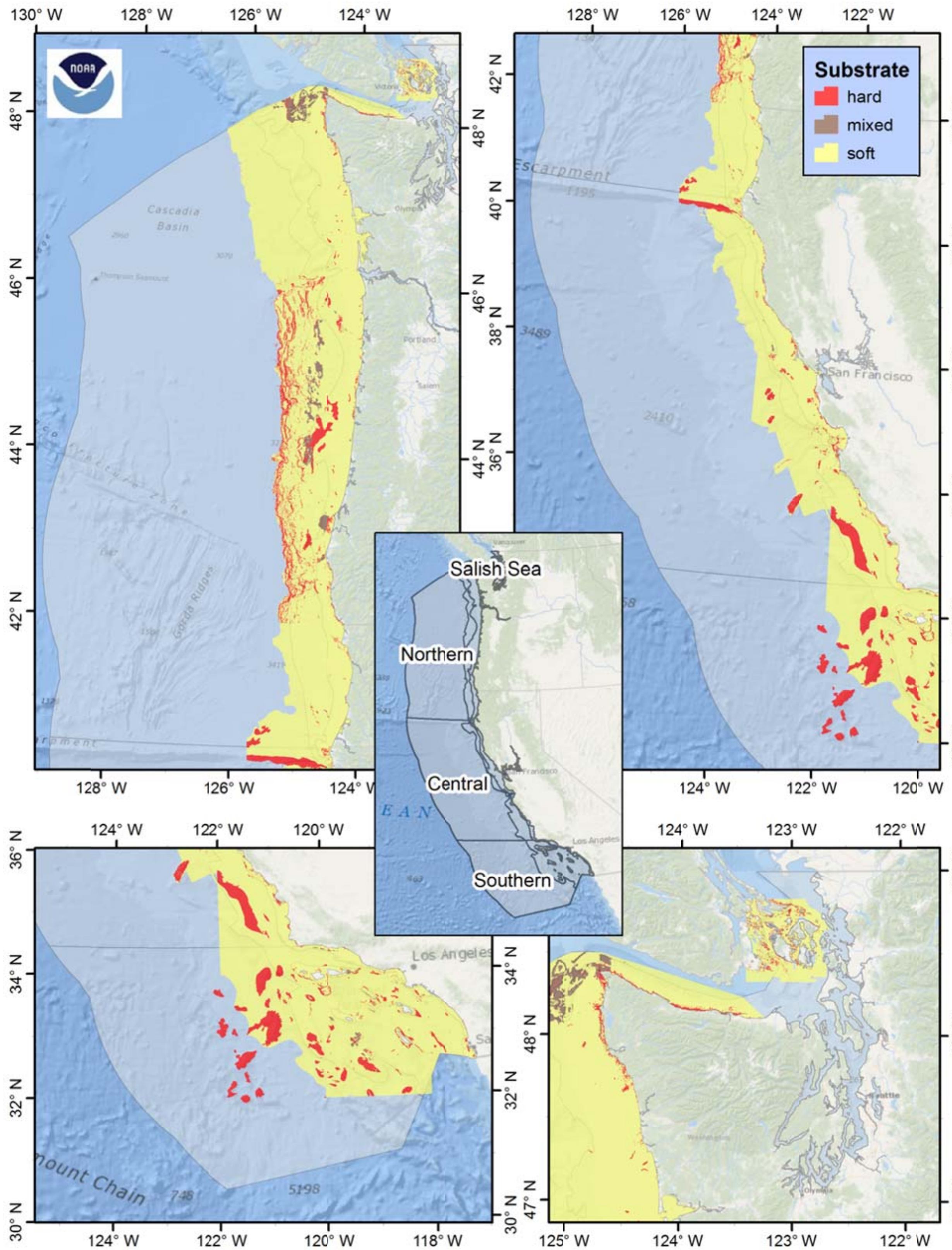


Figure A1.3.2. Map showing the spatial distribution of three major seabed habitat types: hard, mixed and soft. Much of the lower slope has not been classified in terms of substrate type.

Table A1.3.1. Distribution of seabed habitat types by depth zones both coastwide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Last row shows relative contribution to the sub-region.

		BIOGEOGRAPHIC SUB-REGION								COASTWIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	*Substrate*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	Total	3,404,867	11.1%	1,715,270	5.8%	775,396	3.6%	739,957	100.0%	6,635,491	8.0%
	hard	170,661	0.6%	104,228	0.4%	52,064	0.2%	15,701	2.1%	342,655	0.4%
	mixed	94,430	0.3%	5,277	0.0%	15,054	0.1%	7,469	1.0%	122,230	0.1%
	soft	3,049,609	9.9%	1,469,779	5.0%	691,704	3.2%	213,668	28.9%	5,424,760	6.6%
	undefined	90,167	0.3%	135,986	0.5%	16,574	0.1%	503,119	68.0%	745,846	0.9%
Upper Slope[2]	Total	3,021,125	9.8%	2,389,292	8.1%	4,669,633	21.6%	0	0.0%	10,080,050	12.2%
	hard	103,766	0.3%	267,468	0.9%	242,023	1.1%	0	0.0%	613,257	0.7%
	mixed	105,496	0.3%	3,175	0.0%	18,555	0.1%	0	0.0%	127,226	0.2%
	soft	2,811,725	9.1%	2,107,156	7.1%	4,400,561	20.3%	0	0.0%	9,319,442	11.3%
	undefined	138	0.0%	11,493	0.0%	8,495	0.0%	0	0.0%	20,125	0.0%
Lower Slope[3]	Total	24,311,081	79.1%	25,381,145	86.1%	16,184,376	74.8%	0	0.0%	65,876,603	79.8%
	hard	324,537	1.1%	143,068	0.5%	578,992	2.7%	0	0.0%	1,046,598	1.3%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,525,125	8.2%	2,681,556	9.1%	2,119,680	9.8%	0	0.0%	7,326,361	8.9%
	undefined	21,461,420	69.8%	22,556,521	76.5%	13,485,704	62.3%	0	0.0%	57,503,645	69.6%
Column Total		30,737,074	100.0%	29,485,708	100.0%	21,629,405	100.0%	739,957	100.0%	82,592,144	100.0%
Sub-Region		30,737,074	37.2%	29,485,708	35.7%	21,629,405	26.2%	739,957	0.9%	82,592,144	100.0%

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

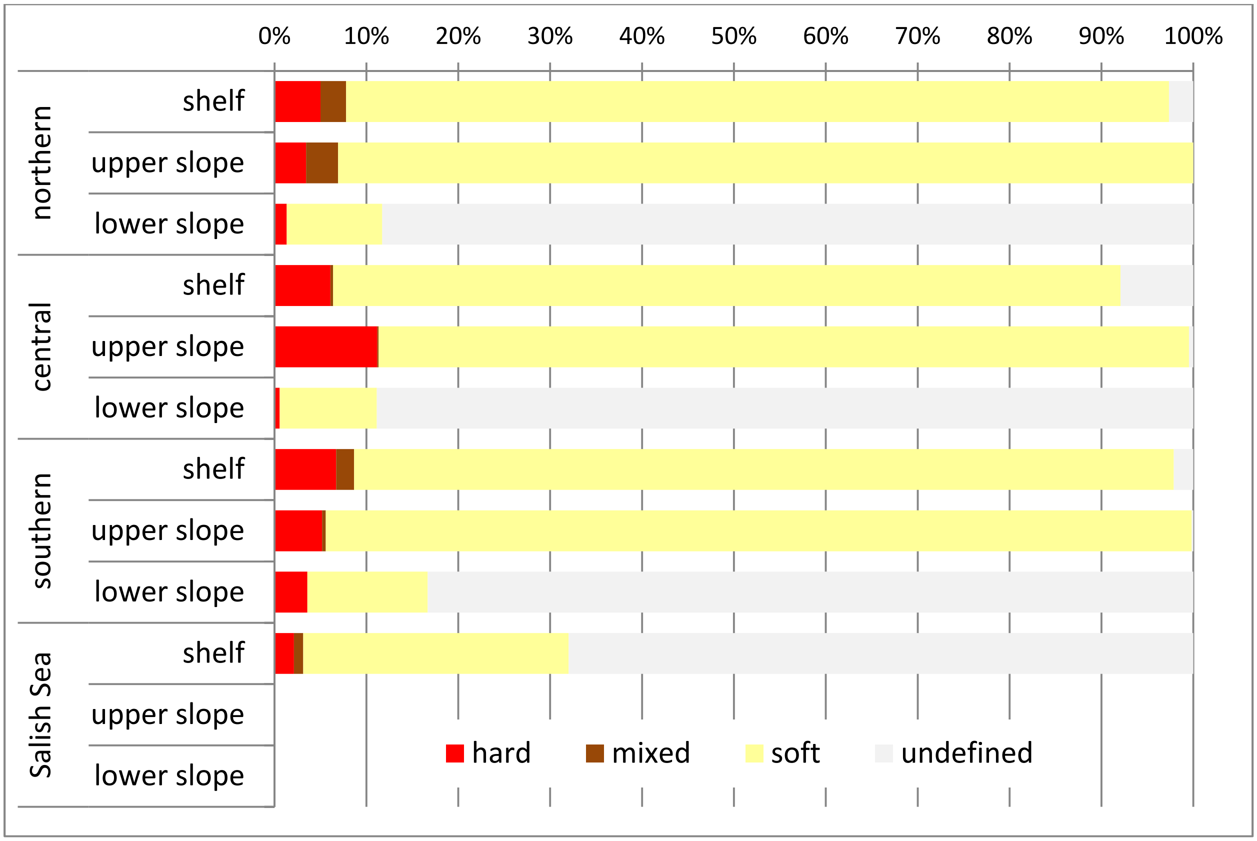


Figure A1.3.3. Relative distribution of seabed habitat types by depth zones in four biogeographic sub-regions. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

Table A1.3.2a. Distribution of seabed habitat types and EFH-specific gear prohibitions by depth zones in the "northern" biogeographic sub-region: Cape Flattery, WA to Cape Mendocino, CA. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

NORTHERN BIOGEOGRAPHIC SUB-REGION											
		Total		Bottom Contact Prohibited		Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)		Bottom Trawl Prohibited		Bottom Trawl Prohibited (except demersal seine)	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**3,404,867**	**11.1%**	**0**	**0.0%**	**0**	**0.0%**	**113,964**	**0.5%**	**921**	**1.3%**
	hard	170,661	0.6%	0	0.0%	0	0.0%	48,453	0.2%	168	0.2%
	mixed	94,430	0.3%	0	0.0%	0	0.0%	28,440	0.1%	0	0.0%
	soft	3,049,609	9.9%	0	0.0%	0	0.0%	37,071	0.2%	754	1.0%
	undefined	90,167	0.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Upper Slope[2]	**Total**	**3,021,125**	**9.8%**	**0**	**0.0%**	**0**	**0.0%**	**211,092**	**0.9%**	**15,119**	**20.8%**
	hard	103,766	0.3%	0	0.0%	0	0.0%	10,375	0.0%	0	0.0%
	mixed	105,496	0.3%	0	0.0%	0	0.0%	18,063	0.1%	0	0.0%
	soft	2,811,725	9.1%	0	0.0%	0	0.0%	182,654	0.7%	15,119	20.8%
	undefined	138	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**24,311,081**	**79.1%**	**142,405**	**100.0%**	**0**	**0.0%**	**24,251,201**	**98.7%**	**56,661**	**77.9%**
	hard	324,537	1.1%	0	0.0%	0	0.0%	324,537	1.3%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,525,125	8.2%	0	0.0%	0	0.0%	2,524,792	10.3%	56,661	77.9%
	undefined	21,461,420	69.8%	142,405	100.0%	0	0.0%	21,401,872	87.1%	0	0.0%
Column Total		**30,737,074**	**100.0%**	**142,405**	**100.0%**	**0**	**0.0%**	**24,576,257**	**100.0%**	**72,702**	**100.0%**
Sub-Region		**30,737,074**	**100.0%**	**142,405**	**0.5%**	**0**	**0.0%**	**24,576,257**	**80.0%**	**72,702**	**0.2%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.2b. Distribution of seabed habitat types and EFH-specific gear prohibitions by depth zones in the "central" biogeographic sub-region: Cape Mendocino, CA to Point Conception, CA. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

CENTRAL BIOGEOGRAPHIC SUB-REGION											
		Total		**Bottom Contact Prohibited**		**Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)**		**Bottom Trawl Prohibited**		**Bottom Trawl Prohibited (except demersal seine)**	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**1,715,270**	**5.8%**	**6,836**	**100.0%**	**0**	**0.0%**	**0**	**0.0%**	**157,979**	**9.4%**
	hard	104,228	0.4%	3,102	45.4%	0	0.0%	0	0.0%	33,255	2.0%
	mixed	5,277	0.0%	171	2.5%	0	0.0%	0	0.0%	1,224	0.1%
	soft	1,469,779	5.0%	3,564	52.1%	0	0.0%	0	0.0%	122,850	7.3%
	undefined	135,986	0.5%	0	0.0%	0	0.0%	0	0.0%	650	0.0%
Upper Slope[2]	**Total**	**2,389,292**	**8.1%**	**0**	**0.0%**	**0**	**0.0%**	**1**	**0.0%**	**599,655**	**35.7%**
	hard	267,468	0.9%	0	0.0%	0	0.0%	0	0.0%	137,969	8.2%
	mixed	3,175	0.0%	0	0.0%	0	0.0%	0	0.0%	81	0.0%
	soft	2,107,156	7.1%	0	0.0%	0	0.0%	1	0.0%	452,429	26.9%
	undefined	11,493	0.0%	0	0.0%	0	0.0%	0	0.0%	9,176	0.5%
Lower Slope[3]	**Total**	**25,381,145**	**86.1%**	**0**	**0.0%**	**200,899**	**100.0%**	**5,893,967**	**100.0%**	**923,502**	**54.9%**
	hard	143,068	0.5%	0	0.0%	45,695	22.7%	143,068	2.4%	64,575	3.8%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,681,556	9.1%	0	0.0%	56,901	28.3%	2,616,542	44.4%	684,916	40.7%
	undefined	22,556,521	76.5%	0	0.0%	98,304	48.9%	3,134,357	53.2%	174,011	10.4%
Column Total		**29,485,708**	**100.0%**	**6,836**	**100.0%**	**200,899**	**100.0%**	**5,893,968**	**100.0%**	**1,681,136**	**100.0%**
Sub-Region		**29,485,708**	**100.0%**	**6,836**	**0.0%**	**200,899**	**0.7%**	**5,893,968**	**20.0%**	**1,681,136**	**5.7%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.2c. Distribution of seabed habitat types and EFH-specific gear prohibitions by depth zones in the "southern" biogeographic sub-region: Point Conception, CA to U.S.-Mexico maritime border. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

SOUTHERN BIOGEOGRAPHIC SUB-REGION											
		Total		Bottom Contact Prohibited		Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)		Bottom Trawl Prohibited		Bottom Trawl Prohibited (except demersal seine)	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**775,396**	**3.6%**	**41,786**	**50.4%**	**0**	**0.0%**	**0**	**0.0%**	**57,176**	**9.8%**
	hard	52,064	0.2%	2,633	3.2%	0	0.0%	0	0.0%	5,744	1.0%
	mixed	15,054	0.1%	302	0.4%	0	0.0%	0	0.0%	2,061	0.4%
	soft	691,704	3.2%	38,667	46.6%	0	0.0%	0	0.0%	49,171	8.5%
	undefined	16,574	0.1%	183	0.2%	0	0.0%	0	0.0%	201	0.0%
Upper Slope[2]	**Total**	**4,669,633**	**21.6%**	**41,195**	**49.6%**	**0**	**0.0%**	**0**	**0.0%**	**407,036**	**70.0%**
	hard	242,023	1.1%	673	0.8%	0	0.0%	0	0.0%	19,264	3.3%
	mixed	18,555	0.1%	55	0.1%	0	0.0%	0	0.0%	12,141	2.1%
	soft	4,400,561	20.3%	40,467	48.8%	0	0.0%	0	0.0%	375,398	64.6%
	undefined	8,495	0.0%	0	0.0%	0	0.0%	0	0.0%	235	0.0%
Lower Slope[3]	**Total**	**16,184,376**	**74.8%**	**0**	**0.0%**	**0**	**0.0%**	**3,651,408**	**100.0%**	**117,020**	**20.1%**
	hard	578,992	2.7%	0	0.0%	0	0.0%	578,992	15.9%	32,808	5.6%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,119,680	9.8%	0	0.0%	0	0.0%	1,703,013	46.6%	84,211	14.5%
	undefined	13,485,704	62.3%	0	0.0%	0	0.0%	1,369,403	37.5%	0	0.0%
Column Total		**21,629,405**	**100.0%**	**82,981**	**100.0%**	**0**	**0.0%**	**3,651,408**	**100.0%**	**581,232**	**100.0%**
Sub-Region		**21,629,405**	**100.0%**	**82,981**	**0.4%**	**0**	**0.0%**	**3,651,408**	**16.9%**	**581,232**	**2.7%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.2d. Distribution of seabed habitat types and EFH-specific gear prohibitions by depth zones in the Salish Sea: Puget Sound and Straits of Georgia and Juan de Fuca. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region. No EFH Conservation Areas are located in the "Salish Sea."

		SALISH SEA									
		Total		Bottom Contact Prohibited		Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)		Bottom Trawl Prohibited		Bottom Trawl Prohibited (except demersal seine)	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**739,957**	**100.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	15,701	2.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	7,469	1.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	213,668	28.9%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	503,119	68.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Upper Slope[2]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**739,957**	**100.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
Sub-Region		**739,957**	**100.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

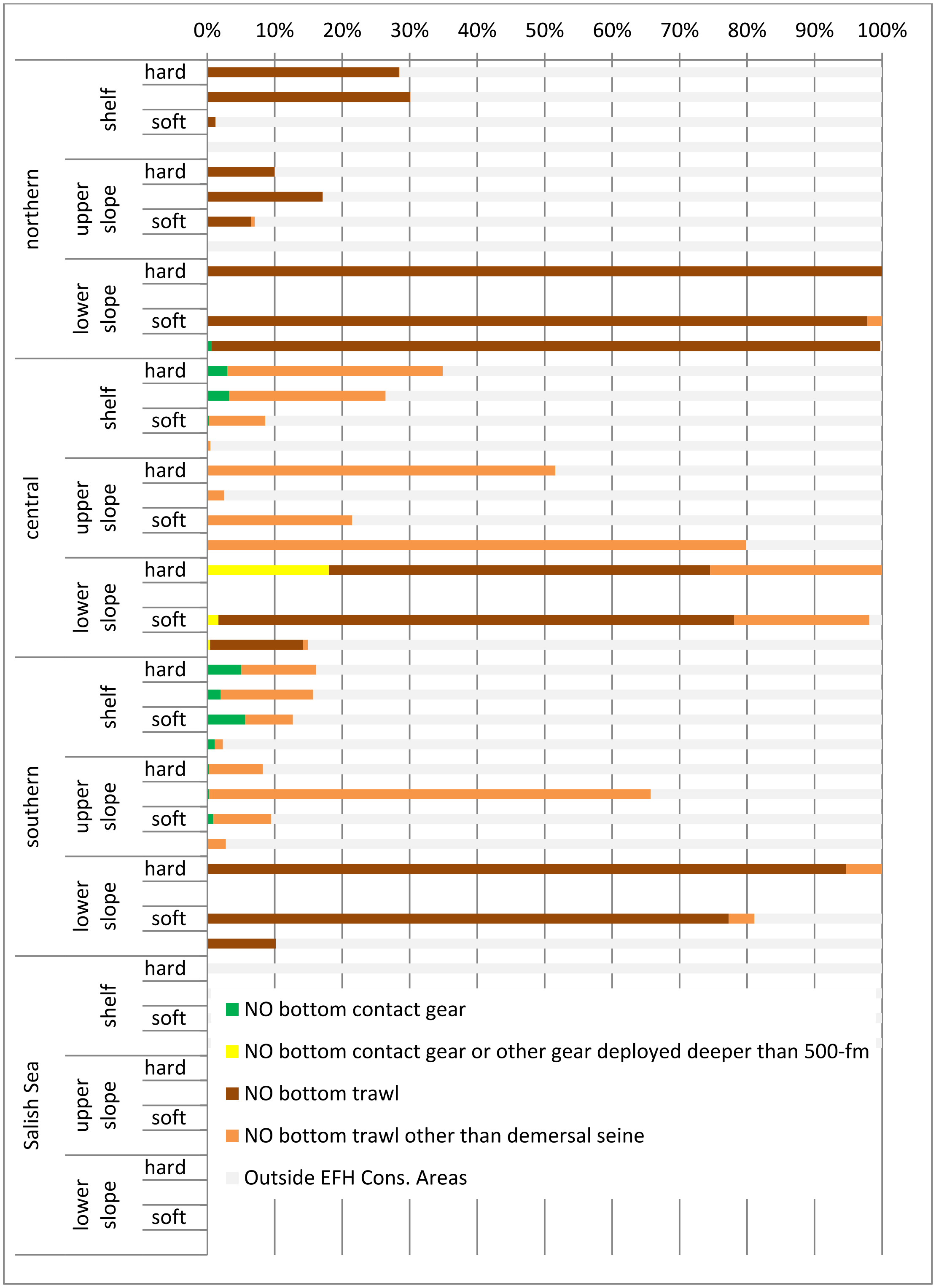


Figure A1.3.4. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the "Salish Sea" and no "mixed" substrate types are known to occur with the lower slope of any biogeographic sub-region.

Table A1.3.3a. Distribution of seabed habitat types and commercial gear prohibitions by depth zones in the "northern" biogeographic sub-region: Cape Flattery, WA to Cape Mendocino, CA. Percentage values represent relative contribution to the sub-region. Last row shows relative contribution to the sub-region.

NORTHERN BIOGEOGRAPHIC SUB-REGION									
		Total		**Bottom Trawl Prohibited**		**Midwater Trawl Prohibited**		**Fixed Gear Prohibited**	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**3,404,867**	**11.1%**	**621,648**	**2.5%**	**183**	**100.0%**	**183**	**0.1%**
	hard	170,661	0.6%	67,292	0.3%	2	0.9%	2	0.0%
	mixed	94,430	0.3%	35,513	0.1%	0	0.0%	0	0.0%
	soft	3,049,609	9.9%	506,031	2.0%	181	98.9%	181	0.1%
	undefined	90,167	0.3%	12,812	0.1%	0	0.2%	0	0.0%
Upper Slope[2]	**Total**	**3,021,125**	**9.8%**	**448,596**	**1.8%**	**0**	**0.0%**	**0**	**0.0%**
	hard	103,766	0.3%	14,221	0.1%	0	0.0%	0	0.0%
	mixed	105,496	0.3%	26,438	0.1%	0	0.0%	0	0.0%
	soft	2,811,725	9.1%	407,935	1.6%	0	0.0%	0	0.0%
	undefined	138	0.0%	2	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**24,311,081**	**79.1%**	**24,251,201**	**95.8%**	**0**	**0.0%**	**142,405**	**99.9%**
	hard	324,537	1.1%	324,537	1.3%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,525,125	8.2%	2,524,792	10.0%	0	0.0%	0	0.0%
	undefined	21,461,420	69.8%	21,401,872	84.5%	0	0.0%	142,405	99.9%
Column Total		**30,737,074**	**100.0%**	**25,321,445**	**100.0%**	**183**	**100.0%**	**142,588**	**100.0%**
Sub-Region		**30,737,074**	**100.0%**	**25,321,445**	**82.4%**	**183**	**0.0%**	**142,588**	**0.5%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.3b. Distribution of seabed habitat types and commercial gear prohibitions by depth zones in the "central" biogeographic sub-region: Cape Mendocino, CA to Point Conception, CA. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

CENTRAL BIOGEOGRAPHIC SUB-REGION									
		Total		Bottom Trawl Prohibited		Midwater Trawl Prohibited		Fixed Gear Prohibited	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**1,715,270**	**5.8%**	**868,685**	**11.6%**	**45,730**	**95.5%**	**52,567**	**20.6%**
	hard	104,228	0.4%	94,048	1.3%	8,777	18.3%	11,879	4.6%
	mixed	5,277	0.0%	5,056	0.1%	338	0.7%	509	0.2%
	soft	1,469,779	5.0%	633,595	8.5%	34,987	73.1%	38,551	15.1%
	undefined	135,986	0.5%	135,986	1.8%	1,628	3.4%	1,628	0.6%
Upper Slope[2]	**Total**	**2,389,292**	**8.1%**	**726,199**	**9.7%**	**2,140**	**4.5%**	**2,140**	**0.8%**
	hard	267,468	0.9%	139,669	1.9%	3	0.0%	3	0.0%
	mixed	3,175	0.0%	1,485	0.0%	0	0.0%	0	0.0%
	soft	2,107,156	7.1%	575,869	7.7%	2,137	4.5%	2,137	0.8%
	undefined	11,493	0.0%	9,176	0.1%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**25,381,145**	**86.1%**	**5,893,967**	**78.7%**	**0**	**0.0%**	**200,899**	**78.6%**
	hard	143,068	0.5%	143,068	1.9%	0	0.0%	45,695	17.9%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,681,556	9.1%	2,616,542	34.9%	0	0.0%	56,901	22.3%
	undefined	22,556,521	76.5%	3,134,357	41.9%	0	0.0%	98,304	38.5%
Column Total		**29,485,708**	**100.0%**	**7,488,851**	**100.0%**	**47,870**	**100.0%**	**255,605**	**100.0%**
Sub-Region		**29,485,708**	**100.0%**	**7,488,851**	**25.4%**	**47,870**	**0.2%**	**255,605**	**0.9%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.3c. Distribution of seabed habitat types and commercial gear prohibitions by depth zones in the “southern” biogeographic sub-region: Point Conception, CA to U.S.-Mexico maritime border. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

		SOUTHERN BIOGEOGRAPHIC SUB-REGION							
		Total		**Bottom Trawl Prohibited**		**Midwater Trawl Prohibited**		**Fixed Gear Prohibited**	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**775,396**	**3.6%**	**587,332**	**12.0%**	**58,801**	**77.8%**	**68,534**	**58.4%**
	hard	52,064	0.2%	41,382	0.8%	5,150	6.8%	5,339	4.5%
	mixed	15,054	0.1%	10,769	0.2%	487	0.6%	629	0.5%
	soft	691,704	3.2%	519,144	10.6%	52,477	69.5%	61,859	52.7%
	undefined	16,574	0.1%	16,037	0.3%	687	0.9%	707	0.6%
Upper Slope[2]	**Total**	**4,669,633**	**21.6%**	**650,456**	**13.3%**	**16,737**	**22.2%**	**48,918**	**41.6%**
	hard	242,023	1.1%	43,463	0.9%	436	0.6%	906	0.8%
	mixed	18,555	0.1%	12,293	0.3%	0	0.0%	55	0.0%
	soft	4,400,561	20.3%	594,203	12.2%	16,301	21.6%	47,957	40.8%
	undefined	8,495	0.0%	497	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**16,184,376**	**74.8%**	**3,651,408**	**74.7%**	**0**	**0.0%**	**0**	**0.0%**
	hard	578,992	2.7%	578,992	11.8%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,119,680	9.8%	1,703,013	34.8%	0	0.0%	0	0.0%
	undefined	13,485,704	62.3%	1,369,403	28.0%	0	0.0%	0	0.0%
Column Total		**21,629,405**	**100.0%**	**4,889,195**	**100.0%**	**75,539**	**100.0%**	**117,452**	**100.0%**
Sub-Region		**21,629,405**	**100.0%**	**4,889,195**	**22.6%**	**75,539**	**0.3%**	**117,452**	**0.5%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.3d. Distribution of seabed habitat types and commercial gear prohibitions by depth zones in the Salish Sea: Puget Sound and Straits of Georgia and Juan de Fuca. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

		SALISH SEA							
		Total		**Bottom Trawl Prohibited**		**Midwater Trawl Prohibited**		**Fixed Gear Prohibited**	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**739,957**	**100.0%**	**739,957**	**100.0%**	**230**	**100.0%**	**230**	**100.0%**
	hard	15,701	2.1%	15,701	2.1%	0	0.0%	0	0.0%
	mixed	7,469	1.0%	7,469	1.0%	0	0.0%	0	0.0%
	soft	213,668	28.9%	213,668	28.9%	0	0.0%	0	0.0%
	undefined	503,119	68.0%	503,119	68.0%	230	100.0%	230	100.0%
Upper Slope[2]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**739,957**	**100.0%**	**739,957**	**100.0%**	**230**	**100.0%**	**230**	**100.0%**
Sub-Region		**739,957**	**100.0%**	**739,957**	**100.0%**	**230**	**0.0%**	**230**	**0.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

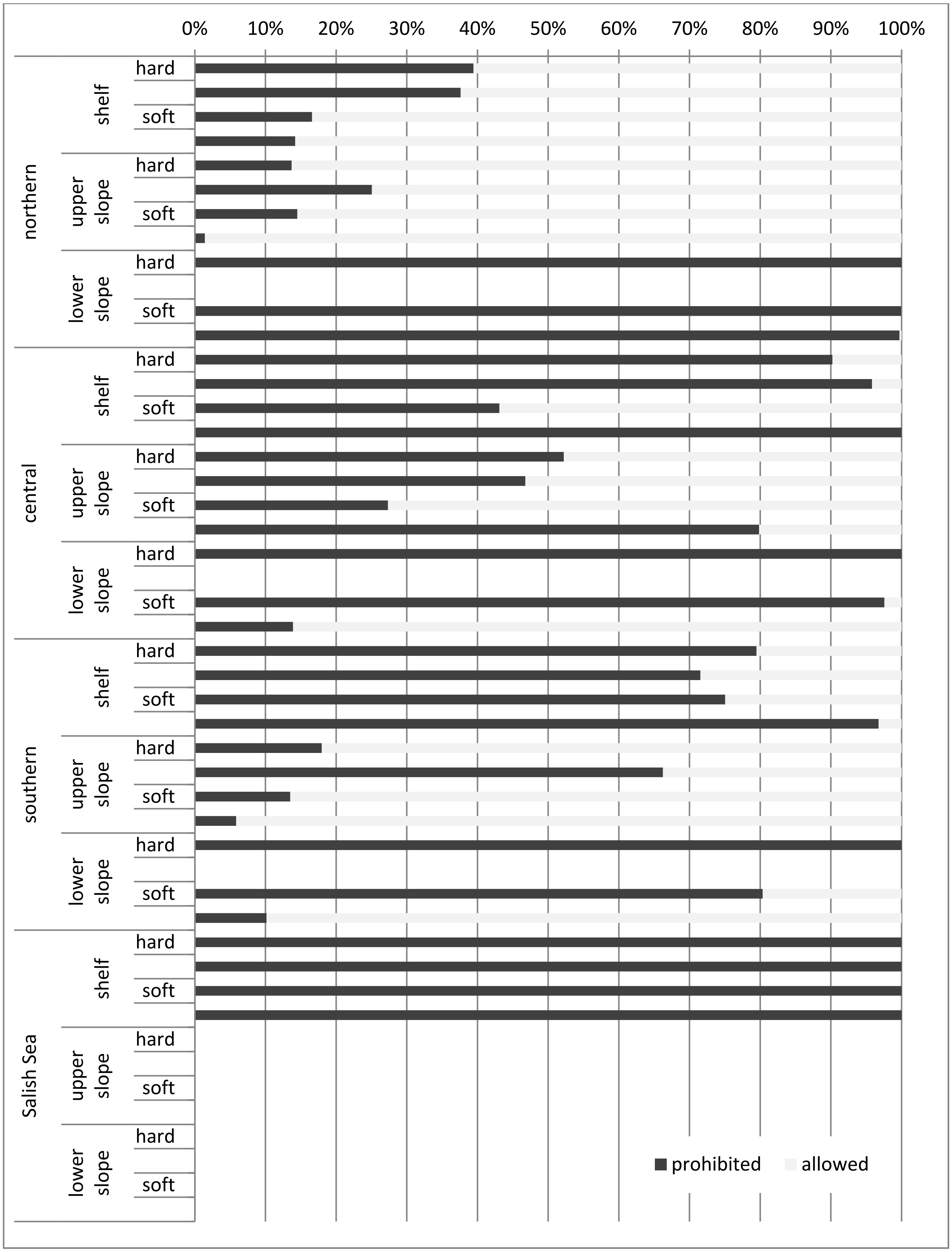


Figure A1.3.5. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where bottom trawling is “prohibited” and “allowed”. The “Salish Sea” only encompasses the shallowest (“shelf”) depth zone.

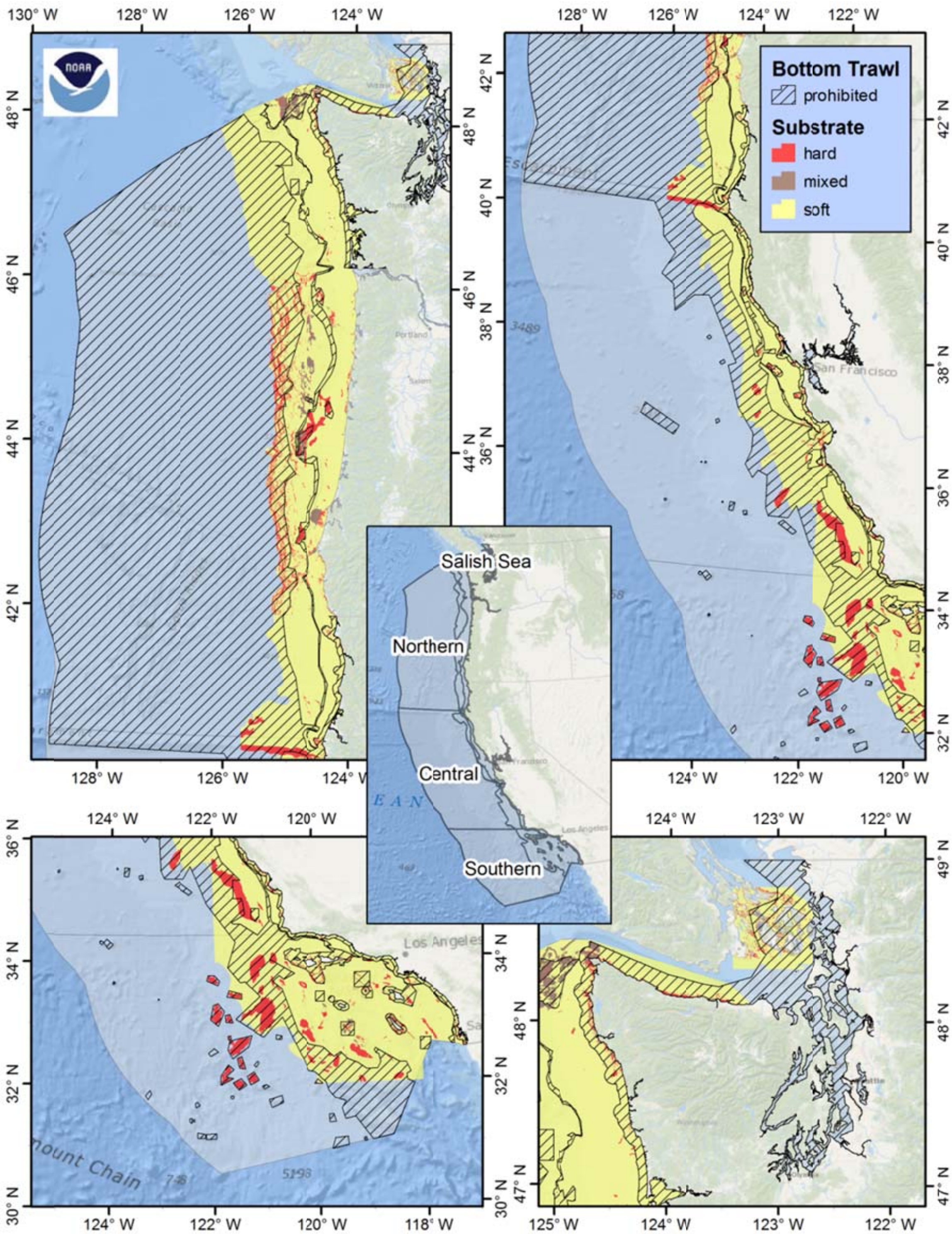


Figure A1.3.6. Map showing the composite area closed to bottom trawling overlain on three major seabed habitat types: hard, mixed and soft. Bottom trawl gear is prohibited in all 51 EFH conservation areas, any state or federal (e.g., Channel Island NMS) "no-take" marine reserve, the state territorial sea of WA and most of CA, and the area of the trawl RCA that has been permanently closed since inception of the RCA.

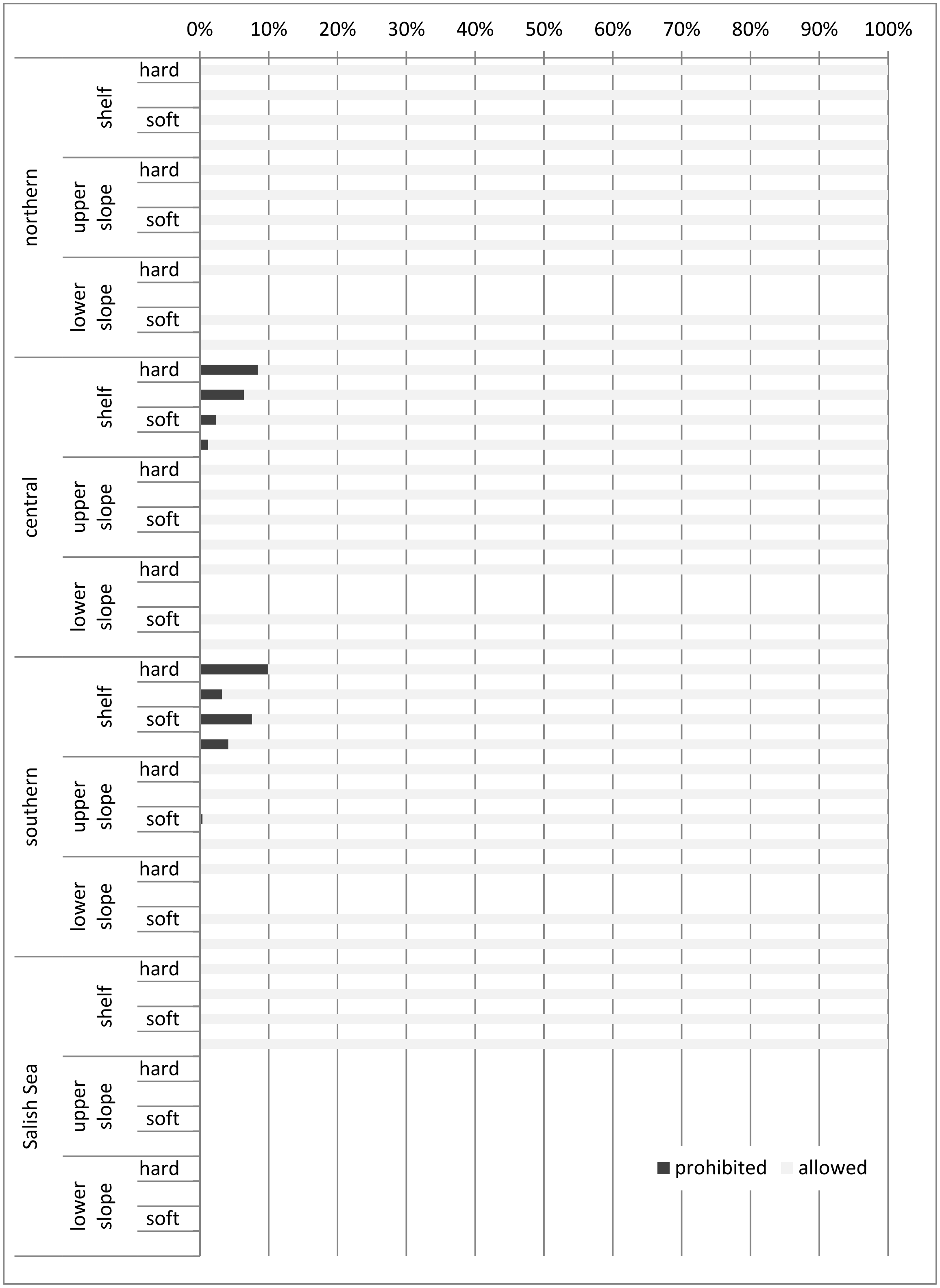


Figure A1.3.7a. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where midwater trawling is “prohibited” and “allowed”. The “Salish Sea” only encompasses the shallowest (“shelf”) depth zone.

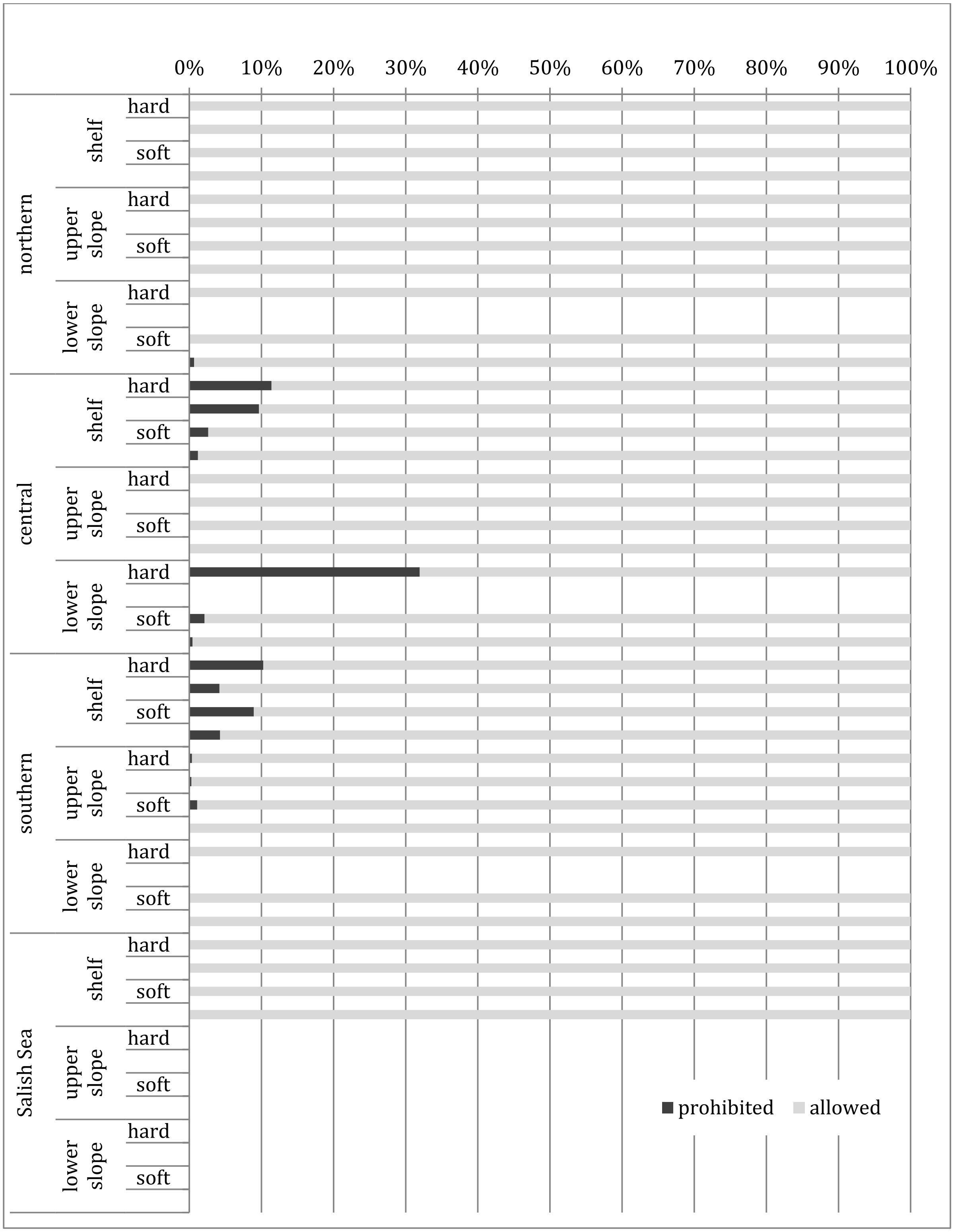


Figure A1.3.7b. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where fixed gears are "prohibited" and "allowed". The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

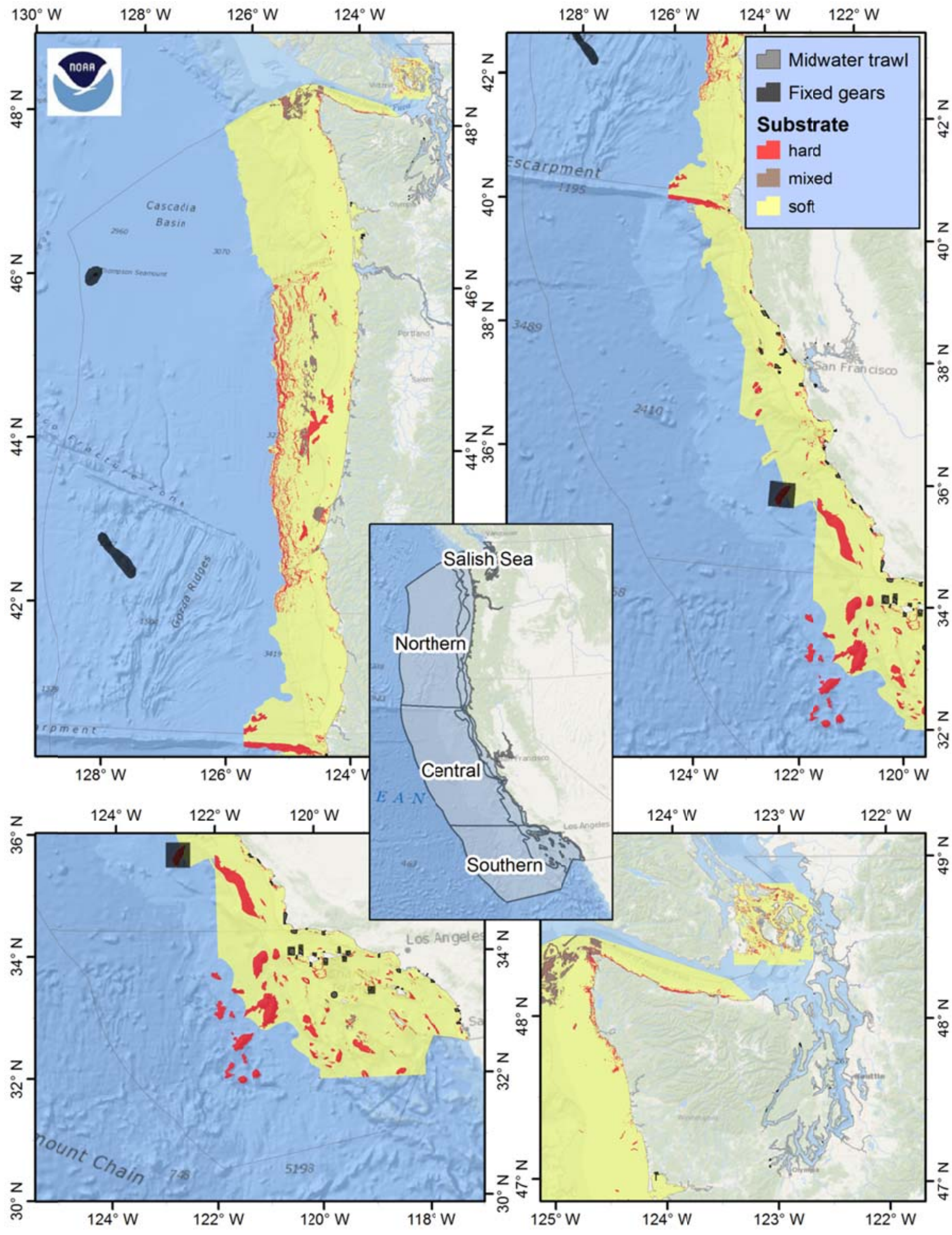


Figure A1.3.8. Map showing the composite area closed to midwater trawling and fixed gears overlain on three major seabed habitat types: hard, mixed and soft. Areas closed to these gear types encompass a relatively small total area compared to those closed to bottom trawling. Fixed gears, since they contact the bottom, or prohibited in 16 of 51 EFH conservation areas, while midwater trawls are only prohibited in state and federal (e.g., Channel Island NMS) "no-take" marine reserves.

Table A1.3.4a. Distribution of seabed habitat types and fishing restrictions by depth zones in the “northern” biogeographic sub-region: Cape Flattery, WA to Cape Mendocino, CA. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

NORTHERN BIOGEOGRAPHIC SUB-REGION									
		Total		Commercial Prohibited		Commercial Restricted		NO Commercial Restrictions	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**3,404,867**	**11.1%**	**183**	**100.0%**	**1,196,295**	**4.6%**	**2,208,561**	**46.3%**
	hard	170,661	0.6%	2	0.9%	73,023	0.3%	97,637	2.0%
	mixed	94,430	0.3%	0	0.0%	62,884	0.2%	31,545	0.7%
	soft	3,049,609	9.9%	181	98.9%	1,046,499	4.0%	2,003,101	42.0%
	undefined	90,167	0.3%	0	0.2%	13,889	0.1%	76,278	1.6%
Upper Slope[2]	**Total**	**3,021,125**	**9.8%**	**0**	**0.0%**	**521,774**	**2.0%**	**2,499,351**	**52.4%**
	hard	103,766	0.3%	0	0.0%	14,877	0.1%	88,889	1.9%
	mixed	105,496	0.3%	0	0.0%	35,855	0.1%	69,641	1.5%
	soft	2,811,725	9.1%	0	0.0%	470,962	1.8%	2,340,764	49.1%
	undefined	138	0.0%	0	0.0%	80	0.0%	57	0.0%
Lower Slope[3]	**Total**	**24,311,081**	**79.1%**	**0**	**0.0%**	**24,251,201**	**93.4%**	**59,880**	**1.3%**
	hard	324,537	1.1%	0	0.0%	324,537	1.2%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,525,125	8.2%	0	0.0%	2,524,792	9.7%	333	0.0%
	undefined	21,461,420	69.8%	0	0.0%	21,401,872	82.4%	59,548	1.2%
Column Total		**30,737,074**	**100.0%**	**183**	**100.0%**	**25,969,269**	**100.0%**	**4,767,793**	**100.0%**
Sub-Region		**30,737,074**	**100.0%**	**183**	**0.0%**	**25,969,269**	**84.5%**	**4,767,793**	**15.5%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.4b. Distribution of seabed habitat types and fishing restrictions by depth zones in the "central" biogeographic sub-region: Cape Mendocino, CA to Point Conception, CA. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

CENTRAL BIOGEOGRAPHIC SUB-REGION									
		Total		Commercial Prohibited		Commercial Restricted		NO Commercial Restrictions	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**1,715,270**	**5.8%**	**45,730**	**95.5%**	**868,546**	**11.6%**	**846,585**	**3.8%**
	hard	104,228	0.4%	8,777	18.3%	94,048	1.3%	10,180	0.0%
	mixed	5,277	0.0%	338	0.7%	5,056	0.1%	221	0.0%
	soft	1,469,779	5.0%	34,987	73.1%	633,456	8.5%	836,184	3.8%
	undefined	135,986	0.5%	1,628	3.4%	135,986	1.8%	0	0.0%
Upper Slope[2]	**Total**	**2,389,292**	**8.1%**	**2,140**	**4.5%**	**726,199**	**9.7%**	**1,663,093**	**7.6%**
	hard	267,468	0.9%	3	0.0%	139,669	1.9%	127,799	0.6%
	mixed	3,175	0.0%	0	0.0%	1,485	0.0%	1,691	0.0%
	soft	2,107,156	7.1%	2,137	4.5%	575,869	7.7%	1,531,287	7.0%
	undefined	11,493	0.0%	0	0.0%	9,176	0.1%	2,317	0.0%
Lower Slope[3]	**Total**	**25,381,145**	**86.1%**	**0**	**0.0%**	**5,893,967**	**78.7%**	**19,487,179**	**88.6%**
	hard	143,068	0.5%	0	0.0%	143,068	1.9%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,681,556	9.1%	0	0.0%	2,616,542	34.9%	65,014	0.3%
	undefined	22,556,521	76.5%	0	0.0%	3,134,357	41.9%	19,422,165	88.3%
Column Total		**29,485,708**	**100.0%**	**47,870**	**100.0%**	**7,488,712**	**100.0%**	**21,996,857**	**100.0%**
Sub-Region		**29,485,708**	**100.0%**	**47,870**	**0.2%**	**7,488,712**	**25.4%**	**21,996,857**	**74.6%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.4c. Distribution of seabed habitat types and fishing restrictions by depth zones in the "southern" biogeographic sub-region: Point Conception, CA to U.S.-Mexico maritime border. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region.

		SOUTHERN BIOGEOGRAPHIC SUB-REGION							
		Total		**Commercial Prohibited**		**Commercial Restricted**		**NO Commercial Restrictions**	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**775,396**	**3.6%**	**58,801**	**77.8%**	**635,159**	**10.5%**	**140,186**	**0.9%**
	hard	52,064	0.2%	5,150	6.8%	46,240	0.8%	5,824	0.0%
	mixed	15,054	0.1%	487	0.6%	14,408	0.2%	646	0.0%
	soft	691,704	3.2%	52,477	69.5%	558,466	9.3%	133,187	0.9%
	undefined	16,574	0.1%	687	0.9%	16,045	0.3%	530	0.0%
Upper Slope[2]	**Total**	**4,669,633**	**21.6%**	**16,737**	**22.2%**	**1,745,921**	**28.9%**	**2,923,637**	**18.7%**
	hard	242,023	1.1%	436	0.6%	103,330	1.7%	138,693	0.9%
	mixed	18,555	0.1%	0	0.0%	18,555	0.3%	0	0.0%
	soft	4,400,561	20.3%	16,301	21.6%	1,623,539	26.9%	2,776,947	17.8%
	undefined	8,495	0.0%	0	0.0%	497	0.0%	7,998	0.1%
Lower Slope[3]	**Total**	**16,184,376**	**74.8%**	**0**	**0.0%**	**3,651,408**	**60.5%**	**12,532,968**	**80.4%**
	hard	578,992	2.7%	0	0.0%	578,992	9.6%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	2,119,680	9.8%	0	0.0%	1,703,013	28.2%	416,668	2.7%
	undefined	13,485,704	62.3%	0	0.0%	1,369,403	22.7%	12,116,301	77.7%
Column Total		**21,629,405**	**100.0%**	**75,539**	**100.0%**	**6,032,488**	**100.0%**	**15,596,792**	**100.0%**
Sub-Region		**21,629,405**	**100.0%**	**75,539**	**0.3%**	**6,032,488**	**27.9%**	**15,596,792**	**72.1%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.4d. Distribution of seabed habitat types and fishing restrictions by depth zones in the Salish Sea: Puget Sound and Straits of Georgia and Juan de Fuca. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

		SALISH SEA							
		Total		Commercial Prohibited		Commercial Restricted		NO Commercial Restrictions	
Depth Zone	***Substrate***	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Shelf[1]	**Total**	**739,957**	**100.0%**	**230**	**100.0%**	**739,957**	**100.0%**	**0**	**0.0%**
	hard	15,701	2.1%	0	0.0%	15,701	2.1%	0	0.0%
	mixed	7,469	1.0%	0	0.0%	7,469	1.0%	0	0.0%
	soft	213,668	28.9%	0	0.0%	213,668	28.9%	0	0.0%
	undefined	503,119	68.0%	230	100.0%	503,119	68.0%	0	0.0%
Upper Slope[2]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	hard	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**739,957**	**100.0%**	**230**	**100.0%**	**739,957**	**100.0%**	**0**	**0.0%**
Sub-Region		**739,957**	**100.0%**	**230**	**0.0%**	**739,957**	**100.0%**	**0**	**0.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

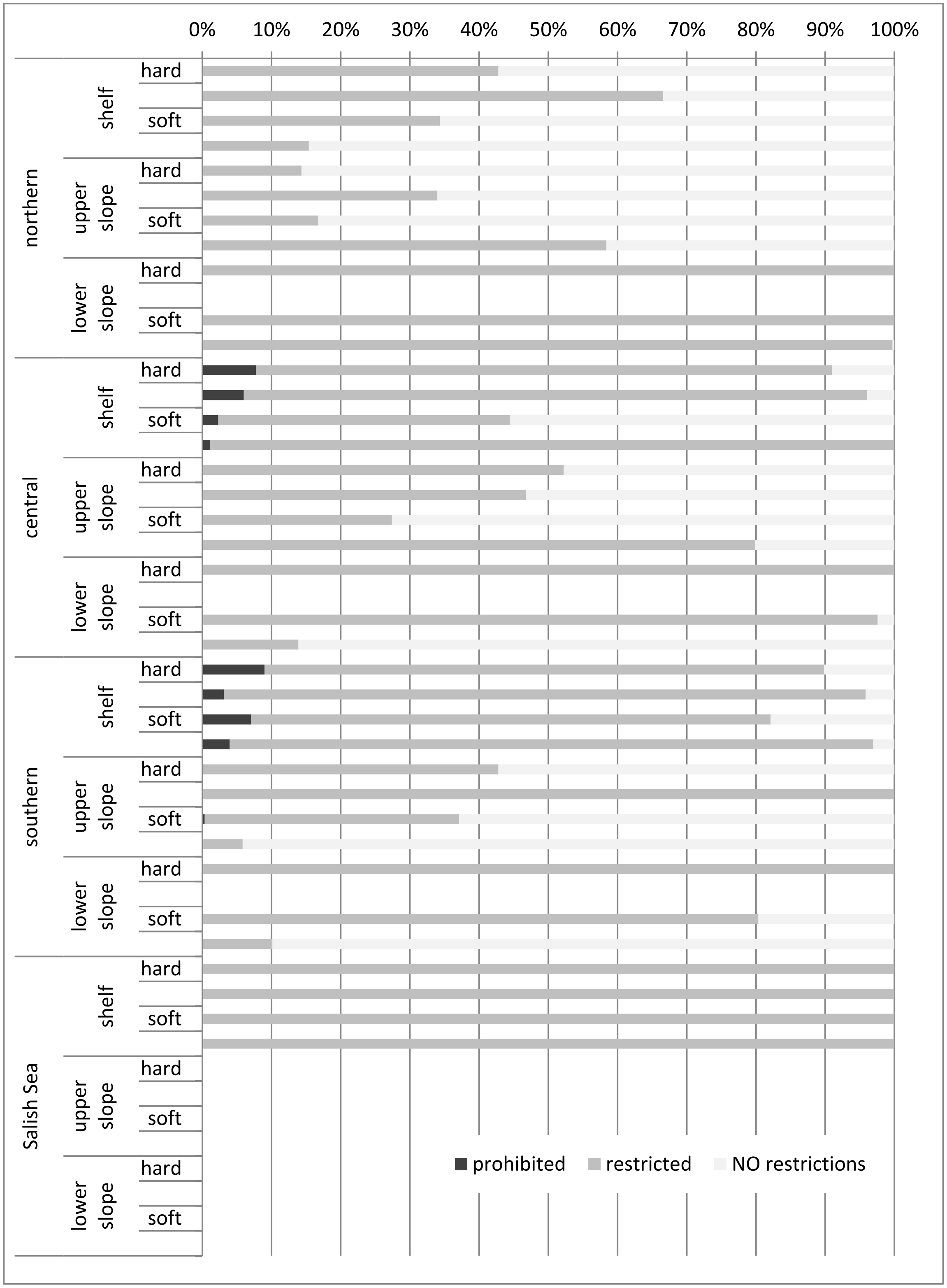


Figure A1.3.9. Percentages of seabed habitat areas by depth zone and biogeographic sub-regions where commercial fishing is "prohibited" (to all gear types), "restricted" (to certain gear types) and allowed ("NO restrictions"). The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

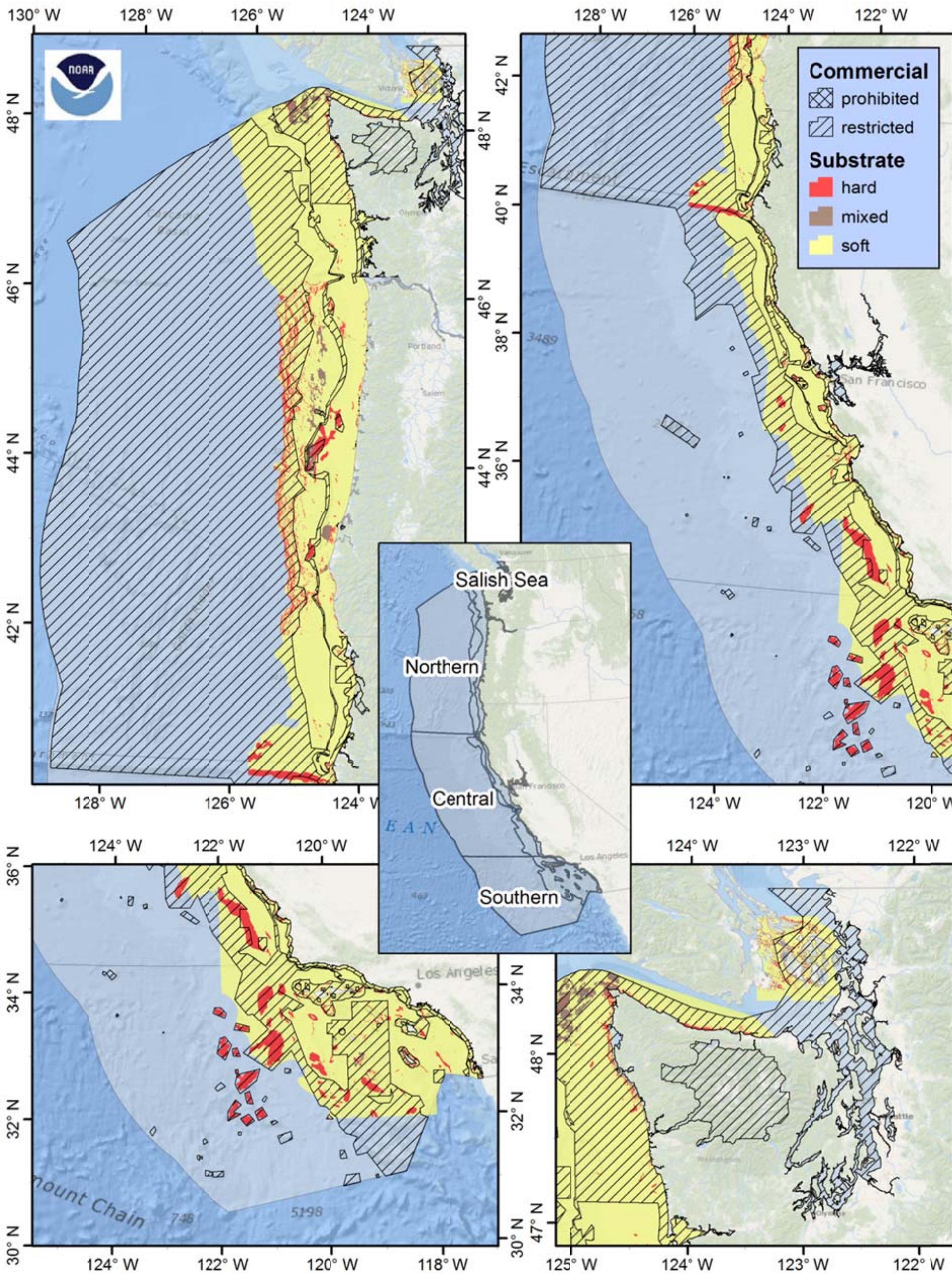


Figure A1.3.10. Map showing the composite area where commercial fishing is either "restricted" or completely "prohibited" overlain on three major seabed habitat types: hard, mixed and soft.

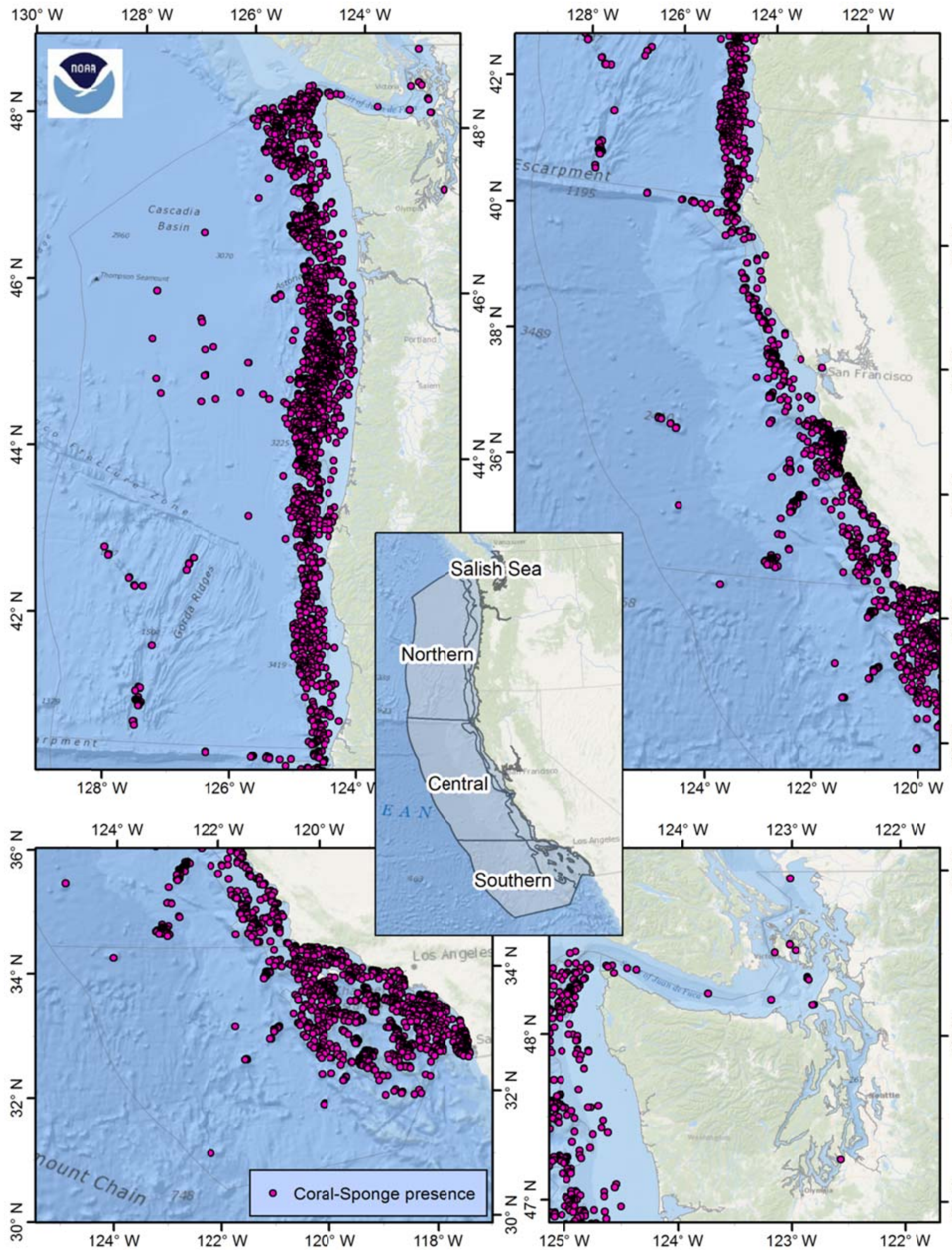


Figure A1.3.11a. Map showing the spatial distribution of coral (excluding pennatulids) and sponge presence, summarized by 1x1 km cells.

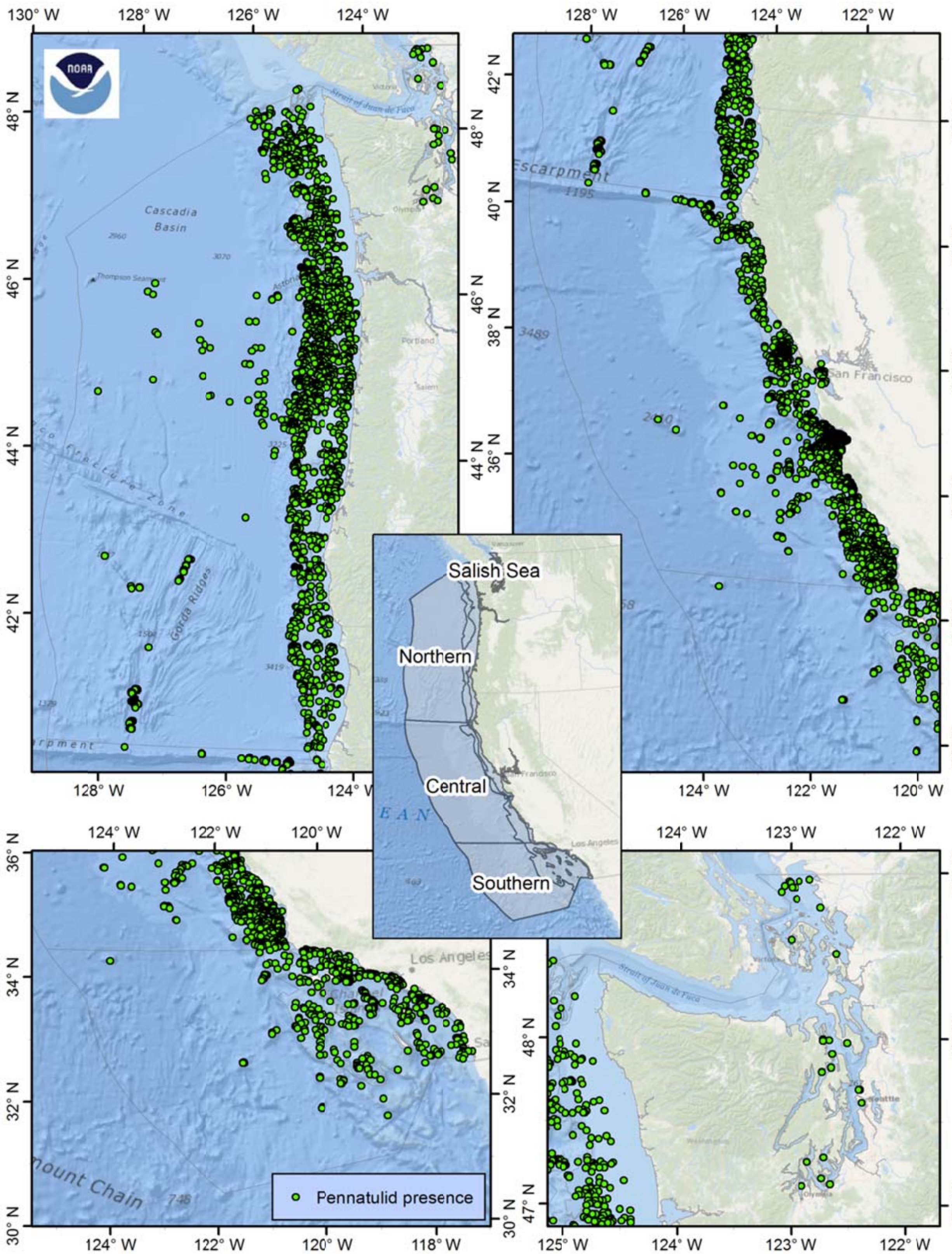
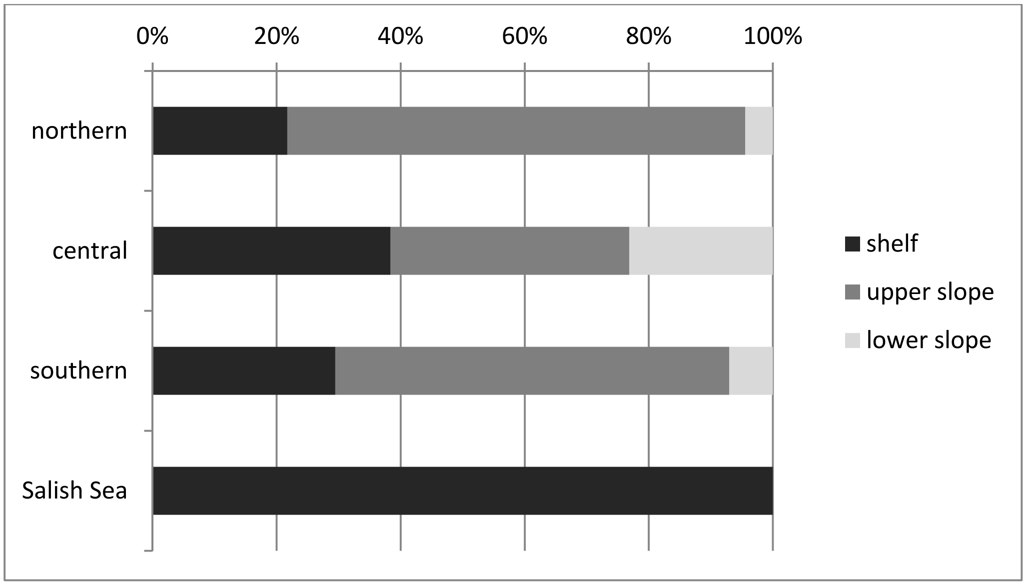


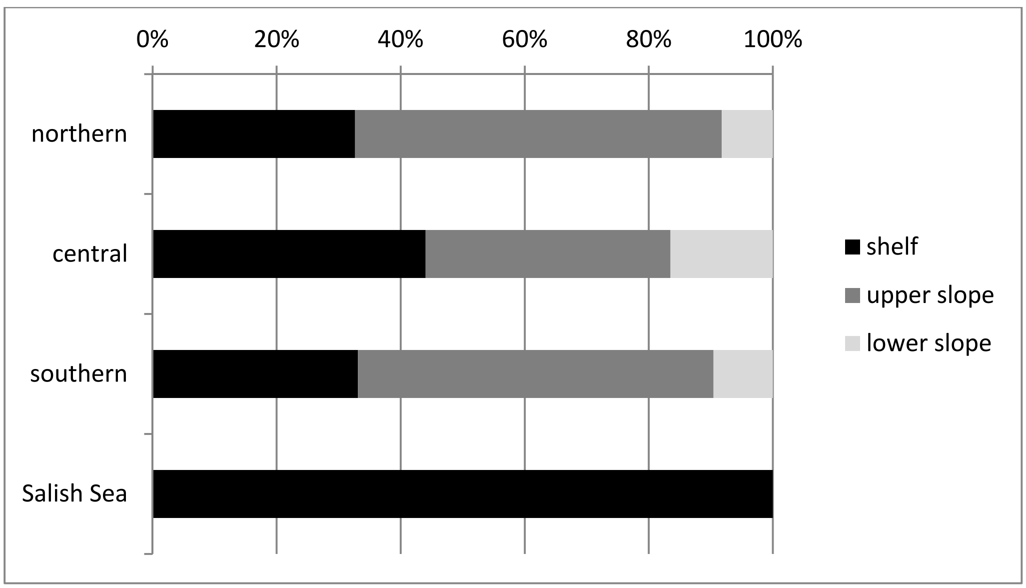
Figure A1.3.11b. Map showing the spatial distribution of pennatulid presence, summarized by 1x1 km cells.

Table A1.3.5. Distribution of presence of two groups of biogenic taxa [coral (excluding pennatulids) and sponge (top); pennatulid (bottom)]by depth zones both coast-wide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Percentage values represent relative contribution to the sub-region. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

	BIOGEOGRAPHIC SUB-REGION								COAST-WIDE	
	Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Shelf[1]	426	21.7%	395	38.4%	323	29.4%	16	100.0%	1,160	28.3%
Upper Slope[2]	1,448	73.8%	396	38.5%	697	63.5%	0	0.0%	2,541	61.9%
Lower Slope[3]	87	4.4%	238	23.1%	77	7.0%	0	0.0%	402	9.8%
Total	**1,961**	**47.8%**	**1,029**	**25.1%**	**1,097**	**26.7%**	**16**	**0.4%**	**4,103**	**100.0%**
	Coral (excluding pennatulids) and Sponge Presence [above] | Pennatulid Presence [below]									
Shelf[1]	586	32.7%	736	44.0%	149	33.1%	27	100.0%	1,498	38.0%
Upper Slope[2]	1,060	59.1%	660	39.5%	258	57.3%	0	0.0%	1,978	50.2%
Lower Slope[3]	148	8.2%	276	16.5%	43	9.6%	0	0.0%	467	11.8%
Total	**1,794**	**45.5%**	**1,672**	**42.4%**	**450**	**11.4%**	**27**	**0.7%**	**3,943**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).[3]





1.3.12a and b. Relative distribution of [a] coral (excluding pennatulids) and sponge presence [top], and [b] pennatulid presence [bottom] by depth zones in four biogeographic sub-regions. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

Table A1.3.6a. Distribution of coral (excluding pennatulids) and sponge presence within areas of various fishing gear restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

CORAL (EXCLUDING PENNATULIDS) AND SPONGE PRESENCE											
		Bottom Contact Prohibited		Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)		Bottom Trawl Prohibited		Bottom Trawl Prohibited (except demersal seine)		Outside EFH Cons. Areas	
SUB-REGION	***Depth Zone***	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**8**	**9.1%**	**0**	**0.0%**	**311**	**53.9%**	**2**	**0.4%**	**1,649**	**54.4%**
	shelf[1]	0	0.0%	0	0.0%	55	9.5%	0	0.0%	371	12.2%
	upper slope[2]	0	0.0%	0	0.0%	169	29.3%	1	0.2%	1,278	42.2%
	lower slope[3]	8	9.1%	0	0.0%	87	15.1%	1	0.2%	0	0.0%
Central	**Total**	**31**	**35.2%**	**73**	**100.0%**	**195**	**33.8%**	**360**	**70.9%**	**506**	**16.7%**
	shelf[1]	31	35.2%	0	0.0%	0	0.0%	187	36.8%	177	5.8%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	110	21.7%	286	9.4%
	lower slope[3]	0	0.0%	73	100.0%	195	33.8%	63	12.4%	43	1.4%
Southern	**Total**	**49**	**55.7%**	**0**	**0.0%**	**71**	**12.3%**	**146**	**28.7%**	**858**	**28.3%**
	shelf[1]	12	13.6%	0	0.0%	0	0.0%	59	11.6%	252	8.3%
	upper slope[2]	37	42.0%	0	0.0%	0	0.0%	60	11.8%	600	19.8%
	lower slope[3]	0	0.0%	0	0.0%	71	12.3%	27	5.3%	6	0.2%
Salish Sea	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**16**	**0.5%**
	shelf[1]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	16	0.5%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**88**	**100.0%**	**73**	**100.0%**	**577**	**100.0%**	**508**	**100.0%**	**3,029**	**100.0%**
Coastwide		**88**	**2.1%**	**73**	**1.7%**	**577**	**13.5%**	**508**	**11.9%**	**3,029**	**70.9%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.6b. Distribution of pennatulid presence within areas of various fishing gear restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

PENNATULID PRESENCE											
		Bottom Contact Prohibited		Bottom Contact Prohibited (or other gear deployed deeper than 500 ftm)		Bottom Trawl Prohibited		Bottom Trawl Prohibited (except demersal seine)		Outside EFH Cons. Areas	
SUB-REGION	***Depth Zone***	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**3**	**8.3%**	**0**	**0.0%**	**240**	**46.4%**	**2**	**0.4%**	**1,553**	**52.0%**
	shelf[1]	0	0.0%	0	0.0%	6	1.2%	1	0.2%	579	19.4%
	upper slope[2]	0	0.0%	0	0.0%	86	16.6%	0	0.0%	974	32.6%
	lower slope[3]	3	8.3%	0	0.0%	148	28.6%	1	0.2%	0	0.0%
Central	**Total**	**5**	**13.9%**	**24**	**100.0%**	**239**	**46.2%**	**483**	**88.8%**	**1,067**	**35.7%**
	shelf[1]	5	13.9%	0	0.0%	0	0.0%	196	36.0%	535	17.9%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	165	30.3%	495	16.6%
	lower slope[3]	0	0.0%	24	100.0%	239	46.2%	122	22.4%	37	1.2%
Southern	**Total**	**28**	**77.8%**	**0**	**0.0%**	**38**	**7.4%**	**59**	**10.8%**	**339**	**11.4%**
	shelf[1]	4	11.1%	0	0.0%	0	0.0%	28	5.1%	117	3.9%
	upper slope[2]	24	66.7%	0	0.0%	0	0.0%	17	3.1%	217	7.3%
	lower slope[3]	0	0.0%	0	0.0%	38	7.4%	14	2.6%	5	0.2%
Salish Sea	**Total**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**27**	**0.9%**
	shelf[1]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	27	0.9%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**36**	**100.0%**	**24**	**100.0%**	**517**	**100.0%**	**544**	**100.0%**	**2,986**	**100.0%**
Coastwide		**36**	**0.9%**	**24**	**0.6%**	**517**	**12.6%**	**544**	**13.2%**	**2,986**	**72.7%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

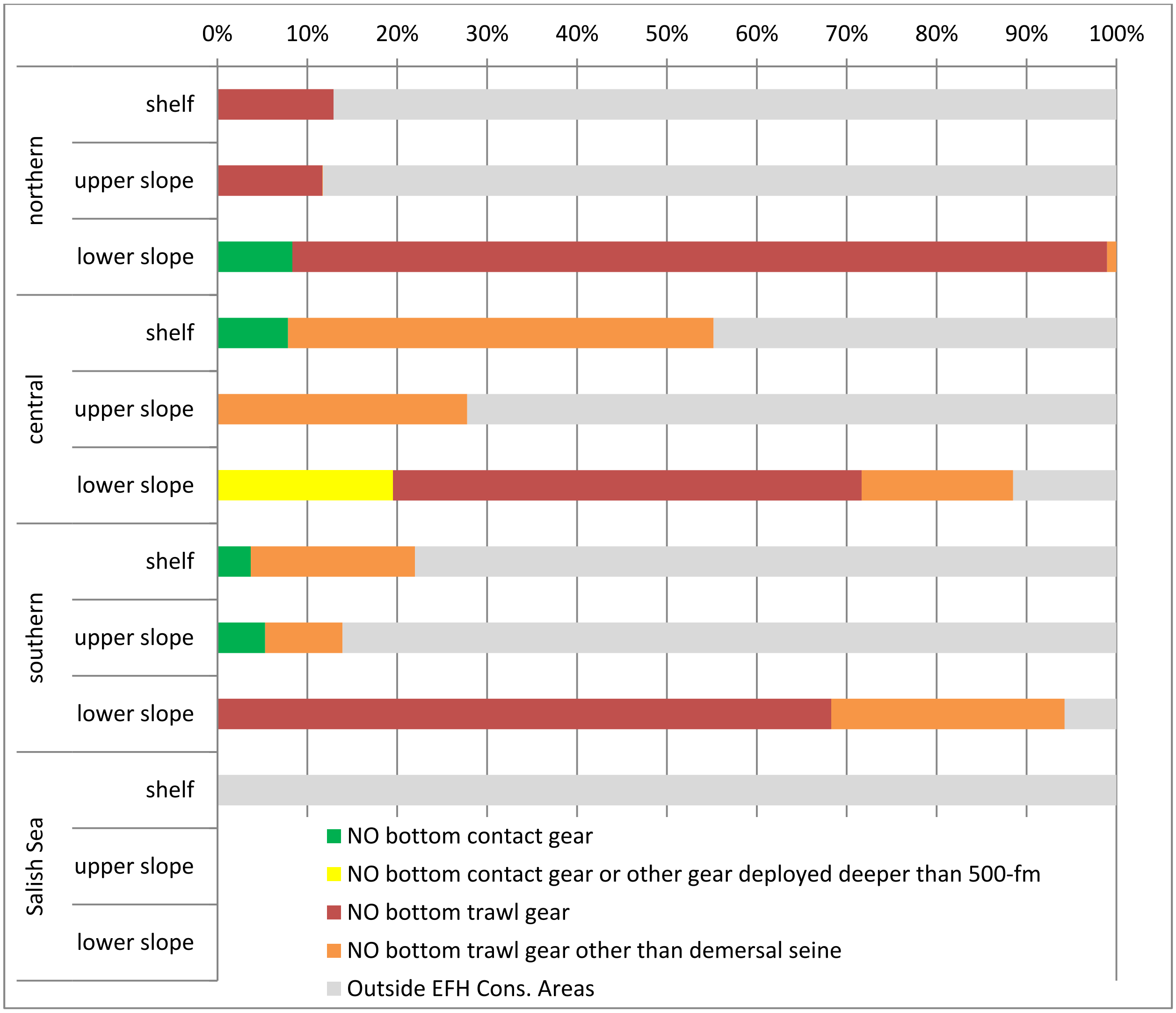


Figure A1.3.13a. Percentages of coral (excluding pennatulids) and sponge presence by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the "Salish Sea".

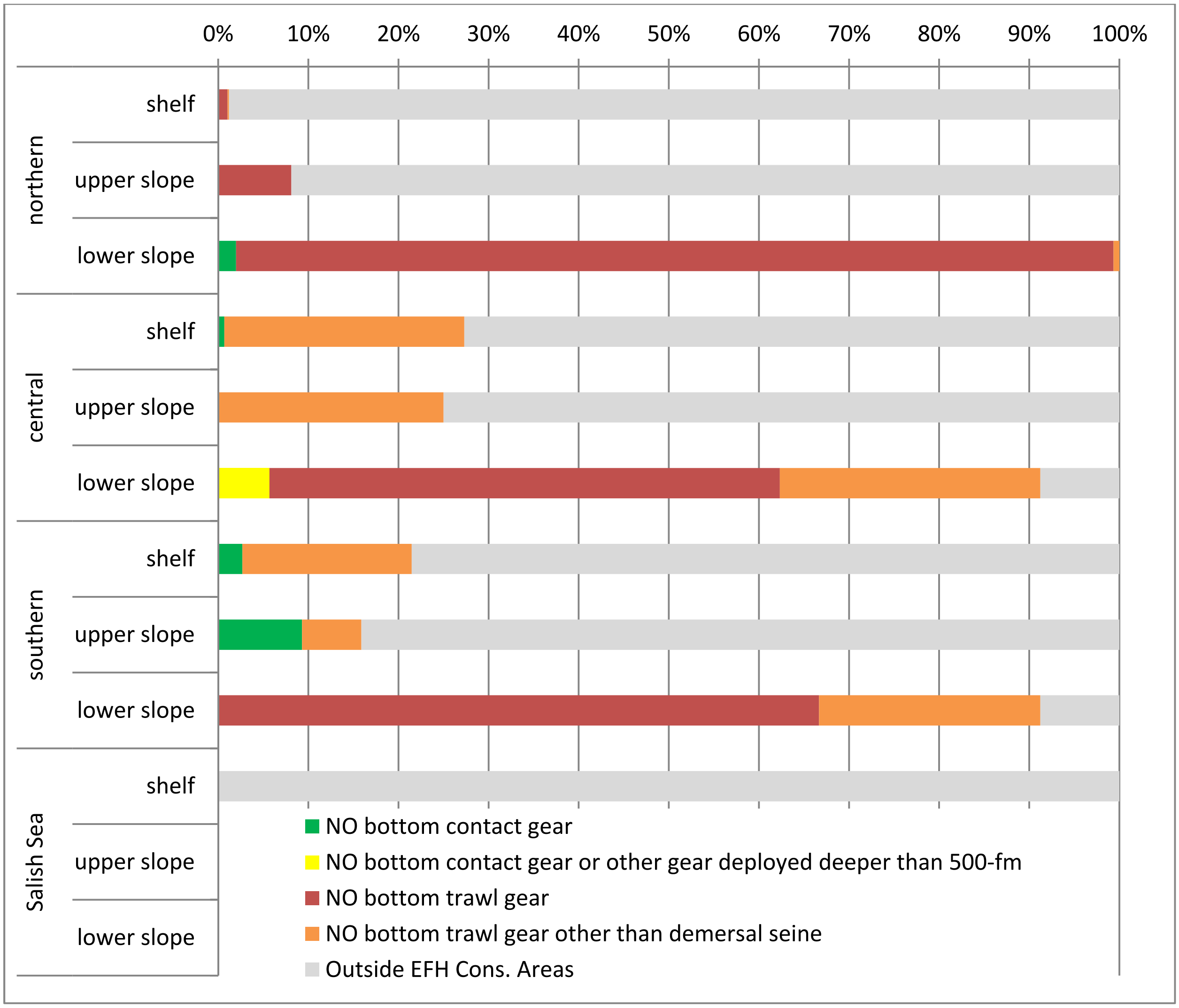


Figure A1.3.13b. Percentages of pennatulid presence by depth zone and biogeographic sub-regions where EFH-specific gear prohibitions apply. No EFH Conservation Areas are located in the "Salish Sea".

Table A1.3.7a. Distribution of coral (excluding pennatulids) and sponge presence within areas of various fishing gear restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

CORAL (EXCLUDING PENNATULIDS) AND SPONGE PRESENCE									
		Bottom Trawl Prohibited		**Midwater Trawl Prohibited**		**Fixed Gear Prohibited**		**NO Gear Prohibitions**	
SUB-REGION	***Depth Zone***	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**440**	**28.4%**	**0**	**0.0%**	**8**	**4.1%**	**1,521**	**59.6%**
	shelf[1]	104	6.7%	0	0.0%	0	0.0%	322	12.6%
	upper slope[2]	249	16.1%	0	0.0%	0	0.0%	1,199	47.0%
	lower slope[3]	87	5.6%	0	0.0%	8	4.1%	0	0.0%
Central	**Total**	**643**	**41.5%**	**25**	**48.1%**	**129**	**65.5%**	**386**	**15.1%**
	shelf[1]	292	18.8%	22	42.3%	53	26.9%	103	4.0%
	upper slope[2]	156	10.1%	3	5.8%	3	1.5%	240	9.4%
	lower slope[3]	195	12.6%	0	0.0%	73	37.1%	43	1.7%
Southern	**Total**	**451**	**29.1%**	**27**	**51.9%**	**60**	**30.5%**	**646**	**25.3%**
	shelf[1]	226	14.6%	21	40.4%	21	10.7%	97	3.8%
	upper slope[2]	154	9.9%	6	11.5%	39	19.8%	543	21.3%
	lower slope[3]	71	4.6%	0	0.0%	0	0.0%	6	0.2%
Salish Sea	**Total**	**16**	**1.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	shelf[1]	16	1.0%	0	0.0%	0	0.0%	0	0.0%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**1,550**	**100.0%**	**52**	**100.0%**	**197**	**100.0%**	**2,553**	**100.0%**
Coastwide		**1,550**	**37.8%**	**52**	**1.3%**	**197**	**4.8%**	**2,553**	**62.2%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.7b. Distribution pennatulid presence within areas of various fishing gear restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

PENNATULID PRESENCE									
		Bottom Trawl Prohibited		Midwater Trawl Prohibited		Fixed Gear Prohibited		NO Gear Prohibitions	
SUB-REGION	*Depth Zone*	*Count*	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**305**	**22.0%**	**0**	**0.0%**	**3**	**3.8%**	**1,489**	**58.2%**
	shelf[1]	35	2.5%	0	0.0%	0	0.0%	551	21.5%
	upper slope[2]	122	8.8%	0	0.0%	0	0.0%	938	36.7%
	lower slope[3]	148	10.7%	0	0.0%	3	3.8%	0	0.0%
Central	**Total**	**847**	**61.2%**	**18**	**75.0%**	**47**	**58.8%**	**825**	**32.3%**
	shelf[1]	389	28.1%	13	54.2%	18	22.5%	347	13.6%
	upper slope[2]	219	15.8%	5	20.8%	5	6.3%	441	17.2%
	lower slope[3]	239	17.3%	0	0.0%	24	30.0%	37	1.4%
Southern	**Total**	**206**	**14.9%**	**6**	**25.0%**	**30**	**37.5%**	**244**	**9.5%**
	shelf[1]	100	7.2%	3	12.5%	4	5.0%	49	1.9%
	upper slope[2]	68	4.9%	3	12.5%	26	32.5%	190	7.4%
	lower slope[3]	38	2.7%	0	0.0%	0	0.0%	5	0.2%
Salish Sea	**Total**	**27**	**1.9%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
	shelf[1]	27	1.9%	0	0.0%	0	0.0%	0	0.0%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Column Total		**1,385**	**100.0%**	**24**	**100.0%**	**80**	**100.0%**	**2,558**	**100.0%**
Coastwide		**1,385**	**35.1%**	**24**	**0.6%**	**80**	**2.0%**	**2,558**	**64.9%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

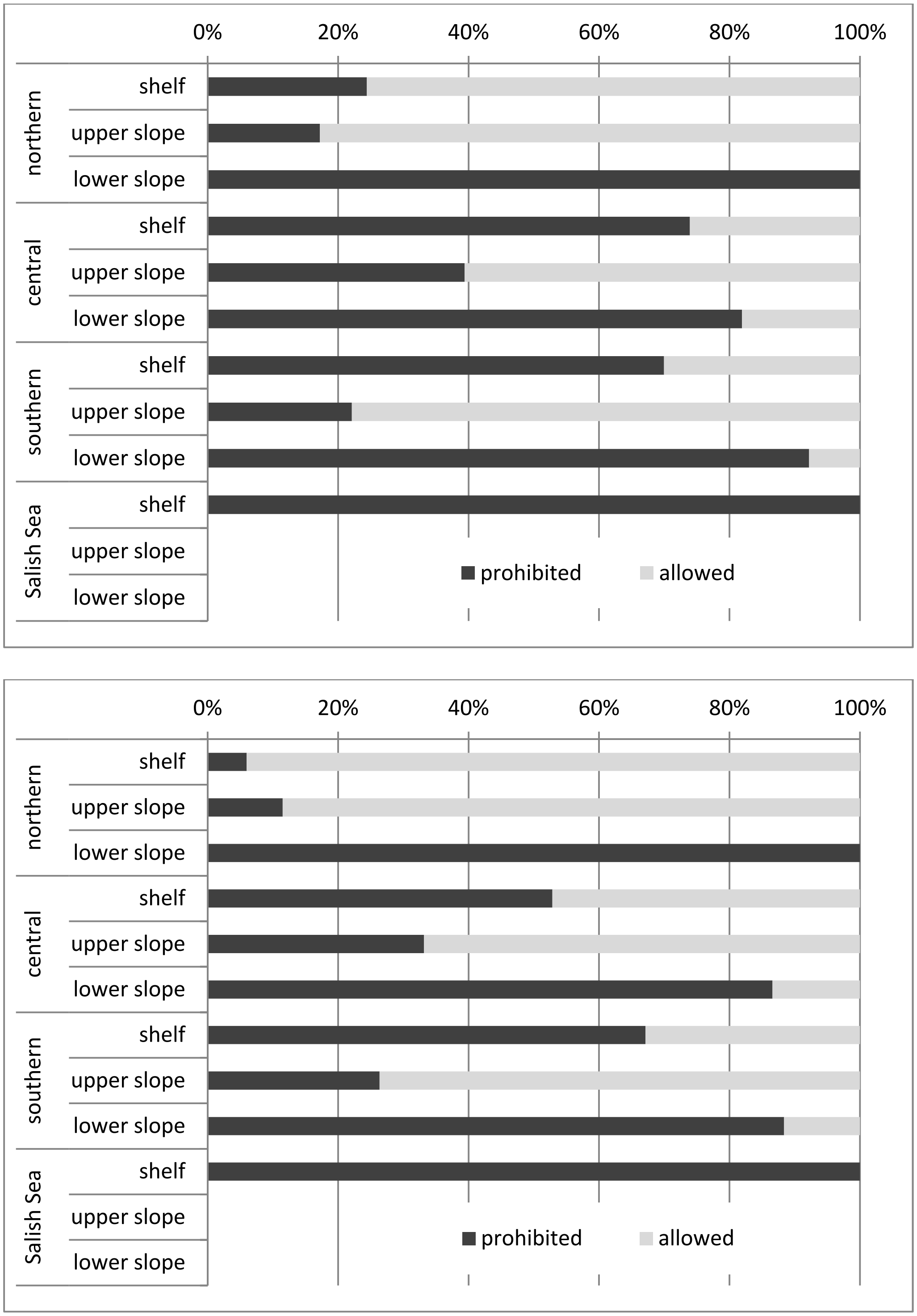
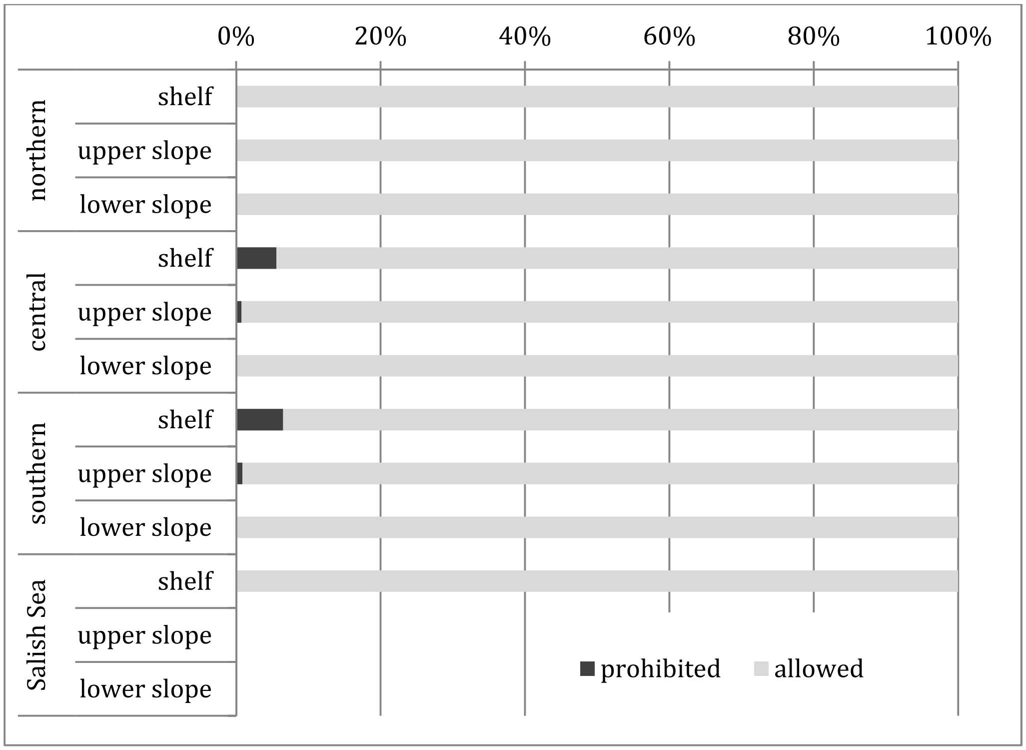


Figure A1.3.14a and b. Percentages of [a] coral (excluding pennatulids) and sponge presence [top], and [b] pennatulid presence [bottom] by depth zone and biogeographic sub-regions where bottom trawling is "prohibited" and "allowed". Presence was summarized within 1x1 km grid cells. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.



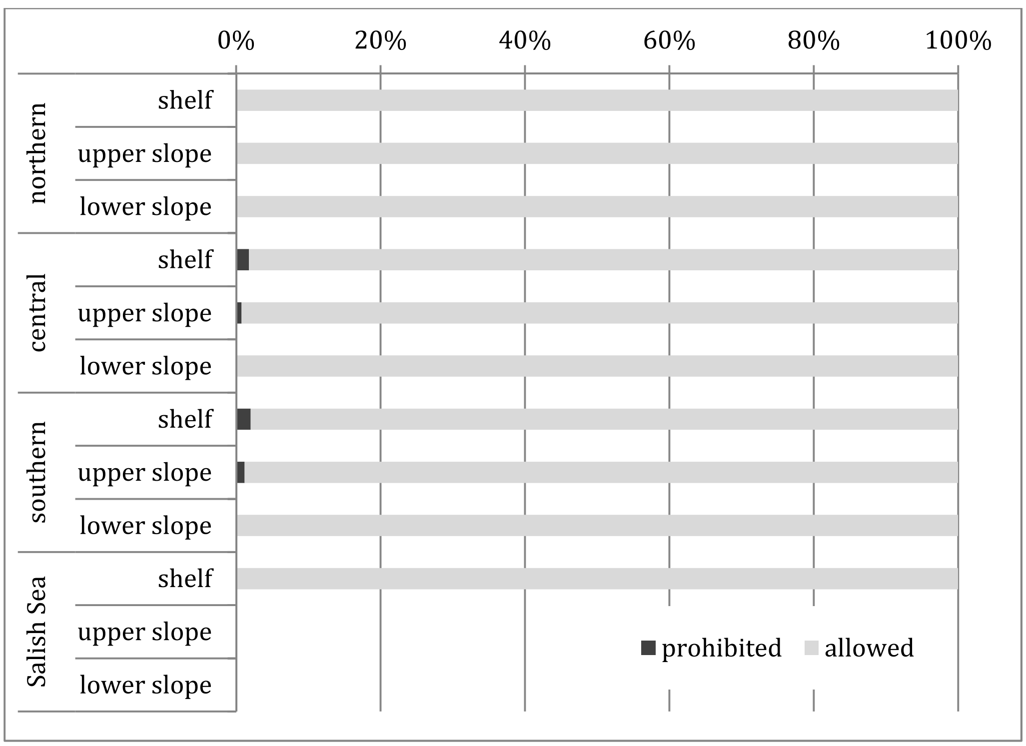
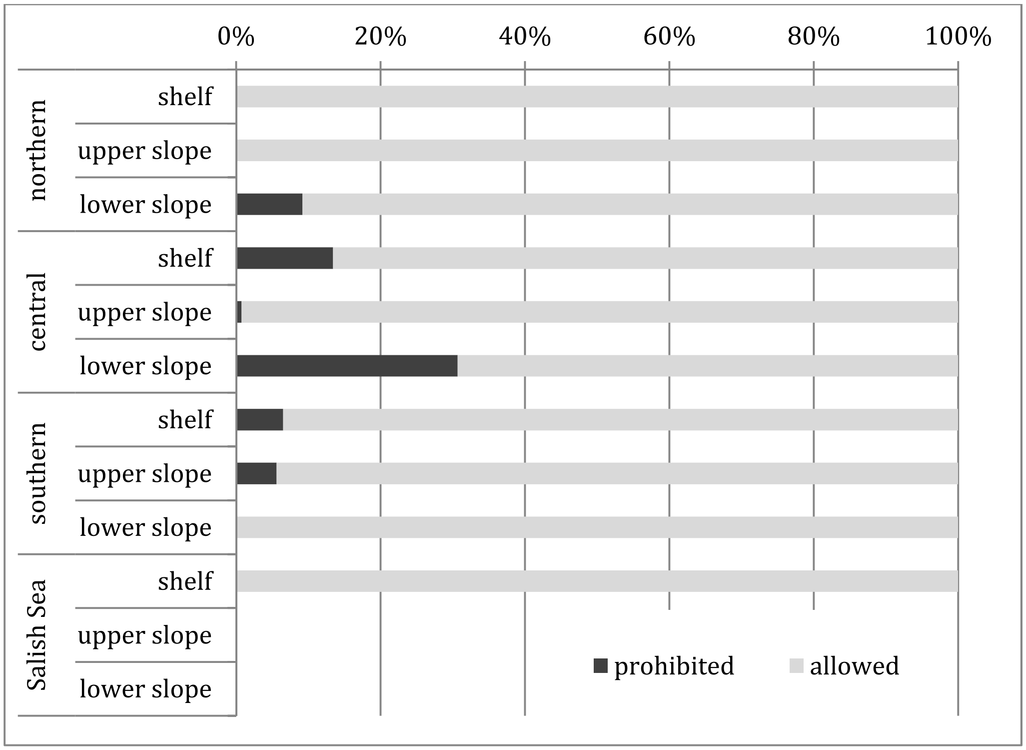


Figure A1.3.15a and b. Percentages of [a] coral (excluding pennatulids) and sponge presence [top], and [b] pennatulid presence [bottom] by depth zone and biogeographic sub-regions where midwater trawling and fixed gears are "prohibited" and "allowed". Presence was summarized within 1x1 km grid cells. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.



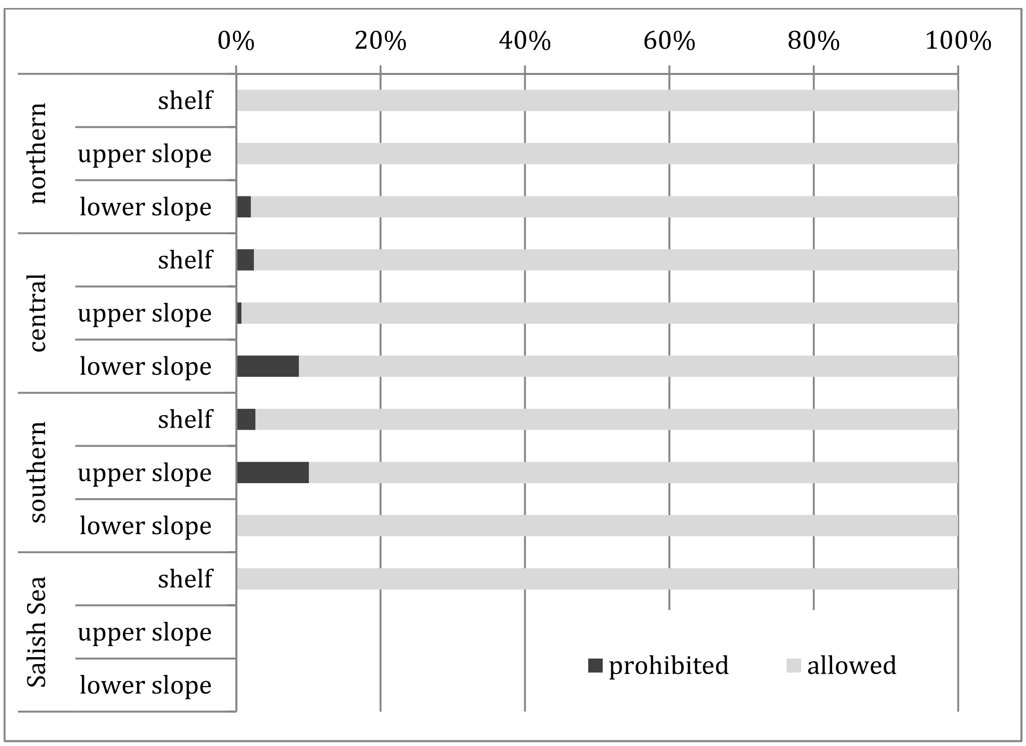


Figure A1.3.15c and d. Percentages of [c] coral (excluding pennatulids) and sponge presence [top], and [d] pennatulid presence [bottom] by depth zone and biogeographic sub-regions where fixed gears are "prohibited" and "allowed". Presence was summarized within 1x1 km grid cells. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone.

Table A1.3.8a. Distribution of coral (excluding pennatulids) and sponge presence within areas of various fishing restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

CORAL (EXCLUDING PENNATULIDS) AND SPONGE PRESENCE							
		Commercial Prohibited		Commercial Restricted		NO Commercial Restrictions	
SUB-REGION	***Depth Zone***	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**0**	**0.0%**	**549**	**30.4%**	**1,412**	**61.4%**
	shelf[1]	0	0.0%	194	10.7%	232	10.1%
	upper slope[2]	0	0.0%	268	14.8%	1,180	51.3%
	lower slope[3]	0	0.0%	87	4.8%	0	0.0%
Central	**Total**	**25**	**48.1%**	**643**	**35.6%**	**386**	**16.8%**
	shelf[1]	22	42.3%	292	16.2%	103	4.5%
	upper slope[2]	3	5.8%	156	8.6%	240	10.4%
	lower slope[3]	0	0.0%	195	10.8%	43	1.9%
Southern	**Total**	**27**	**51.9%**	**597**	**33.1%**	**500**	**21.8%**
	shelf[1]	21	40.4%	270	15.0%	53	2.3%
	upper slope[2]	6	11.5%	256	14.2%	441	19.2%
	lower slope[3]	0	0.0%	71	3.9%	6	0.3%
Salish Sea	**Total**	**0**	**0.0%**	**16**	**0.9%**	**0**	**0.0%**
	shelf[1]	0	0.0%	16	0.9%	0	0.0%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%
Column Total		**52**	**100.0%**	**1,805**	**100.0%**	**2,298**	**100.0%**
Coastwide		**52**	**1.3%**	**1,805**	**43.4%**	**2,298**	**55.3%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

Table A1.3.8b. Distribution pennatulid presence within areas of various fishing restrictions, summarized by depth zones in four biogeographic sub-regions: northern, central, southern and Salish Sea. Percentage values represent relative contribution to the category of fishing restriction. Last row shows relative contribution to the entire FMP area. Counts represent the number of 1x1 km grid cells where coral and/or sponge were present.

		PENNATULID PRESENCE					
		Commercial Prohibited		**Commercial Restricted**		**NO Commercial Restrictions**	
SUB-REGION	***Depth Zone***	*Count*	*%*	*Count*	*%*	*Count*	*%*
Northern	**Total**	**0**	**0.0%**	**392**	**25.9%**	**1,402**	**57.6%**
	shelf[1]	0	0.0%	108	7.1%	478	19.7%
	upper slope[2]	0	0.0%	136	9.0%	924	38.0%
	lower slope[3]	0	0.0%	148	9.8%	0	0.0%
Central	**Total**	**18**	**75.0%**	**847**	**56.1%**	**825**	**33.9%**
	shelf[1]	13	54.2%	389	25.7%	347	14.3%
	upper slope[2]	5	20.8%	219	14.5%	441	18.1%
	lower slope[3]	0	0.0%	239	15.8%	37	1.5%
Southern	**Total**	**6**	**25.0%**	**245**	**16.2%**	**205**	**8.4%**
	shelf[1]	3	12.5%	104	6.9%	45	1.9%
	upper slope[2]	3	12.5%	103	6.8%	155	6.4%
	lower slope[3]	0	0.0%	38	2.5%	5	0.2%
Salish Sea	**Total**	**0**	**0.0%**	**27**	**1.8%**	**0**	**0.0%**
	shelf[1]	0	0.0%	27	1.8%	0	0.0%
	upper slope[2]	0	0.0%	0	0.0%	0	0.0%
	lower slope[3]	0	0.0%	0	0.0%	0	0.0%
Column Total		**24**	**100.0%**	**1,511**	**100.0%**	**2,432**	**100.0%**
Coastwide		**24**	**0.6%**	**1,511**	**38.1%**	**2,432**	**61.3%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

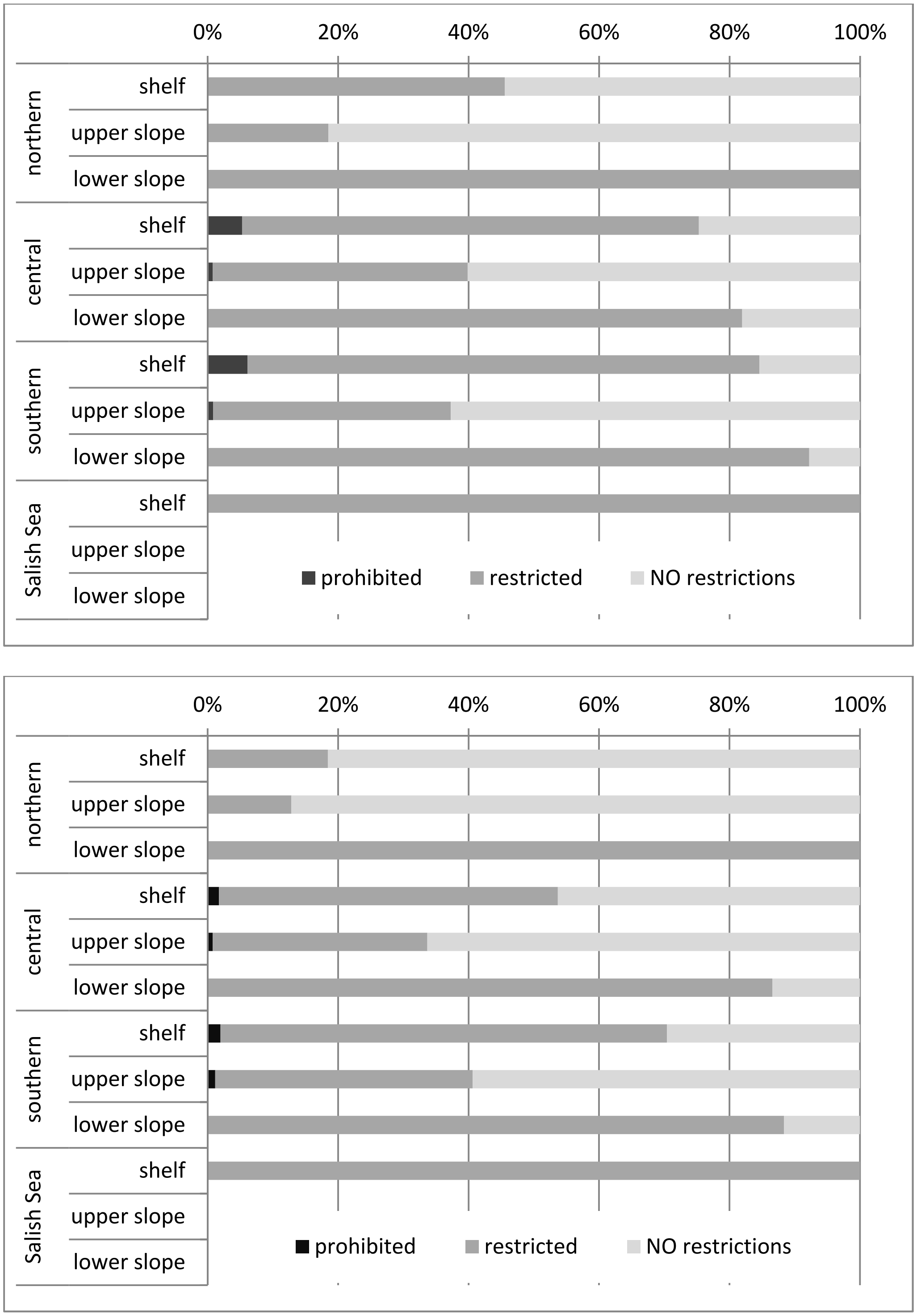
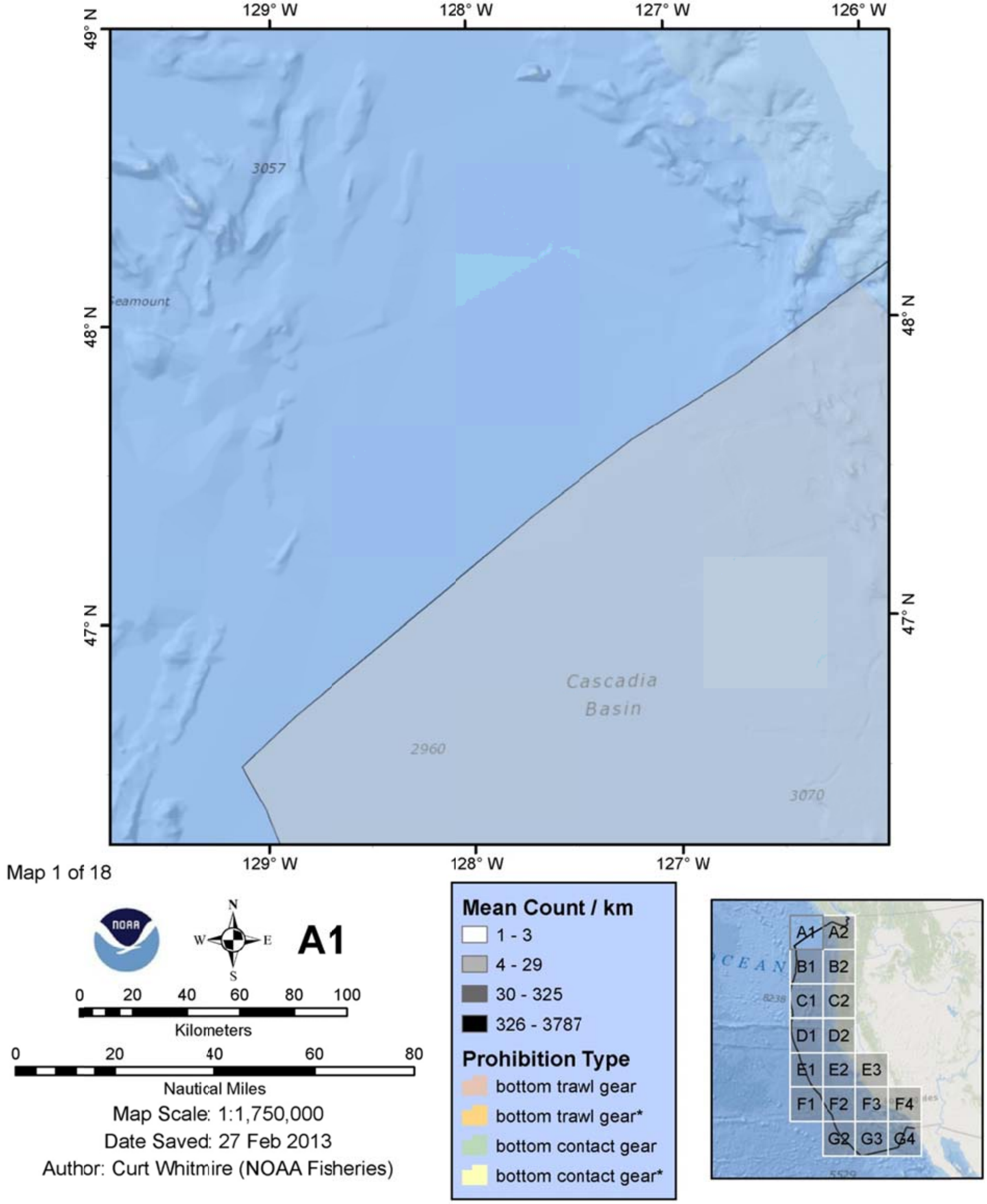


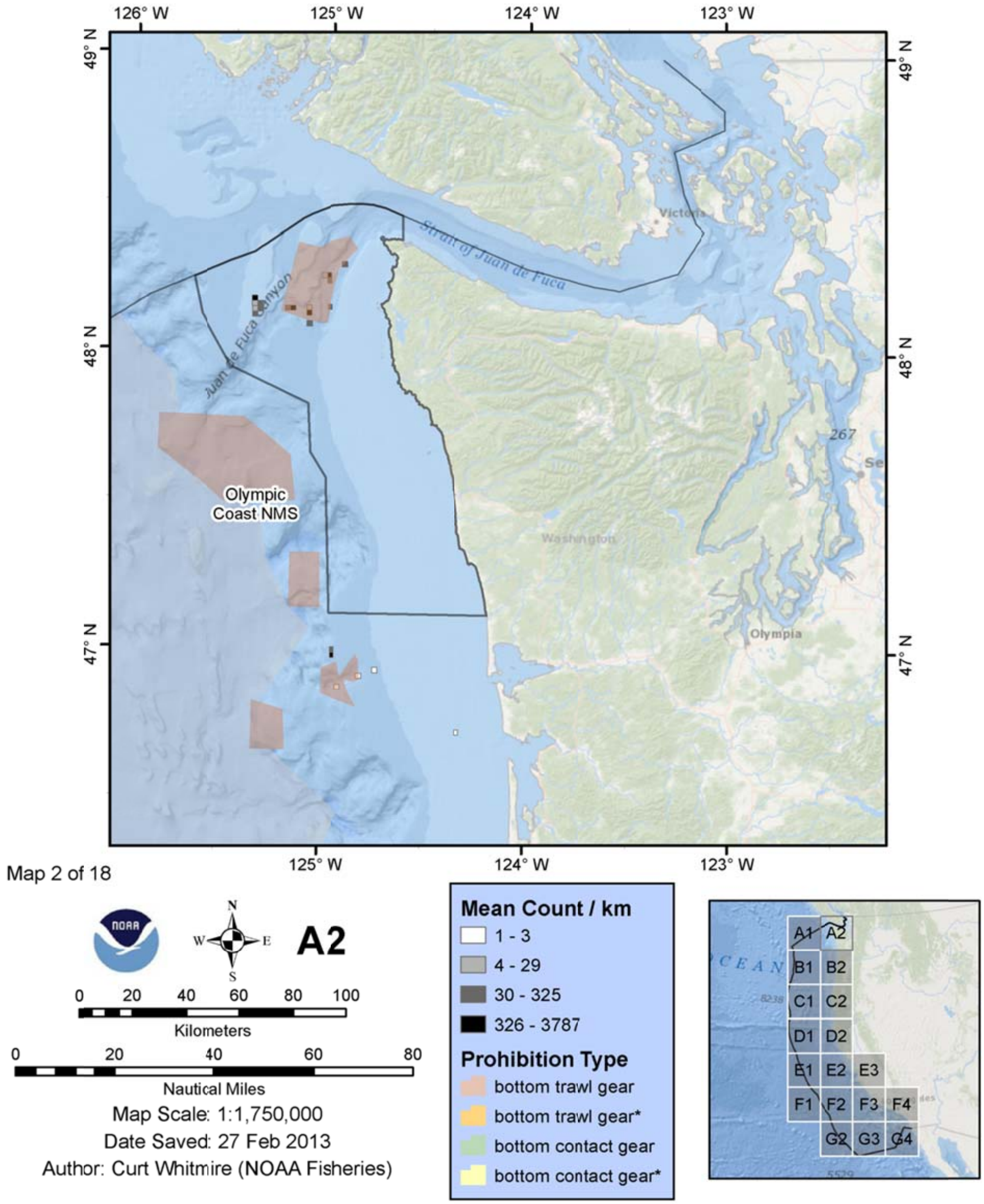
Figure A1.3.16a and b. Percentages of [a] coral (excluding pennatulids) and sponge presence [top], and [b] pennatulid presence [bottom] by depth zone and biogeographic sub-regions where commercial fishing is “prohibited” (to all gear types), “restricted” (to certain gear types) and allowed (“NO restrictions”). Presence was summarized within 1x1 km grid cells. The “Salish Sea” only encompasses the shallowest (“shelf”) depth zone.

Figure A1.3.17a, Maps A1-G4. Map views showing distribution of coral (excluding pennatulids) and sponge in situ observations, summarized as mean counts of observations by km of transect within 2x2 km grid cells. Mean counts per km are symbolized on a gradient of colors from lightest (lowest) to darkest (highest). EFH Conservation Areas are symbolized by gear prohibition, including bottom trawl (light brown), bottom trawl other than demersal seine (orange), bottom contact (green), and bottom contact and other gear deployed deeper than 500 m (yellow). The "Seaward of the 700-fm contour" conservation area is shown in transparent gray. Boundaries of each of the five west coast national marine sanctuaries (NMS) are also shown.

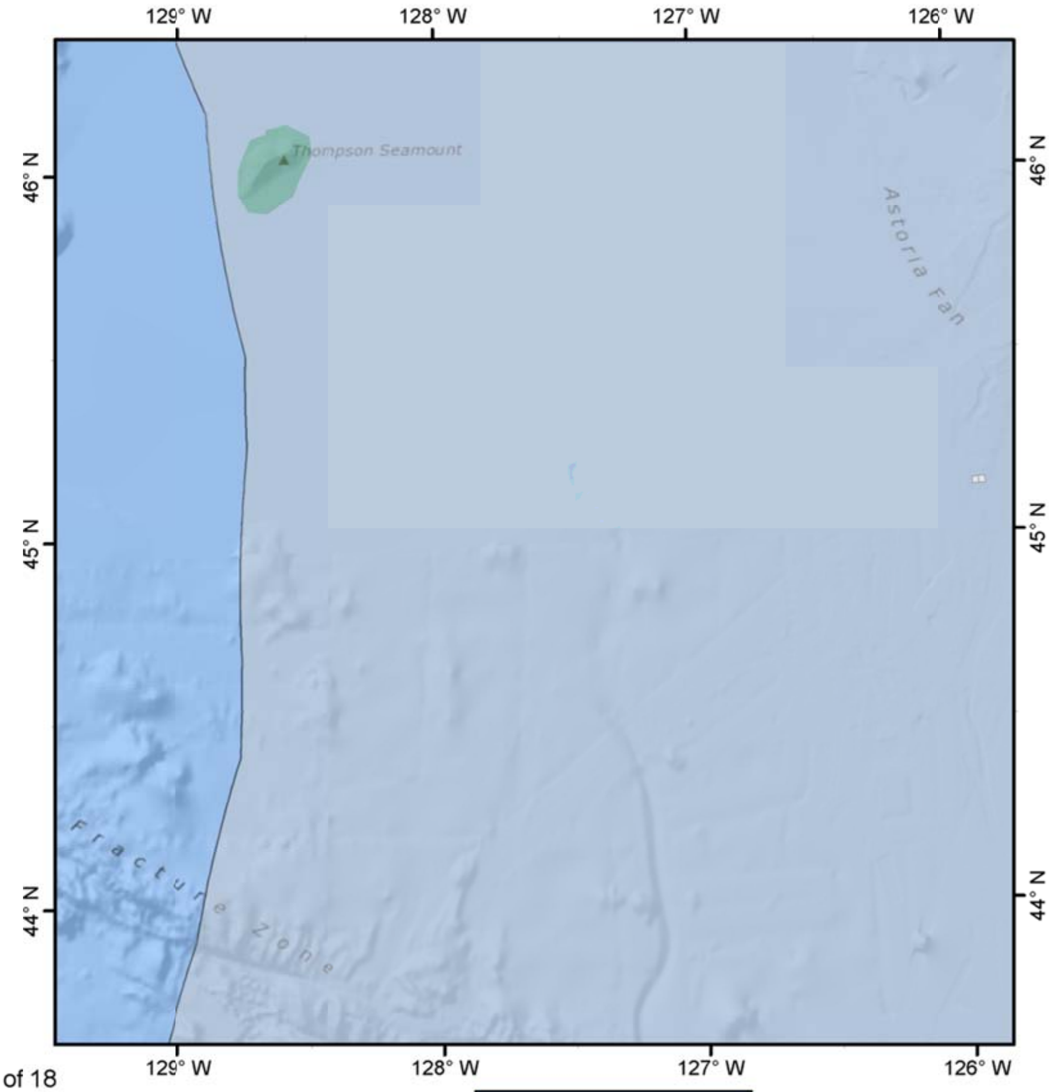
Coral (excluding Pennatulid) and Sponge Observations



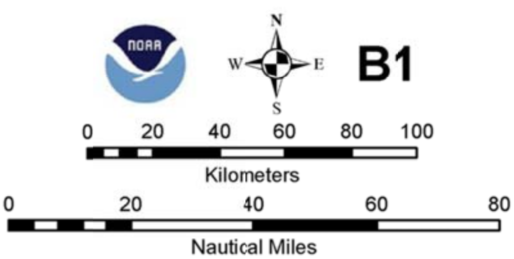
Coral (excluding Pennatulid) and Sponge Observations



Coral (excluding Pennatulid) and Sponge Observations



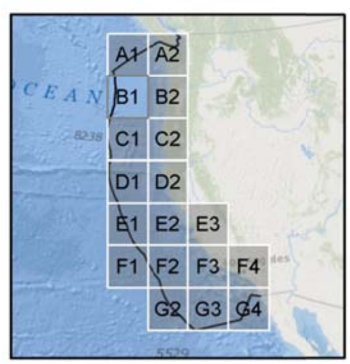
Map 3 of 18



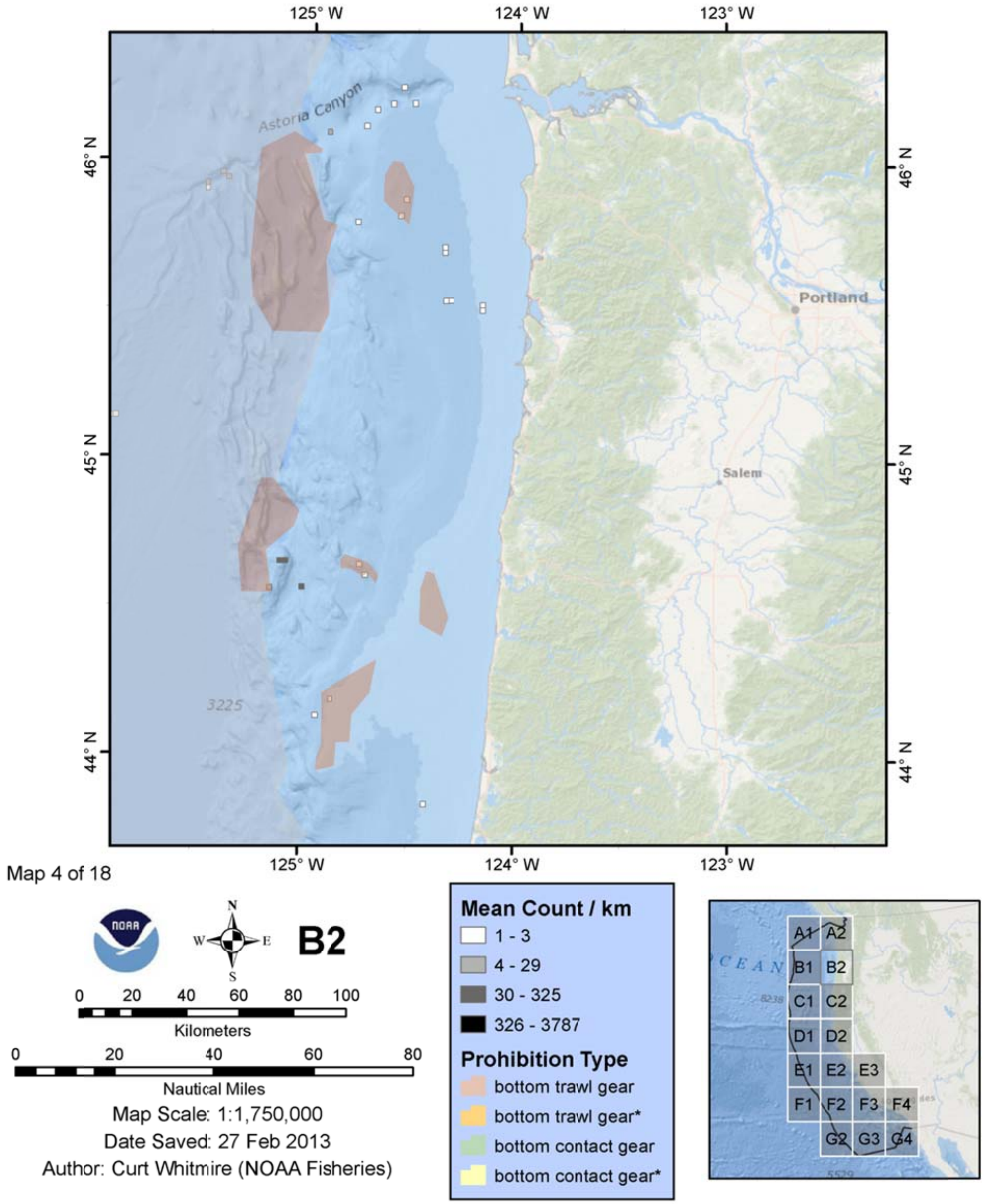
Map Scale: 1:1,750,000
Date Saved: 27 Feb 2013
Author: Curt Whitmire (NOAA Fisheries)

Mean Count / km
- 1 - 3
- 4 - 29
- 30 - 325
- 326 - 3787

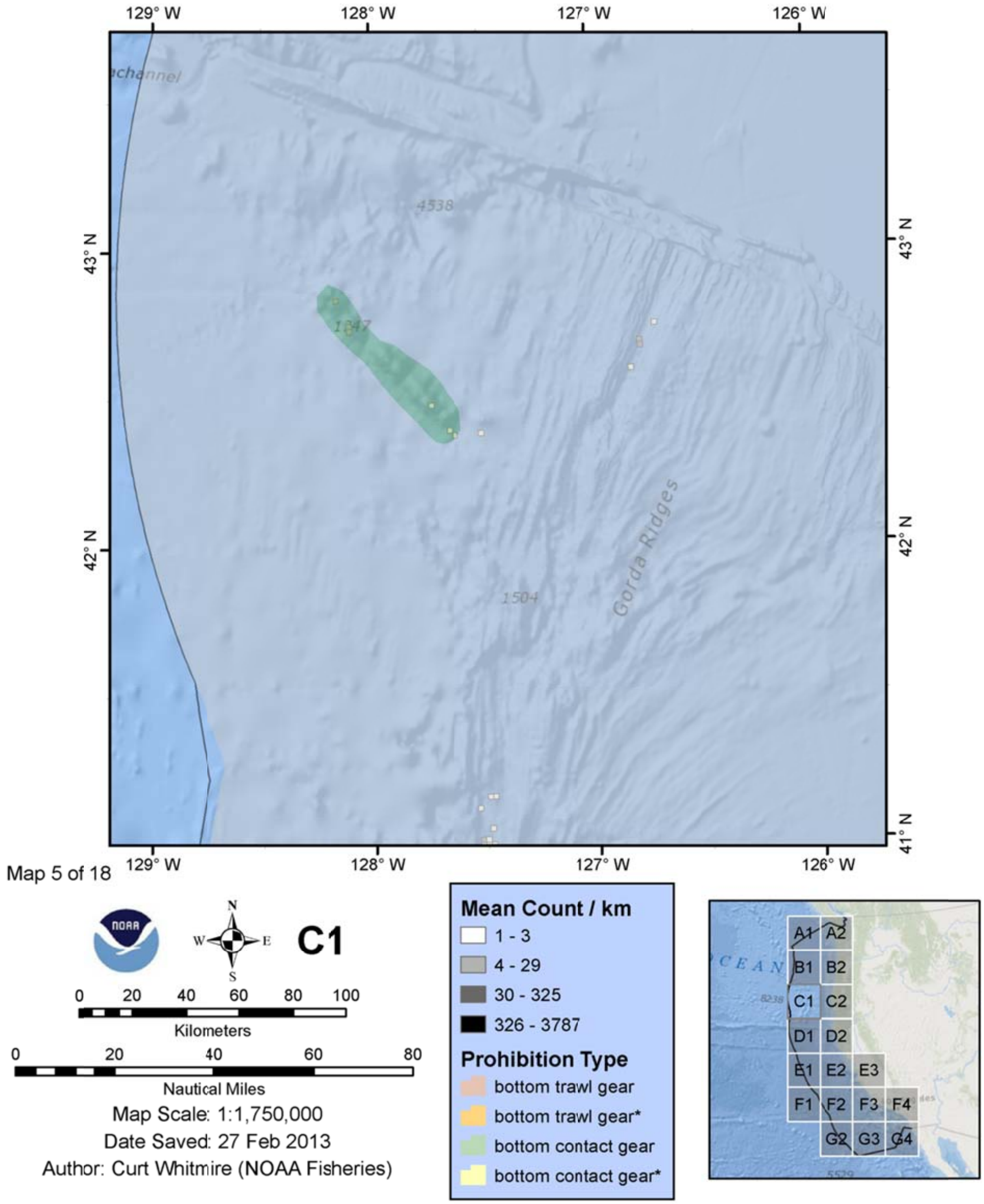
Prohibition Type
- bottom trawl gear
- bottom trawl gear*
- bottom contact gear
- bottom contact gear*

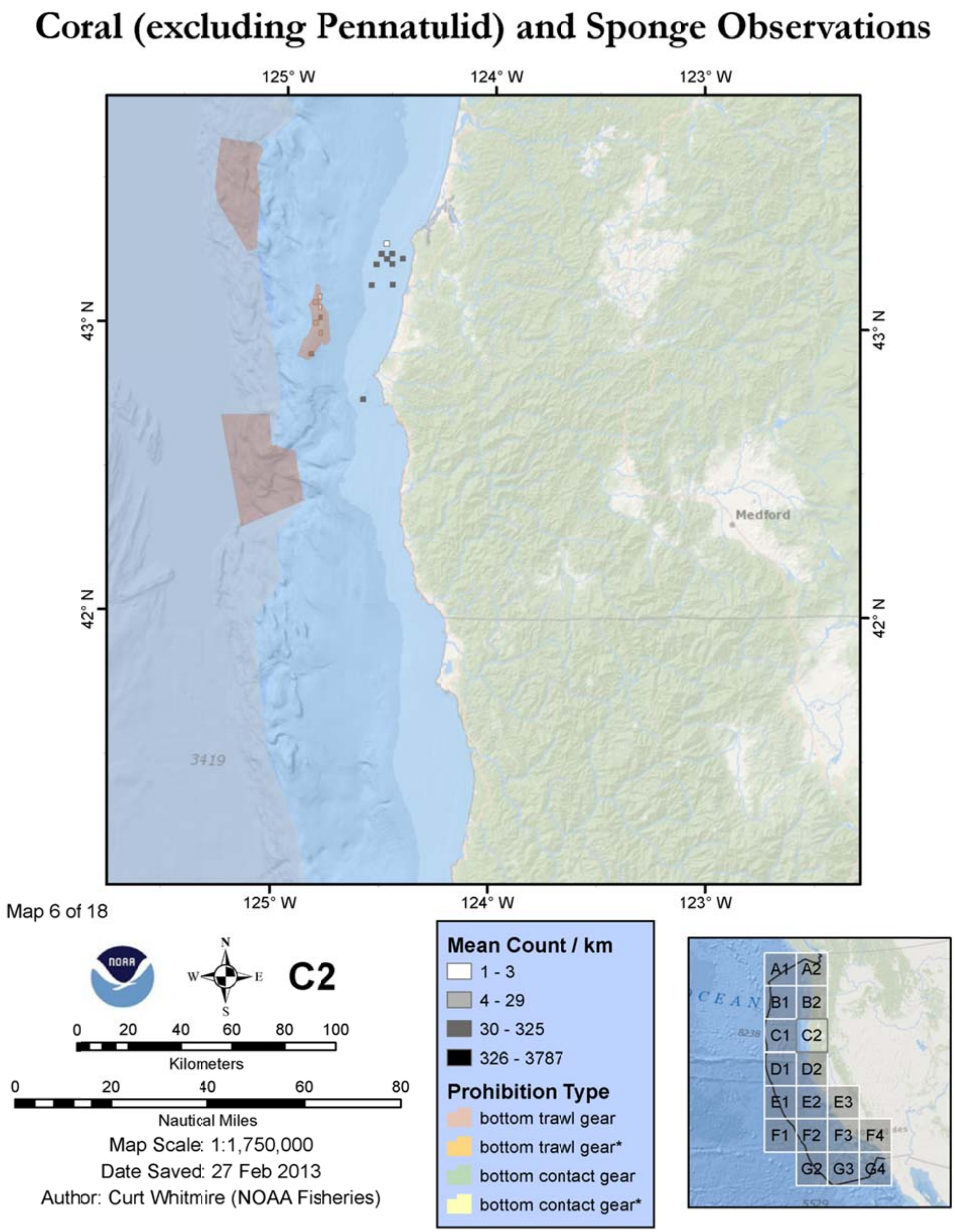


Coral (excluding Pennatulid) and Sponge Observations

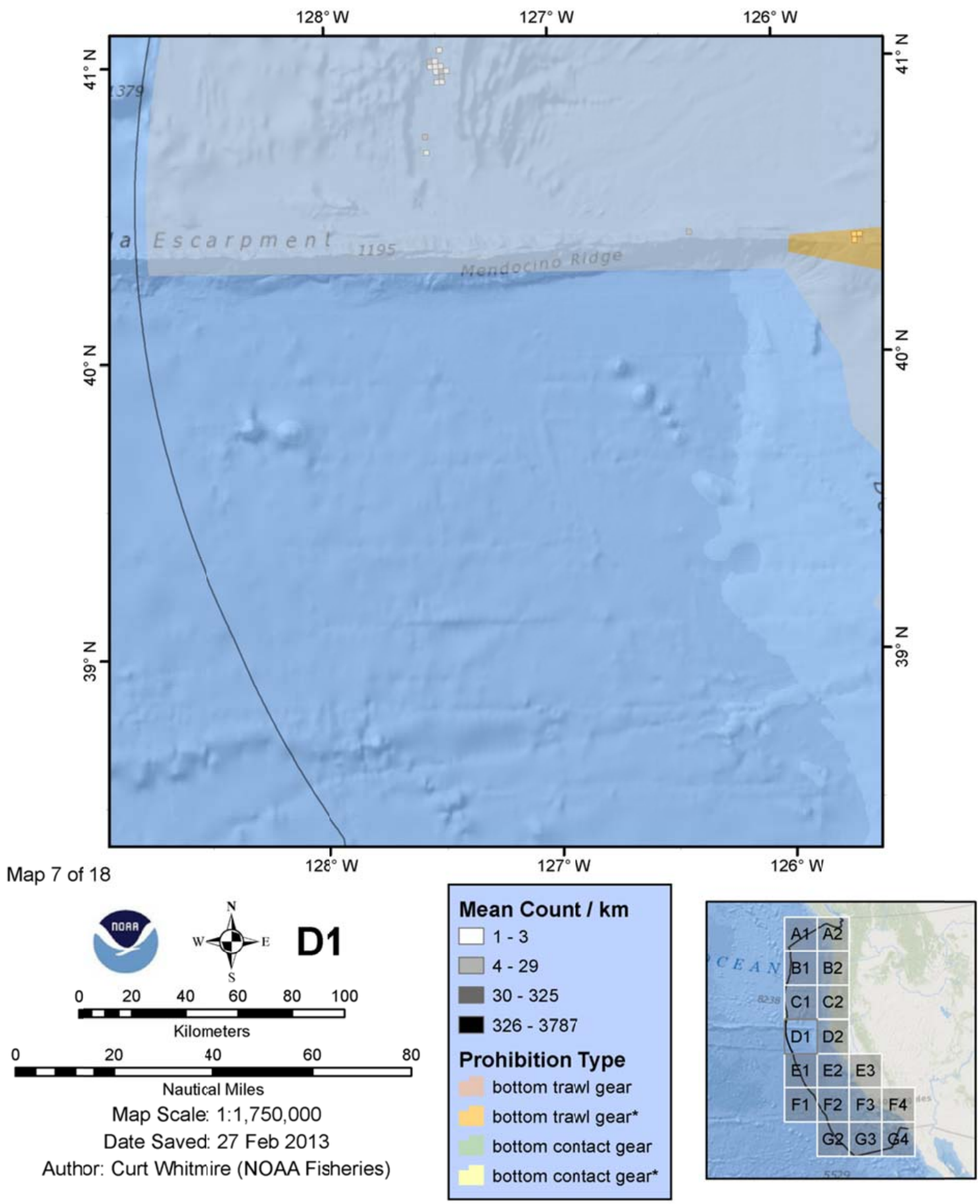


Coral (excluding Pennatulid) and Sponge Observations

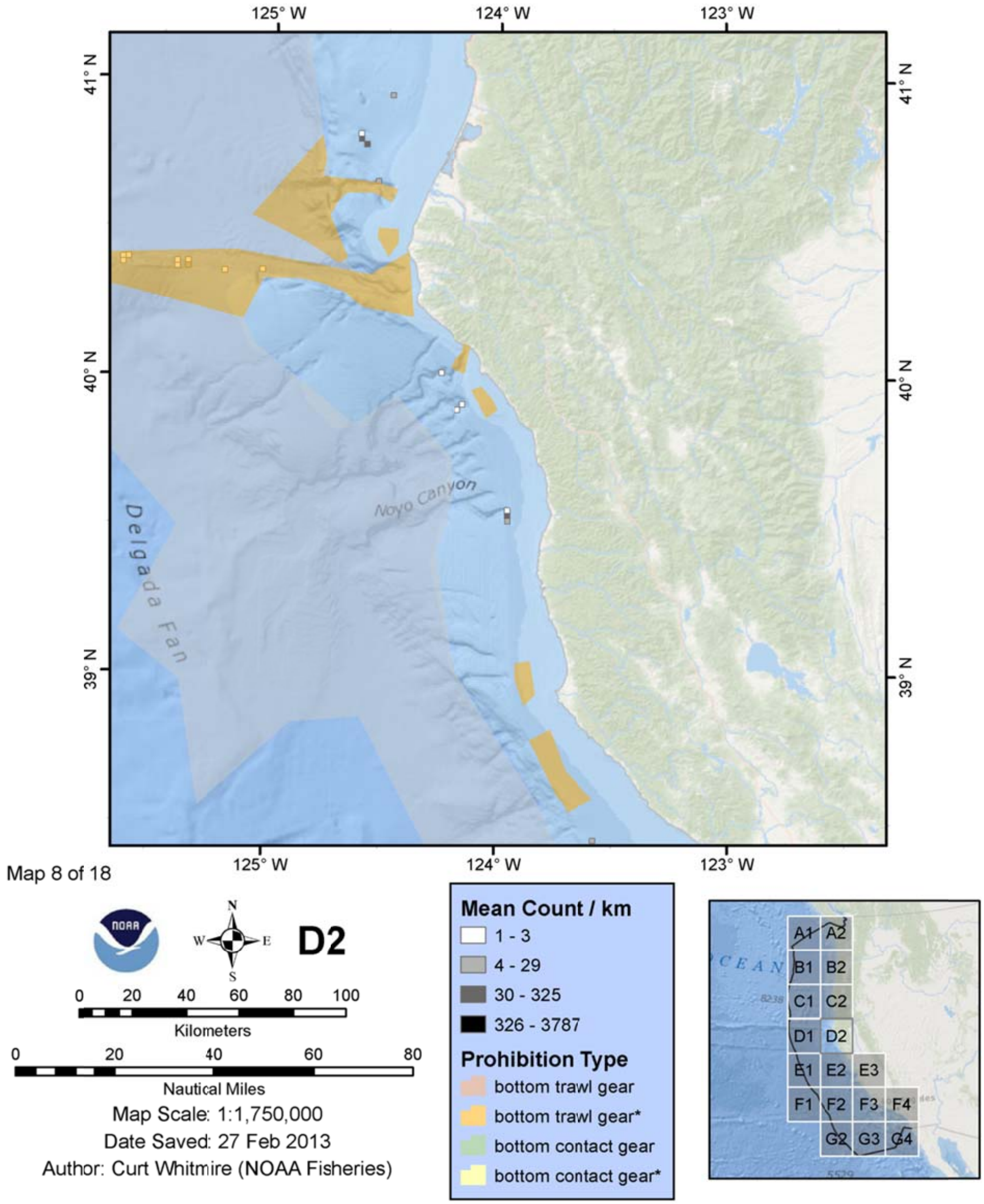



Coral (excluding Pennatulid) and Sponge Observations
125° W
124° W
123° W
43° N
42° N
Medford
3419
Map 6 of 18
C2
N
S
W
E
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map Scale: 1:1,750,000
Date Saved: 27 Feb 2013
Author: Curt Whitmire (NOAA Fisheries)
Mean Count / km
1 - 3
4 - 29
30 - 325
326 - 3787
Prohibition Type
bottom trawl gear
bottom trawl gear*
bottom contact gear
bottom contact gear*
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

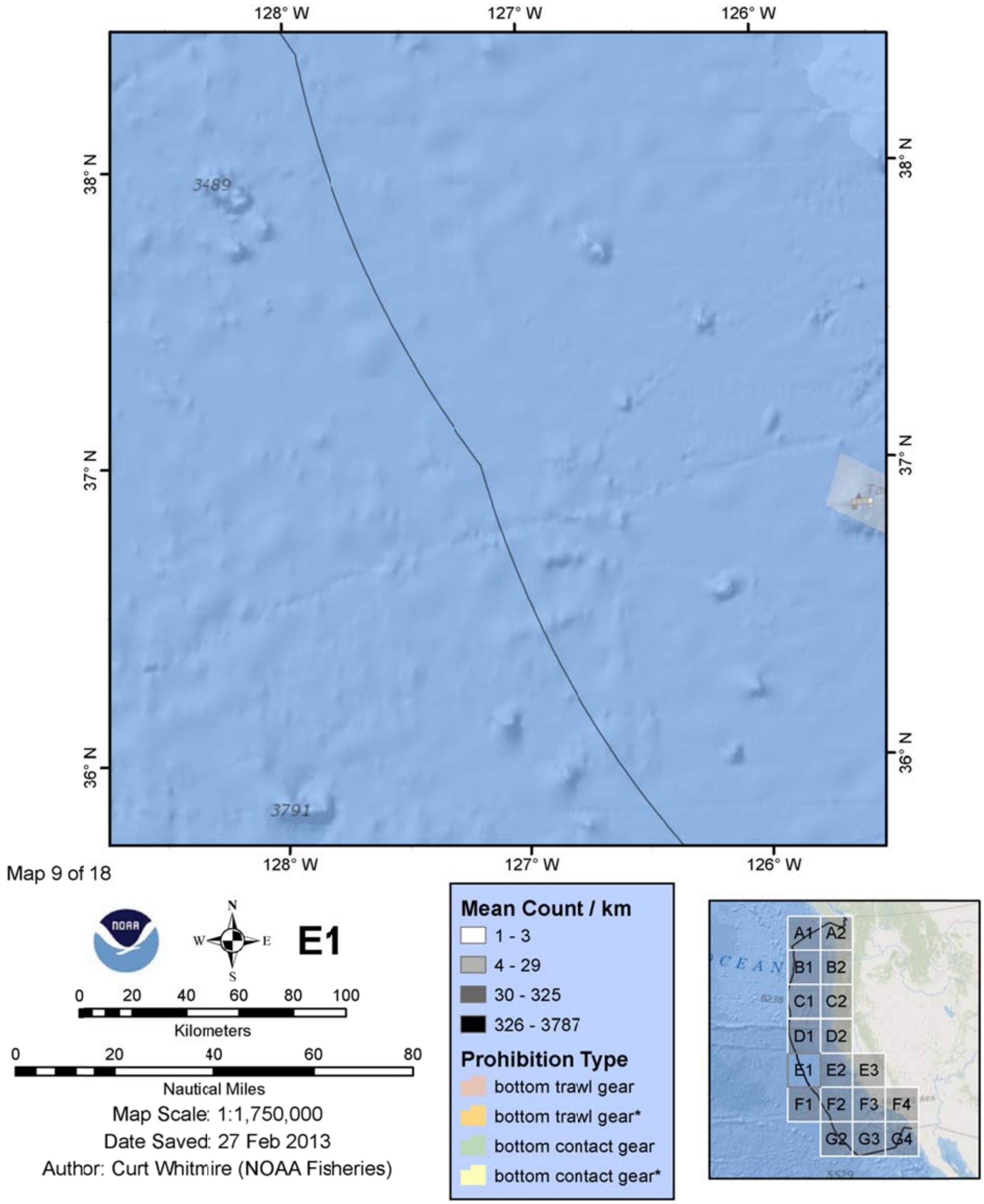
Coral (excluding Pennatulid) and Sponge Observations



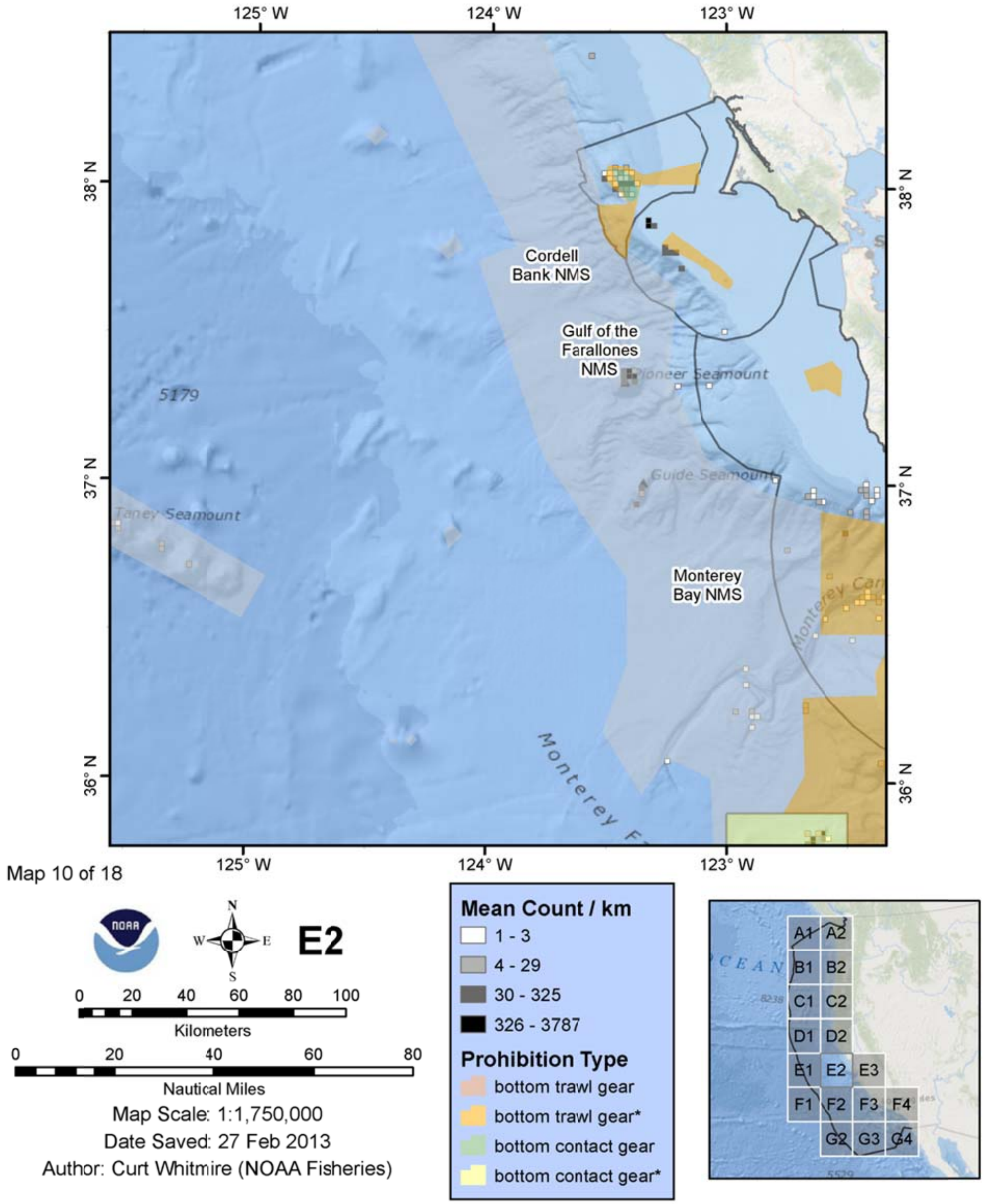
Coral (excluding Pennatulid) and Sponge Observations



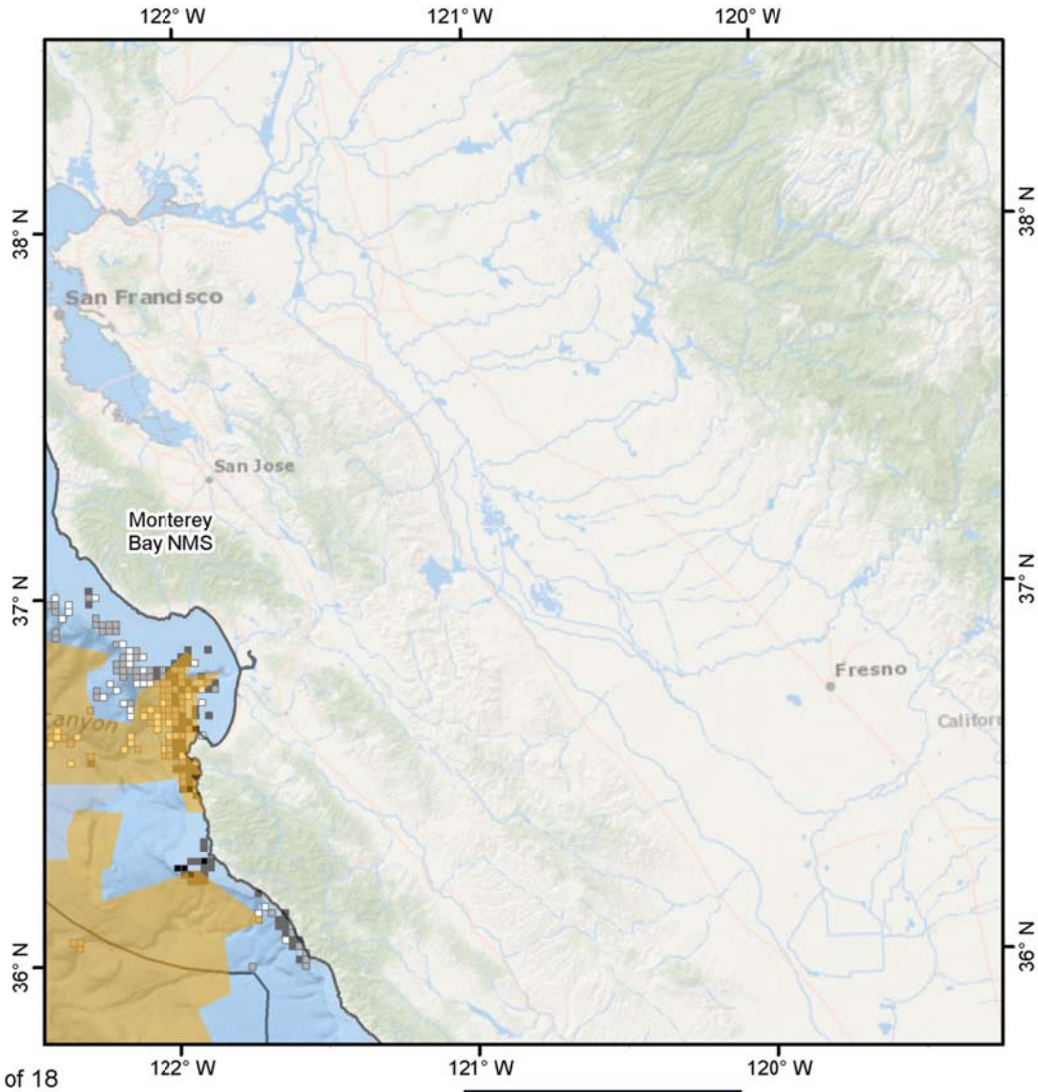
Coral (excluding Pennatulid) and Sponge Observations



Coral (excluding Pennatulid) and Sponge Observations



Coral (excluding Pennatulid) and Sponge Observations



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E3

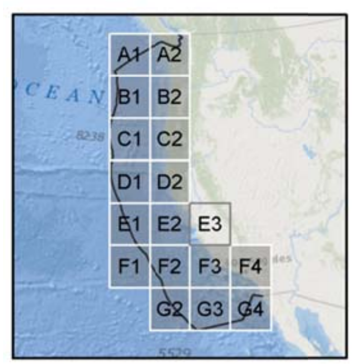
0 20 40 60 80 100
Kilometers

0 20 40 60 80
Nautical Miles

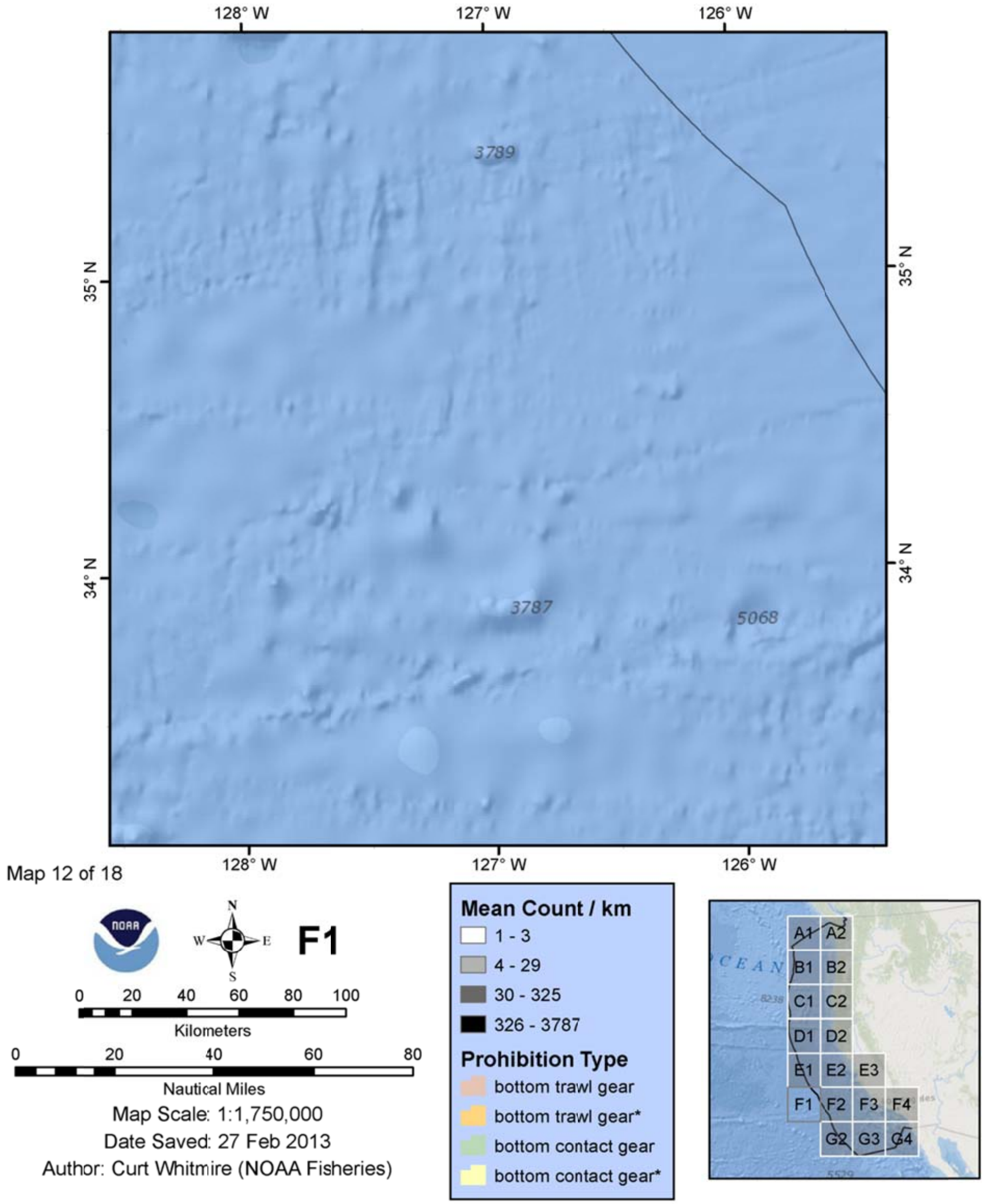
Map Scale: 1:1,750,000
Date Saved: 27 Feb 2013
Author: Curt Whitmire (NOAA Fisheries)

Mean Count / km
- 1 - 3
- 4 - 29
- 30 - 325
- 326 - 3787

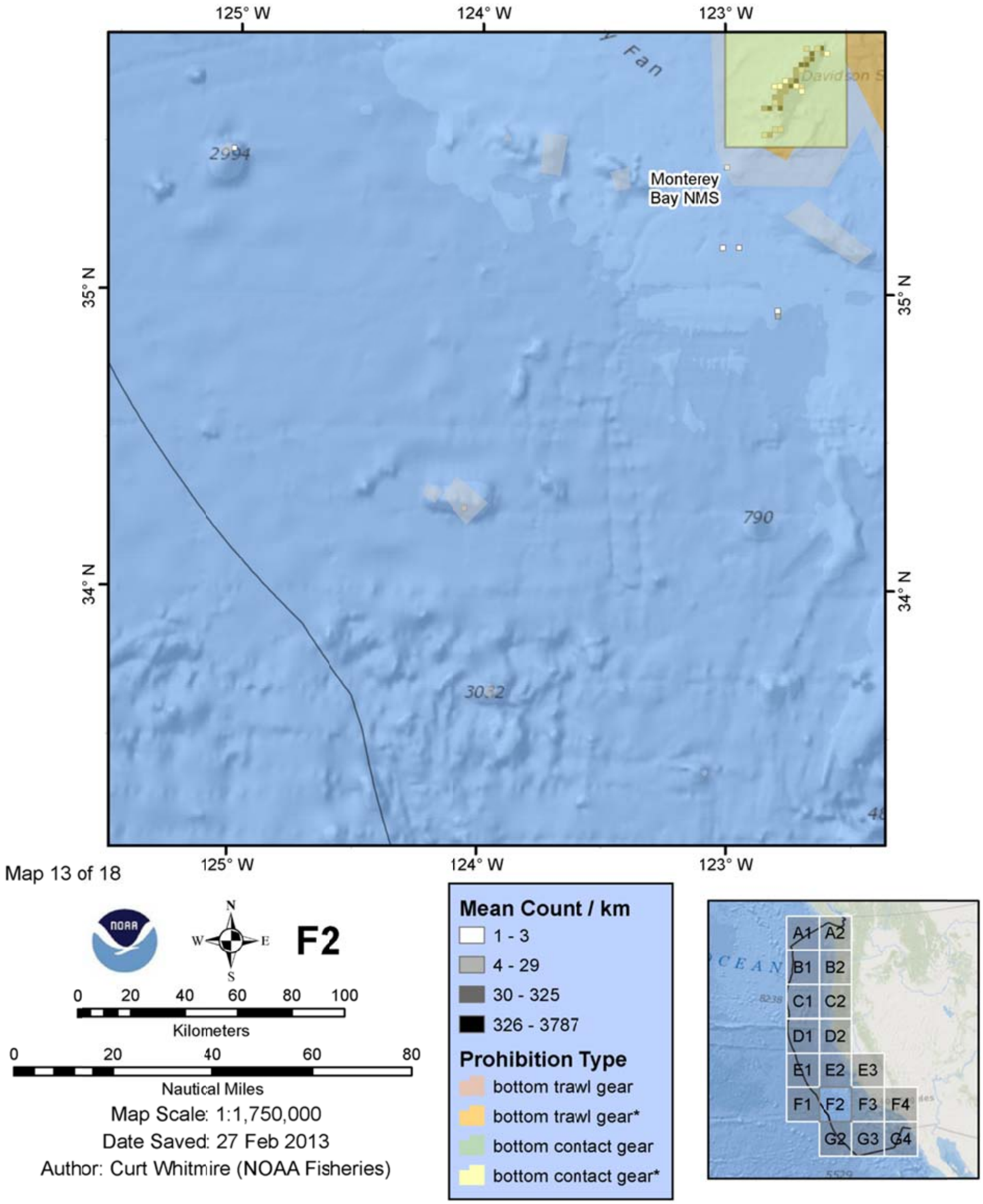
Prohibition Type
- bottom trawl gear
- bottom trawl gear*
- bottom contact gear
- bottom contact gear*



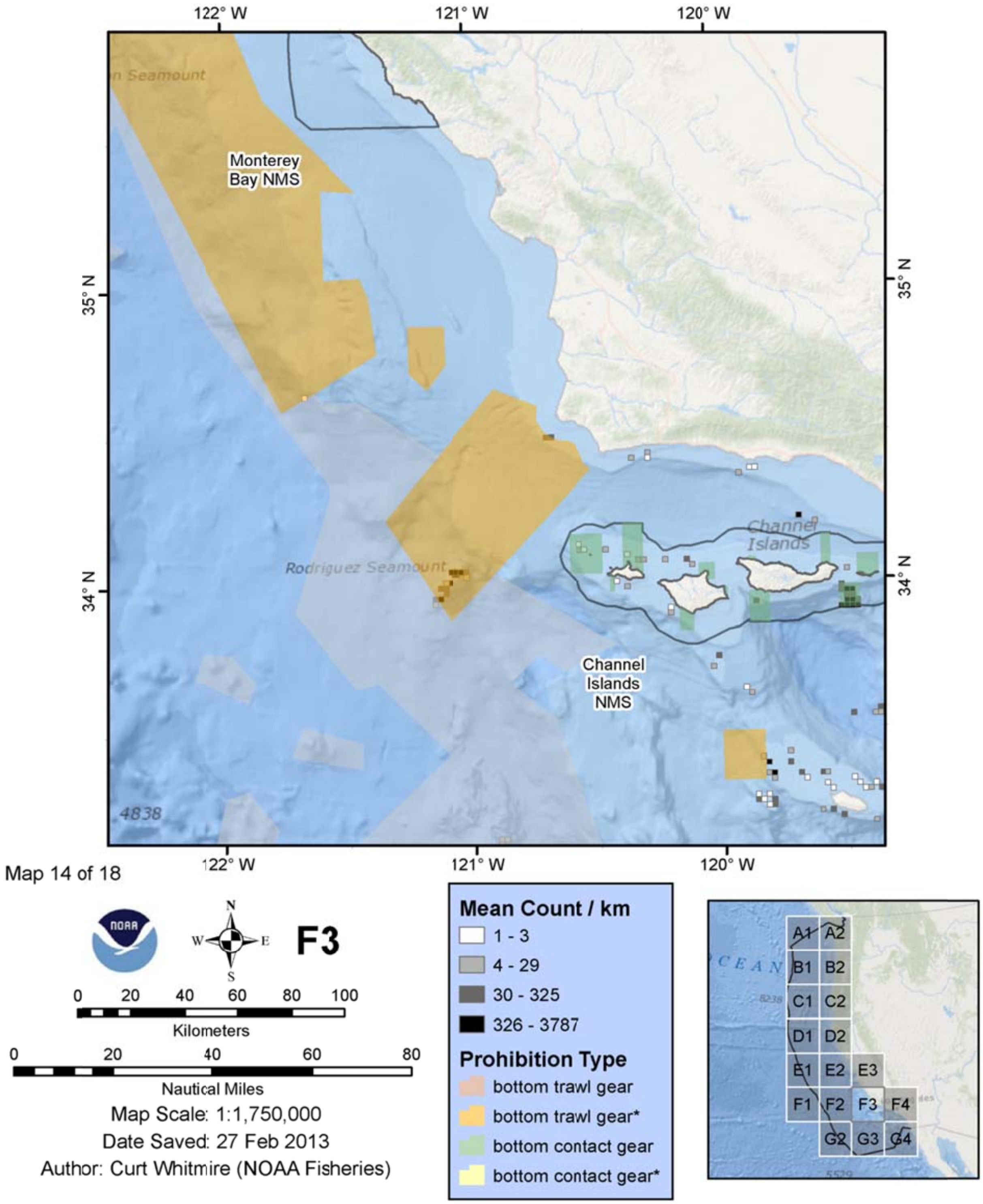
Coral (excluding Pennatulid) and Sponge Observations



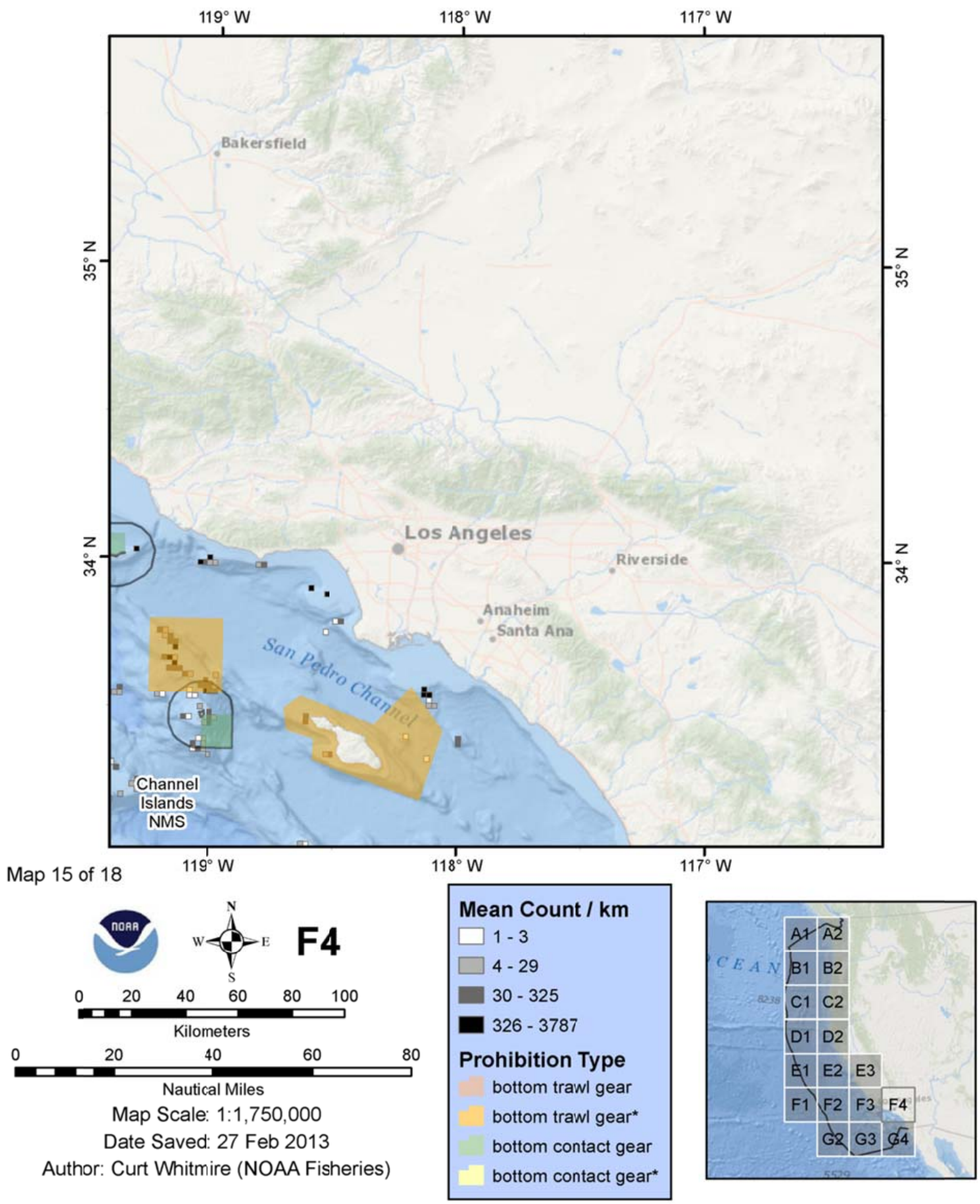
Coral (excluding Pennatulid) and Sponge Observations



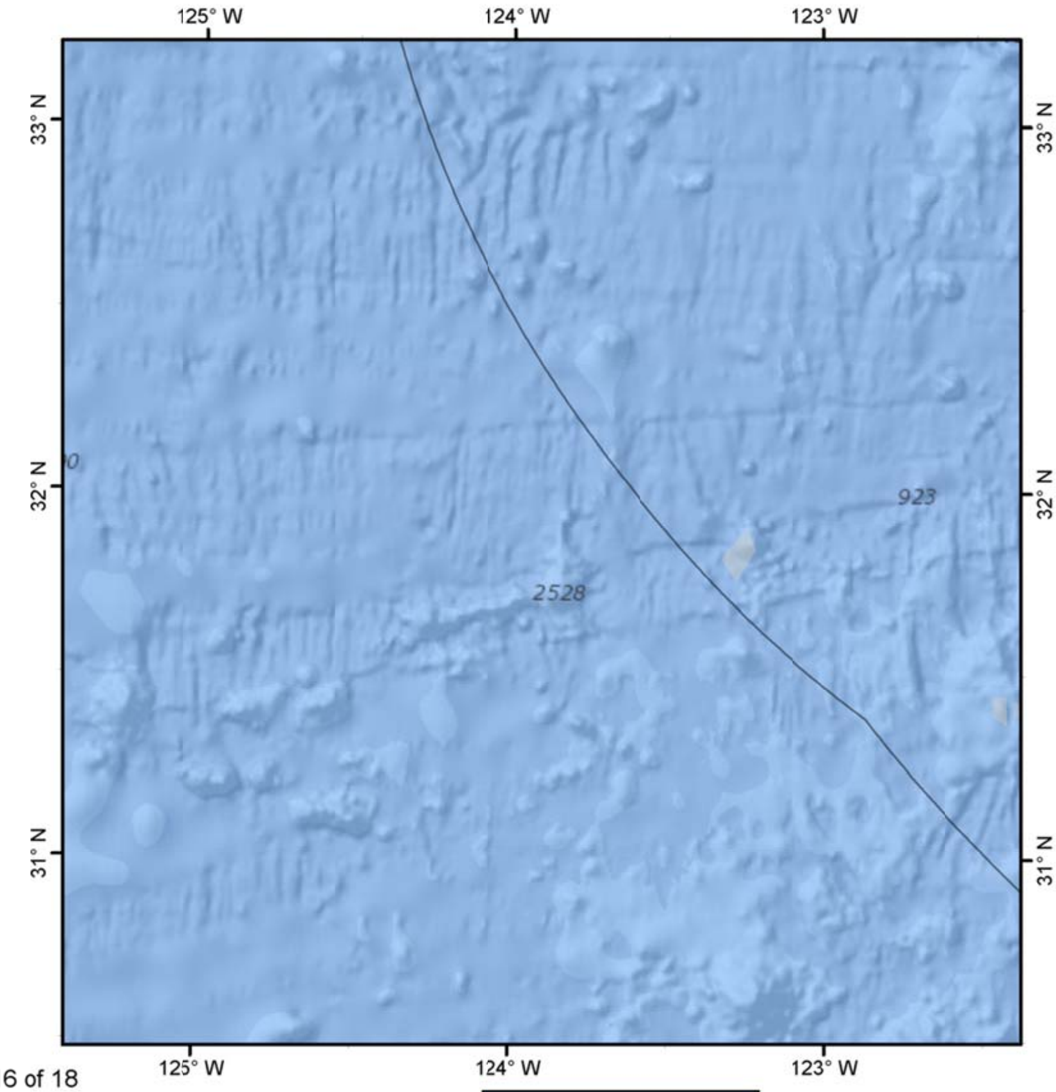
Coral (excluding Pennatulid) and Sponge Observations



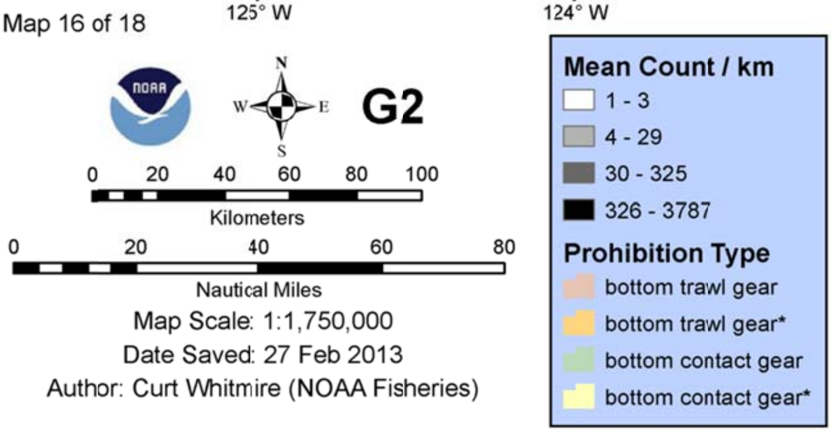
Coral (excluding Pennatulid) and Sponge Observations

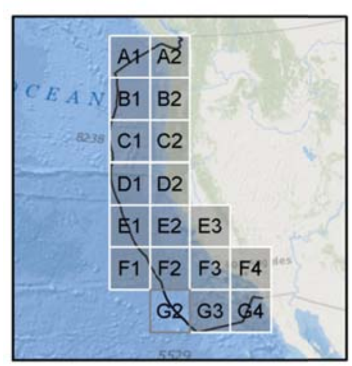


Coral (excluding Pennatulid) and Sponge Observations

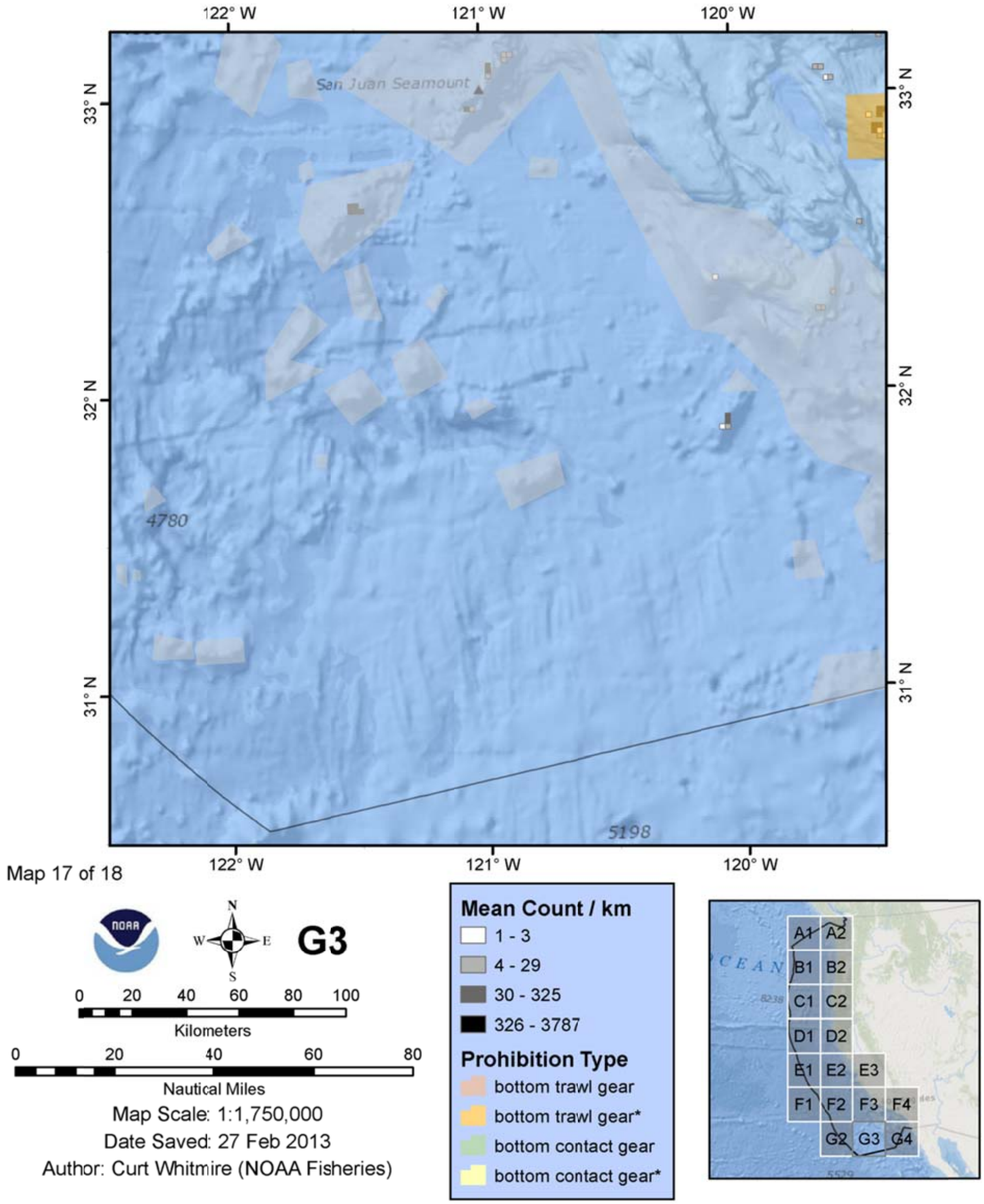


Map 16 of 18

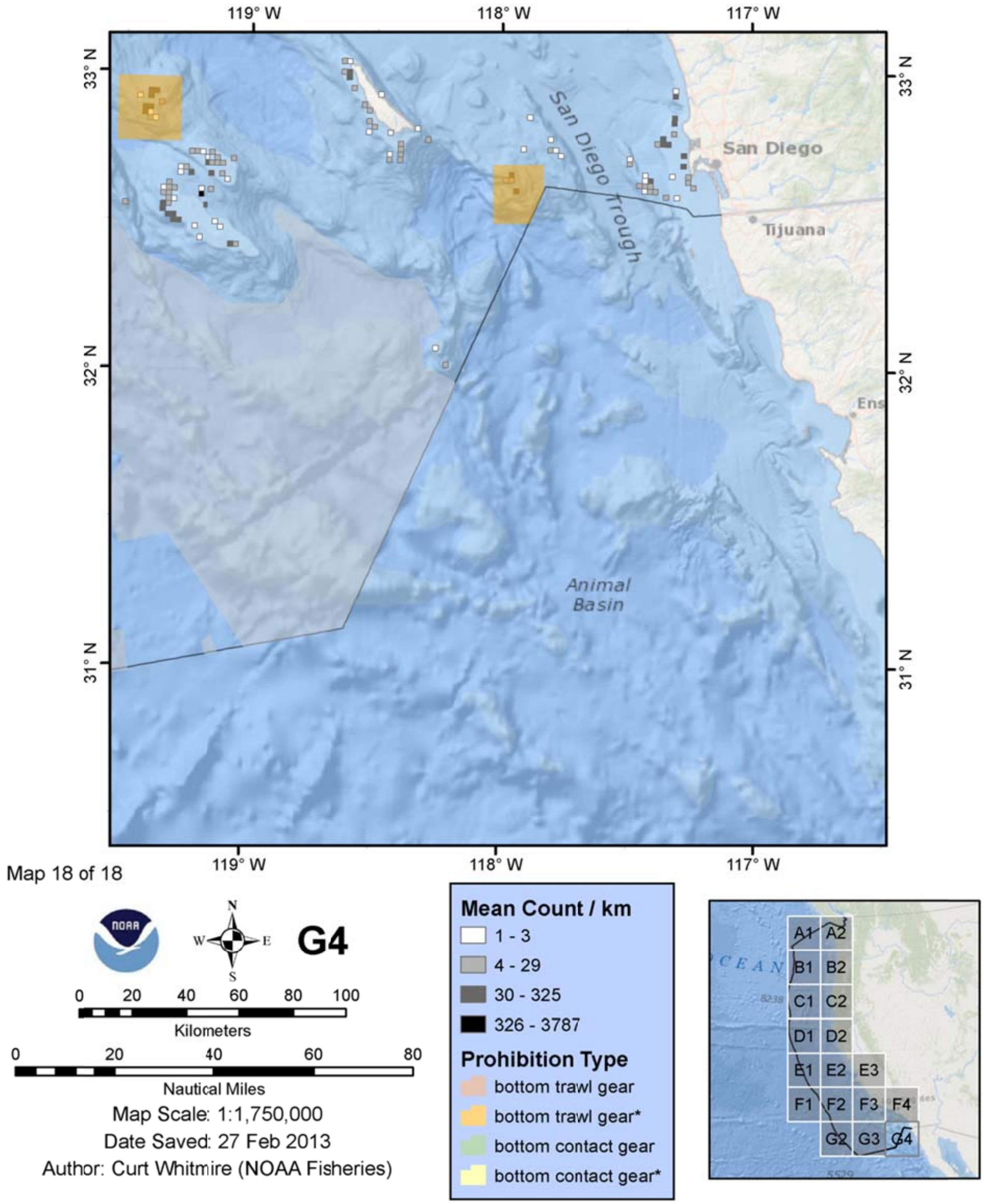




Coral (excluding Pennatulid) and Sponge Observations



Coral (excluding Pennatulid) and Sponge Observations



2.0 METHODS FOR MODELING SPECIES-HABITAT ASSOCIATIONS

2.1 *DESCRIBE BAYESIAN MODELING FRAMEWORK FOR DETERMINING ASSOCIATIONS BETWEEN GROUNDFISH SPECIES AND HABITAT COVARIATES*

2.1.1 Figure and Table labeling conventions:

Here we outline the statistical modeling methods used for estimating species-habitat relationships. We detail the Northwest Fisheries Science Center model (NWFSC model; Section A2.1) and the National Centers for Coastal Ocean Science model (NCCOS model; Section A2.2). Both model descriptions include a discussion of the habitat variables included in the model, model structure, computational issues, and model selection algorithms employed. Both models were applied to the six focal species described in the synthesis section of the document. The NCCOS model was also developed for an additional five species. The primary data source for both models is the west coast NOAA trawl survey. Both models provide estimates for the expected catch at particular locations and the uncertainty associated with the expected catch at each location. For brevity, we present only the point estimates of expected catch in the figures.

Figs. A2.1 to A2.18 are identical to the figures in Section 3 of the main report and display the results for the NWFSC and NCCOS models for the six focal species. Figs. A2.19 to A2.23 show the results for the 5 species modeled by NCCOS but not NWFSC. Figs. A2.24 and A2.25 illustrate the construction of the NWFSC model and Figure A2.26 shows the location of survey trawl locations for 2003-2011.

2.1.2 Shared Data Sources for the NWFSC and NCCOS models

Groundfishes were modeled using species, relative abundance and effort observations collected as part of the annual fishery-independent West Coast Groundfish Bottom Trawl Survey (Slope and Slope/Shelf combined time series). The data was provided by the NWFSC - Fishery Resource Analysis and Monitoring (FRAM) Division (Figure A2.26). The West Coast Groundfish Bottom Trawl Survey was designed specifically to provide a fishery-independent data basis for the statistical assessments required by the fisheries management process, and its unbiased statistical design lends itself to assessing habitats within areas well-sampled by the survey.

The sampling design and gear used by the NWFSC has been explained by Keller et al. (2008 and 2012) and Bradburn et al. (2011). Briefly, the NWFSC has been conducting annual bottom trawl surveys off the U.S. West Coast since 1998. We use only data collected after 2003, which is when the sampling design was changed to expand the depth coverage and measure additional fishes. After 2003, tows were collected on the shelf and slope in depths from 55-1280 meters in the U.S. exclusive economic zone. On average 700 randomly positioned tows were collected each year using a sampling design stratified by geographic region and depth. Tows were taken targeting a fishing time of 15 minutes and a speed of 2.2 knots. Vessels were equipped with customized Aberdeen style nets with a small mesh (3.8 cm stretched measure) liner in the codend, a 25.9-m headrope, and a 31.7-m foot rope and a differential geographic positioning system (DGPS). DGPS data were used to estimate tow position and distance fished. Area swept was provided in the received dataset and was the product of the mean net width and the distance fished. All fish and invertebrates were sorted to species (or the lowest possible taxon), and then weighed. For more information on the West Coast Groundfish Bottom Trawl Survey contact the NWFSC's FRAM division or visit their website at: http://www.nwfsc.noaa.gov/research/divisions/fram/index.cfm.

2.1.3 NWFSC model

2.1.3.1 Data Sources

The NWFSC model primarily used data from the trawl survey (described above; years 2003-2011) but also supplemented trawl data with visual survey data from submersibles. While the trawl survey is a rich data set, it provides a fundamentally biased sampling of benthic habitats (e.g. Jagielo et al 2003). Because bottom trawl gear does not function well in areas with steep, rocky seafloor, these habitats are largely unsampled during the survey. As a result, any species that is strongly affiliated with rocky habitats is poorly sampled during the trawl survey. While this fact has a number of broader implications - it makes it difficult to account for unsampled areas in stock assessments - in the context of EFH it affects the ability to estimate species-habitat associations by limiting the range of bottom-type habitats sampled. For example, it is impossible to determine if a species prefers sandy or boulder substrate if we only sample sandy substrates. Fortunately, the habitats that are impossible to sample with trawl gear have been investigated using other sampling techniques. The rocky outcrops have been studied with underwater submersibles and visual surveys (Yoklavich et al. 2000, Jagielo et al. 2003, Tissot et al. 2007; Table A2.1.1). In general, visual surveys provide much more detailed information about small-scale habitat associations (on the 10s to 100s m^2 scales) than trawls which integrate abundance information on the 10,000m^2 scale.

Due to time limitations, we were only able to include a subset of the available submersible survey information for the west coast (see Table A2.1.1). We hope to gradually incorporate more submersible survey information in the coming years.

While the visual surveys potentially provide information on the probability of occurrence and abundance aspects of the model, in our analysis we only used submersible surveys to inform the probability of occurrence portion of δ-GLM. We did this primarily because virtually all submersible surveys occurred before 2003 (some occurred in the 1980s). We felt comfortable modeling all of the submersible surveys as if they occurred in 2003 for the probability of occurrence because we viewed it as vital to include the observations from these poorly sampled habitats, even if it resulted in confusing temporal and spatial processes. All visual surveys occurring before 2003 were modeled as if they occurred in 2003. Because of the much larger variability in the abundance data and the fact that the submersible surveys reported counts for each species not biomass, we elected to rely exclusively on the trawl data to inform the abundance model.

In some cases we were able to compile transect by transect data from the submersible surveys. In such cases, we tallied whether the species was observed during the transect and used the transect midpoint to extract the relevant habitat values from those locations. We used the area visually searched by the submersible as the area offset. Generally, the area searched by submersibles was substantially lower than the area swept during the trawl survey. This means we assume that the detectability of fish in the trawl survey is equivalent to the visual surveys. While this assumption is likely violated in practice, we have no information about the selectivity of trawl surveys relative to visual surveys and so cannot directly account for any potential detectability variation between survey methods. In some cases we extracted information from published literature that did not have the individual tows. We also developed methods for incorporating these aggregated survey data in a small number of instances (<10 observation; see *Parameter models* below).

2.1.3.2 NWFSC Model Description (Non-technical)

The statistical model is designed to identify the relationship between habitat and fish abundance in the California current ecosystem. The habitat data included are described elsewhere in this document (see Section 1 and Section 2.1). We rely primarily on the NOAA west coast bottom trawl survey as for data on fish abundance.

The statistical model is divided into two components. The first component models the probability of occurrence for each species and the second component models the abundance of fish. Each component is subsequently comprised of two additive parts. Because both the probability of occurrence model and abundance models have the same basic model structure, we will only describe the probability of occurrence model here.

Taking the probability of occurrence portion of model, we can describe generic probability of occurrence model for species "*A*" as: the probability of occurrence of species *A* at point *s* is proportional to the effect of habitat plus the effect of space. Here "effect of habitat" is the contribution of habitat variables at location *s* to the probability observing at least one individual of species *A*. In our modeling we considered four habitat variables: water depth, bottom temperature, seafloor sediment grain size (ranging from rock to silt), and the distance from the observation to the nearest rock outcrop. The overall effect of habitat on probability of occurrence is a linear combination of habitat variables. For example, one potential model is: effect of habitat = effect of depth + effect of bottom temperature + effect of distance to rock. The model estimates how well each habitat variable explains the observed occurrence of species in the trawl survey.

The contribution of each habitat variable to the probability of occurrence is relatively intuitive. However, no matter how well we choose our habitat variables, we will likely not have included all of the important aspects that drive a species occurrence and abundance. There are other variables that are important determinant of the distribution of species that are not included. Some of these variables may be habitat related (e.g. the presence of corals or other biogenic habitats) while others may be biological or physical (e.g. a species is unable to disperse to a particular location). Furthermore, there will be some component of randomness that introduces variation into the observed fish abundance in a trawl. Overall, these unobserved and random components mean that some locations will have higher probability of occurrence than we expect based on their habitat alone while other locations will have lower probability of occurrence. Furthermore, we expect areas that are close together in space tend to be similar in their deviation from the habitat effect. The "effect of space" term above takes the spatial clustering of unusually high or low predictions by the habitat variables and estimates a smooth surface that tries to account for the variation not explained by the habitat variables.

Using this basic model structure, we estimated a series of models using our four habitat variables. We use Bayesian statistical methods to estimate the model parameters. Bayesian models are particularly useful because they allow for the incorporation of prior information about parameters. We then use model selection techniques to identify which habitat covariates should be retained and included in the final model. Finally, we use the preferred model to create a predictive map of the probability of occurrence and abundance for each species and contrast our results with the NCCOS model.

2.1.3.3 NWFSC Model Description (Technical)

We develop a hierarchical generalized linear model to describe species-habitat associations (see Cressie and Wikle 2011, Wikle 2010). The model focuses on the NOAA trawl survey data because this is the largest single source of available data for west coast groundfish. However, other types of information can be incorporated into the same modeling framework as shown below. We use Bayesian statistical framework because of its flexibility and ability to incorporate prior information. Additionally, the Bayesian framework allows for explicit incorporation of uncertainty in the spatial component of the model. In general, the models we employ are known in the fisheries literature as δ-GLM models (Stefánsson 1996, Maunder and Punt 2004) and in the spatial statistics literature as hurdle models (Ver Hoef and Jansen 2007).

We model the trawl and submersible data as a point process. We treat the fish collected during each trawl or transect as if it were collected at the midpoint of the trawl or visual transect. We acknowledge that the trawl and submersible surveys are not actually point observations but rather an aggregation of fish collected (or visually counted) over a larger area. However, the sampled transect is small relatively to the distance between samples and so we view treating the data as point observations as a reasonable approximation that provides flexibility in modeling the spatial structure (Royle and Wikle 2005, Latimer et al. 2009).

In the following sections, we begin by outline the statistical model. The model consists of three main components: 1) a data model that describes the process of observing fish, 2) a process model that describes the variation in the fish abundance as a result of habitat variables, and 3) a parameter model which describes our prior assumptions about model parameters. After describing the model structure, we describe the selection of habitat covariates to include in the habitat model. Finally, we discuss the model implementation, model diagnostics, model selection, and other technical details.

Notation

Throughout our mathematical description of the model, capital letters indicate random variables, lowercase Greek letters indicate scalar parameters and latent variables, bold lowercase symbols indicate vectors, and bold uppercase denote matrices. We always use base *e (“natural”)* logarithms.

Data Model

We start by writing a model for the catch of a single species at position s_{iy} during the NMFS trawl survey, $Z(s_{iy})$, where i indexes the observation and y indexes year. For notational simplicity and clarity, in the following description we consider observations that occur within a single year and omit the y index. Generally, $Z(s_i)$ is reported in biomass but poorly described by a single continuous distribution; $Z(s_i)$ cannot be negative and but can have a large number of 0 observations. This fact motives the use of mixture distributions that can break the observed catches into two components, a probability of occurrence component to account for observed 0 catches and a positive component that describes the distribution of catches conditioned on the presence of fish (Stefánsson 1996, Maunder and Punt 2004). In recent years, this modeling approach has gained favor for modeling trawl catches because it can accommodate the abundance of zero-observations in trawl data. We follow this trend and write the random variable $Z(s_i)$ as a mixture distribution conditioned on model parameters,

$$Z(s_i)|\phi(s_i), \mu(s_i), \psi \sim Bernoulli(\phi(s_i))Gamma(\mu(s_i), \psi) \qquad \text{(A2.1.1)}$$

Here $\phi(s_i)$ is the probability of catching at least one fish; therefore, the probability of catching zero fish is 1- $\phi(s_i)$. Then $Gamma(\mu(s_i),\psi)$ determines the distribution of catches for the non-zero tows. We parameterize the gamma distribution in terms of its mean, μ, and coefficient of variation, ψ[1]. We assume that the CV of observed catches scales with the mean catch in a consistent manner across all sites (i.e. ψ does not have a spatial or temporal component). The gamma distribution is only one of several possible alternative models for the probability density function of positive observations. Other authors have used a range of other positive distributions to model observed catches (Maunder and Punt 2004). These alternate distributions can easily be used in place of the gamma distribution. Throughout our model description and results, we refer to the Bernoulli component of the mixture as the "probability of occurrence" part of the model and the gamma component as the "abundance" or "positive" part of the model. It is possible to allow the two components of eqn A2.1.1 to be correlated such that the probability of occurrence component informs the abundance component (Thorsen and Ward *In review*). It is computationally and conceptually easier to treat the two processes as independent. We treat them independently here.

In the results, we show two plots for each species. The first is a result for the Bernoullli component, titled "probability of occurrence" maps (see Figs A2.1 to A2.18) which show the expected value of $\phi(s_i)$, $E[\phi(s_i)]$. We also show results for the full abundance model that includes both the Bernoulli and gamma components of the model, which the product of the expectations for the two components: $E[\phi(s_i)]E[\mu(s_i)]$.

Process Model

Thus far we have specified a data model which describes how the random variable $\boldsymbol{Z}$ is a mixture distribution. We join the parameters of the mixture distribution to measurable attributes of the environment using a generalized linear model. We write the mean for the two components of our model as a linear combination of explanatory variables, $\boldsymbol{X}$, fixed regression parameters, $\boldsymbol{\beta}$, and spatial effects, $\boldsymbol{w}$. We also need to account for variation in the amount of effort expended in catching the observed fish. Let Y be the effort offset. We use a logit-link function for the probability of occurrence and a log-link for the abundance component,

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[1]So, $f(x;\mu,\psi) = Gamma(\mu,\psi) = \frac{(\mu\psi^2)^{-\psi^{-2}}}{\Gamma(\psi^{-2})} x^{\psi^{-2}-1} e^{-(\mu\psi^2)^{-1}x}$ where Γ is the Gamma function. The expected value of this parameterization is $E[x] = \mu$ and coefficient of variation, $CV[x] = \psi$. This Gamma density can be connected to the more familiar $Gamma(\alpha,\beta)$ parameterization by substituting $\alpha = \psi^{-2}$ and $\beta = (\mu\psi^2)^{-1}$.

$$\begin{aligned}\text{logit}(\phi(\boldsymbol{s})) &= \boldsymbol{X_1}(\boldsymbol{s})\boldsymbol{\beta_1} + \gamma_1 Y_1 + \boldsymbol{w_1}(\boldsymbol{s}) \\ \log(\mu(\boldsymbol{s})) &= \boldsymbol{X_2}(\boldsymbol{s})\boldsymbol{\beta_2} + \gamma_2 Y_2 + \boldsymbol{w_2}(\boldsymbol{s})\end{aligned} \qquad \text{(A2.1.2)}$$

We introduce the subscripts 1 and 2 to emphasize that the explanatory variables and spatial effects need not be identical between the two models. The matrices ***X(s)*** contains measured habitat covariates at each point. In our model we considered a suite of available habitat covariates including depth, bottom temperature, sediment characteristics, and distance from rocky substrate (see below for details). We also include categorical offsets for the area of bottom swept by each trawl and a fixed effect for each year that is intended to account for temporal variation in abundance. For the positive model component, we use *log(Area swept)* as our offset, Y_2 = *log(area swept),* and assume catch is proportional to effort, $\gamma_2 = 1$. For the probability of occurrence model, we use Y_1 = *area swept,* and again assume $\gamma_1 = 1$. In other cases, it may be advantageous to assume $\gamma_1 = 0$ (Thorson et al. 2011).

Note that eqn A2.1.2 does not have a non-spatial error term (ie. a "nugget" effect in spatial statistics). Because the trawl survey is unreplicated – no point is sampled multiple times – a non-spatial error term is likely to be statistically unidentifiable. Preliminary efforts to estimate the nugget effect confirmed this difficulty and we did not attempt to estimate a non-spatial error term in any of our models.

We also estimated models using the non-spatial version of eqn A2.1.2 in which $w_1(\mathbf{s})$ and $w_2(\mathbf{s})$ are set equal to 0. In the non-spatial model, trawl observations are then assumed to be independent. In the following we will refer to $\phi(s_i)$ and $\mu(s_i)$ as "latent variables" and treat them as quantities to be estimated. This has computational benefits that speed model estimation.

Eqns A2.1.1 and A2.1.2 produce a model that parallels the δ-GLM models used in west coast stock assessment (e.g. Stewart et al. 2010, Thorsen et al. 2011, Thorson and Ward *In review*). However, the spatial component of the model above is not currently incorporated into stock assessments. While there are a number of subtle differences between the spatial and non-spatial formulations, the important distinction is that in the non-spatial model the expected mean abundance is identical for each observation within a strata (for example, theoretical strata might be: shallow waters north of Cape Mendicino in a given year), whereas for the spatial model each observed point will have a distinct expected mean that depends on the habitat covariates observed at each location and the observations of abundance near that point.

We make the standard assumption that the spatial effects are multivariate normal distributed random variables (Cressie 1993, Cressie and Wikle 2011) so $\boldsymbol{w_1} \sim MVN(0, \boldsymbol{\Sigma_{w1}}(d,\theta_1))$ and $\boldsymbol{w_2} \sim MVN(0, \boldsymbol{\Sigma_{w2}}(d,\theta_2))$, where $\boldsymbol{\Sigma_w}(d,\theta)$ is a covariance matrix with scale parameter θ that controls the correlation between points as a function of distance, d.

Because we used 9 years of the annual trawl survey data (2003 – 2011), the data contains information about both the spatial and temporal patterns of abundance. To avoid confusing temporal trends in abundance with spatial variation, we constructed a covariance matrix that only allowed samples collected within a given year to have spatial covariance. Therefore we made the spatial covariance matrix, $\boldsymbol{\Sigma_w}$, block-diagonal with diagonal elements comprised of year-specific spatial covariance matrices,

$$\boldsymbol{\Sigma_w} = \begin{bmatrix} \boldsymbol{\Sigma_{2003}} & 0 & \cdots & 0 \\ 0 & \boldsymbol{\Sigma_{2004}} & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & 0 & \boldsymbol{\Sigma_{2011}} \end{bmatrix} \qquad \text{(A2.1.3)}$$

where $\boldsymbol{\Sigma_{2003}}$ is the covariance matrix for observations in 2003, for example. This general structure allows between year spatial covariances to be independent and allows for the fish to move between years and cluster in different locations between years. This is a simple formulation of a broad, general class of spatio-temporal models (Cressie and Wikle 2011). More complicated spatio-temporal model structures that allow some covariation between years are certainly possible and reasonable. We hope to develop more sophisticated models in future efforts. Our current method this provides a method for identification of locations that are persistently of higher abundance across year and can aid in the identification of "hot spots" for particular species (see Figs. A2.1.24, A2.1.25).

We assume the spatial variance is homogeneous within a year and the covariance function between any two locations (e.g. s and s') is only a function of the distance, d, between them (ie. it is isotropic) so

$$\text{cov}(s, s') = \sigma_y^2 r(d, \theta) \qquad \text{(A2.1.4)}$$

where $r_\eta(d,\theta)$ is the correlation function, and σ_y^2 is the spatial variance. In all of the models considered here we assume $r_\eta(d,\theta)$ is an exponential correlation function, $r_\eta(d,\theta) = exp(-d/\theta)$. The parameter θ controls the spatial scale of correlation among observations with larger values of θ corresponding to increased correlation with distance. For the exponential correlation function the effective range is 3θ (effective range is the distance between observations at which correlation falls to 0.05; Cressie 1993). We considered model structures in which σ_y^2 was allowed to vary among years as well as models in which it was constant among years (ie. $\sigma_y^2 = \sigma^2$). While we initially attempted to estimate a θ for each year, we found the model unmanageable and so estimated a single shared θ for all years in the final model runs. This model assumption forces the scale of spatial aggregation to be similar in all years, but allows the location and amplitude of spatial aggregation to vary.

Parameter models

A key component of Bayesian models is the specification of prior distributions for the parameters. By tradition, non-informative priors have been used in most ecological and fisheries applications. In our case, however, there are clearly sources of information apart from the measured covariates that should be allowed to inform our model inference. We discuss two potential ways to incorporate prior information in the model structure. First, priors can be placed on the regression parameters, $\boldsymbol{\beta}$, that specify the relationship between habitat characteristics and abundance. We did not have enough information to generate reasonable priors for $\boldsymbol{\beta}$, so we do not utilize prior information on $\boldsymbol{\beta}$ in any of the models.

Second, in a spatial context, priors can be placed on the latent variable components of the δ-GLM model described above. For example, we might have prior information on the probability of occurrence for a particular location that is not observed during the trawl survey. If this were true, we could place a prior on probability of occurrence for that location (ie. $\phi(s_i)$). Such prior information could come from unpublished data or expert opinion. These locations do not necessarily correspond to trawl survey locations. Such priors must be constructed carefully to ensure they are on the appropriate measurement scale and ensure they are comparable to the observed trawl data. We collected data from non-trawl sources and included some of it in the analysis via prior information on $\phi(s)$. We used priors for $\phi(s)$ in cases where we did not have individual transect level information from the visual surveys. We aggregated observations from clusters of transects to produce a prior distribution at the center of the cluster. For more detailed information, contact the authors.

Table A2.1.2 summarizes the prior distributions for the parameters. We used diffuse multivariate prior distributions for the regression parameters, conjugate inverse-gamma distributions for σ_y^2, and uniform distributions for θ and ψ. We constrained the scale parameter θ to the range {20,1000} for all species in the probability of occurrence model based on visual inspection of the spacing of trawl survey locations with the intention of precluding the possibility of estimating spatial structure that is at a finer scale than the survey data. Because the abundance part of the model only includes non-zero observations and thus comprises a smaller subset of the data, the density of observations decreased and distance between observations increased. Therefore, we used $\theta \sim$ *Unif(50,1000)* for less frequently observed species (darkblotched and greenstriped rockfishes) while maintaining for $\theta \sim$ *Unif(20,1000)* for sablefish, longspine thornyhead, and petrale sole. We did not have enough positive observations to feel confident in the quality of an abundance model for yelloweye rockfish.

Table A2.1.2: Prior distributions used in the NWFSC statistical model. (**I** is the identity matrix)

	Probability of Occurrence	**Abundance**
Parameter		
β	Multivariate Normal(0, $100^2\boldsymbol{I}$)	Multivariate Normal(0, $100^2\boldsymbol{I}$)
σ_y^2	Inverse-Gamma (3,1)	Inverse-Gamma (0.75,0.5)
ϑ	Uniform (20,1000)	Uniform (20,1000); Uniform (50,1000)
ψ	NA	Uniform (0.1,5)

Covariate Selection

We used only data sources for covariates that were available for the entire spatial domain of the trawl survey. After perusing the available data layers used in EFH Phase 1 report (PFMC 2012), we decided to use depth, bottom temperature, and sediment characteristics as continuous habitat covariates in our model (Table A2.1.3). Descriptions of these data layers can be found elsewhere in Section 1 of this appendix). We added a fourth continuous covariate, distance to nearest rocky habitat, which represented proximity to habitat features deemed important to demersal fishes. We used the "Nearest Features" tool (Jenness Enterprises, v. 3.8b) in ESRI ArcView (v. 3.2a) to calculate the distance from each of the trawl survey sites to the nearest rock habitat patch. Rock was defined as any grid cell in the substrate type datalayer with a value of 1 or 4. We only used rocky patches greater than 1 ha in area. All habitat covariates were centered before model estimation. While we expect many of the habitat attributes of the trawl locations, such as depth and bottom type to be constant across the entire trawl time-series, we know that other factors that we could not include are also affecting fish populations. For example, the total abundance of a particular species may be changing over time — declining due to fishing pressure or poor recruitment or increasing due to fishing restrictions or favorable oceanographic conditions. Therefore, we also included the option of estimating a fixed categorical value for each year. Adding such a year effect allows for the probability of occurrence and overall abundance to vary across the time-series. We do not allow for interactions between the categorical year effects and thus we assumed a constant effect of habitat variables across years and only allowed for a discrete shift up or down between years. Recall, however, that the spatial effect allows for the deviation from this overall habitat mean to vary spatially among years.

While we allow for temporal trends in both the probability of occurrence and abundance component of the models to account for temporal patterns, developing methods to directly include known pressures (e.g. local fishing effort) would be an important model improvement and next step.

We initially considered including information about biogenic habitats, our initial survey of available data for biogenic habitats concluded that the data were too limited in quality and their spatial extent to be included in our coast-wide model (Section 1.1 of this appendix). Future work should emphasize developing broad scale information about biogenic habitat that can be incorporated fully into species-habitat models.

We do not include any region-specific categorical variables in our model because we did not have good *a priori* ideas for locations at which habitat-area relationships might change. We wished to avoid arbitrarily imposing a spatial structure for species-habitat relationships. We hoped that the spatial component of the model would provide the needed flexibility to account for spatial variation in the species-habitat relationship.

We only considered models using the main effects of the habitat covariates and did not consider any interactions among the covariates. Thus our model included at most 16 parameters. This small number of parameter ensures that the parameters maintain biological interpretability. The small model dimension also reduces the likelihood of model over-fitting and reduces the importance of performing extensive cross-validation testing to avoid overfitting.

After some exploratory analysis, we elected to transform depth and distance to rock outcrop before their inclusion in the models. We $\log_e$-transformed depth and square-root transformed the distance to nearest rock outcrop. The transformation of depth improved the explanatory value of depth in all species examined and the square-root transformation was effective at increasing the contrast between locations that are in close proximity to rocky outcrop and reducing the statistical leverage of points at great distances from any rock outcrop.

Finally, we used a habitat confidence layer to incorporate uncertainty in sediment grain size data (see Section 1 of this appendix). Given that the grain size map covers areas derived from surveys of varying quality – ranging from detailed side-scan sonar surveys conducted in the last decade to grab sample surveys completed nearly a century ago – it is reasonable to assume that our certainty about sediment grain size will vary along the coast (PFMC 2012). Therefore we elected to add uncertainty to each sediment grain size by making the sediment grain size a normal random variable. For location i, $X_{i,grain.size} \sim N(\kappa_i, \tau_i^2)$, where κ_i is the value from the grain size map. For hard habitats, we used $\kappa_i = -8.5$ and $\tau_i = 0.25, 0.5,$ and 0.75 for high, medium, and low substrate certainty, respectively. For mixed substrate, we used $\kappa = -4$ and $\tau_i = 2, 3,$ and 4 for high, medium, and low substrate certainty, respectively. For soft substrates, we let κ_i be the predicted value derived from the sediment map, and set and $\tau = 1, 2,$ and 3 for high, medium, and low certainty locations. These values were developed after extensive discussion amongst the NOAA scientific staff, but other values of τ may be reasonable.

Model fitting involved standard Markov chain Monte Carlo (MCMC, see below) techniques. For each iteration of the MCMC estimation process we drew a new value for each location from $X_{i,grain.size}$. This approach ensured that our parameter estimates integrated over the uncertainty in sediment characteristics. We acknowledge that this is a somewhat inelegant statistical method for incorporating uncertainty in sediment size, but it is an important first step toward including spatially variable quality of information into species-habitat associations.

Table A2.1.3. A list of the habitat covariates included in the NWFSC statistical model.

Habitat Covariates	**Forms included in the model**
Depth (m)	Log(depth) Log(depth)2
Bottom temperature (C)	Bottom Temperature (Bottom Temperature)2
Sediment grain size (Φ Scale; Krumbein and Sloss 1963)	Grain Size (Grain Size)2
Distance to nearest rocky outcrop (km)	(km)0.5

2.1.3.4 Model Estimation

General Procedure

Within the general model form outlined in the preceding section, there is a great amount of flexibility with regards to which habitat covariates are included into the model. There are also options for the specific form the spatial components of the model component. We followed a three-part model estimation procedure. We first estimated a series of non-spatial models using all combinations of habitat covariates using standard Markov chain Monte Carlo (MCMC) techniques (see *MCMC details* below). For the non-spatial models we identified between four and ten models using two model selection criteria: a formal scoring metric based on the posterior predictive distribution known as the log-score (Gelfand and Day 1994, Gelfand and Ghosh 1998, Draper and Krnjajić 2010; see *Model Selection* below), and an qualitative inspection of model fit which included inspection of MCMC chains and plots of the marginal posterior distributions of regression parameters.

After the set of preferred models was identified, we estimated parameters for the full spatial model using the identified habitat covariates. We used posterior parameter estimates from the non-spatial model to initiate the MCMC chains in the spatial model to reduce the burn-in and computing time. We again used log-score and qualitative model inspection to identify a preferred spatial model and for comparing spatial and non-spatial models.

For the preferred model, we then constructed a series of predictive maps for the probability of occurrence and abundance on a 2 x 2 km grid of the west coast (see below).

Computational Issues for Spatial Models

Spatial data present a series of computational problems. In particular, when the number of observations gets large (say > 2000 observations), standard procedures to estimate parameters in a point process model become computationally difficult and intolerably slow (Banerjee et al. 2008). The computational issues are entirely driven by estimation of the spatially term, $\boldsymbol{w}$. Problems arise because the covariance matrix $\boldsymbol{\Sigma_w}$ is large and not diagonal. Because estimation involves calculating the matrix inverse of $\boldsymbol{\Sigma_w}$, compuation can be exceedingly slow. This is known as the “large N” problem in spatial statistics (Banerjee et al. 2004, Banerjee et al 2008, Cressie and Wikle 2011) and remains a difficult problem even when explicit matrix inversion is replaced with fast linear solvers.

A number of approaches based on approximating the covariance matrix have been proposed to speed the computation of spatial models (see e.g. Royle and Wikle 2005, Latimer et al 2009). We employ the predictive process modeling approach to improve model computation speed. A thorough discussion of predictive process approach can be found elsewhere (Banerjee et al. 2008, Finley et al. 2009, Latimer et al. 2009), so we only outline the methods here. Briefly, the predictive process approach develops an approximation of the full covariance matrix $\boldsymbol{\Sigma_w}$ using a much smaller covariance matrix. To do this, we establish new set of points that are interspersed with the observed locations. These locations are known as “knots” and the number of knots is much smaller than the number of observations. For the statistical model, we have to estimate a spatial component for each knot location, $\boldsymbol{w^*}$, instead of a spatial component for each observation, $\boldsymbol{w}$. We estimate a spatial covariance matrix among the knots and predict the value of spatial effects at the observed points from the knots. The key advantage of introducing the knots is that we only have to calculate the inverse of the covariance matrix of the knots and because the length of $\boldsymbol{w^*}$ is much less than the length of $\boldsymbol{w}$ the computational savings are substantial. We employ the “modified” predictive process model described by Finley et al. (2009). This “modified” model contains an adjustment parameter estimates to avoid bias in the estimation the spatial parameters. Bayesian estimation of $\boldsymbol{w}$ also allows for uncertainty in estimates of the spatial scale parameter θ.

The use of predictive process models requires the consideration of two additional model aspects. The number of knots needs to be specified and the location knots needs to be determined. Using a smaller number of knots will speed computation time but result in a smoother, less rugose spatial surface compared to a model that uses the raw data. Following some preliminary exploration, we used 150 knots for the probability of occurrence models. For the abundance component, we used the minimum number of observations in a single year for each species except for sablefish, where we used 300 knots (Table A2.1.4). To determine the knot locations we selected a single set of knot locations using a k-means clustering algorithm on all years of observations simultaneously (via the "kmeans" function in R; Hartigan and Wong 1979). We then used this single set of knot locations for each year in the model estimation.

Table A2.1.4: N is total number of observations across all years for the probability of occurrence and the number of observations with > 0 kg observed for the abundance component of the model. Number in parentheses is the number of observations used from submersible surveys. We do not include non-trawl information for petrale sole because they are difficult to identify in submersible surveys. Longspine thornyhead were never reported in any of the submersible surveys.

Species	**Probably of Occurrence**		**Abundance**	
	N	knots	N	knots
Darkblotched rockfish	5808 (77)	150	1026	91
Greenstriped rockfish	5808 (77)	150	1482	132
Yelloweye rockfish	5812 (81)	150	-	-
Petrale sole	5731 (0)	150	2376	198
Sablefish	5731 (0)	150	3767	300
Longspine thornyhead	5731 (0)	150	2096	196

MCMC details

We are interested in calculating the posterior density for the parameters and latent states given the observed data. Let $z_1(\boldsymbol{s})$ represent the observed presence-absence data of the model, then the full posterior for the presence-absence component can be written,

$$\begin{aligned} p(\phi(\boldsymbol{s}), \boldsymbol{w}^*, \theta, \boldsymbol{\sigma}^2 | z_1(\boldsymbol{s})) \propto \quad & p(z_1(\boldsymbol{s})|\phi(\boldsymbol{s})) \\ & p(\phi(\boldsymbol{s})|\boldsymbol{w}^*, \boldsymbol{\beta}, \theta, \boldsymbol{\sigma}^2) \\ & p(\boldsymbol{w}^*|\theta, \boldsymbol{\sigma}^2) \\ & p(\boldsymbol{\beta}, \theta, \boldsymbol{\sigma}^2) \qquad \text{(A2.1.5)} \end{aligned}$$

with the right hand side showing how the posterior can be factored into four components. We can write a similar model for the abundance model. Non-spatial models are simpler because they do not involve estimating $\boldsymbol{w}^*$, θ, or $\boldsymbol{\sigma}^2$. For both non-spatial and spatial model we use using a mix of Gibbs and Metropolis-Hastings sampling steps to estimate parameters (Gelman et al. 2004). To both of the non-spatial models we added a small, fixed amount of pure error to the model to ease MCMC sampling: e.g. the non-spatial model for the probability of occurrence is then $logit(\phi(s_i)) = \boldsymbol{X}(s_i)\boldsymbol{\beta} + \varepsilon_i$, where ε_i are independent and $\varepsilon \sim N(0,\tau^2)$. Abundance models had an analogous form. For the probability of occurrence and abundance models, we set $\tau^2 = 0.01$.

Due to a large number of models we considered we initially ran a single MCMC chain for each model. For the models that appeared to best match the data, we ran subsequent MCMC chains from dispersed starting point to verify convergence to a single stationary distribution. For probability of occurrence models, visual inspection of chains suggested non-spatial models converged relatively slowly but had decent mixing properties. Thus we ran a very long burn-in chain of 100,000 iterations and a monitoring chain of 50,000 iterations. While both of these chain lengths were excessive, the chain length removed any questions about model convergence. We then used the ending values from the non-spatial model to initiate the spatial models. Because spatial models ran much more slowly and the parameter values were already near their stationary distribution, we ran a 10,000 iteration burn-in and a 25,000 iteration monitoring run. In most cases, the MCMC chains for the spatial model converged but mixed relatively slowly (ie. MCMC draws from the stationary distribution were highly autocorrelated).

The positive model had better MCMC characteristics overall. We used a burn-in of 30,000 and a monitored MCMC of 50,000 iterations for the non-spatial model and a burn-in of 5,000 and monitored MCMC of 10,000 iterations. The mixing properties of both abundance models were improved greatly over the probability of occurrence model.

Model Selection

An important component of devising and applying new statistical models is comparing the relative effectiveness of various models at describing available data. In this section, we discuss how we compare among the possible spatial models using posterior predictive scoring rules. Generally, we are interested in identifying models that make good predictions. A way of formalizing this desire for good predictions is to say that we want to maximize the predicted probability of observing the value of a new data point, z_{new}, given our previously observed data and our estimated parameters. For notational simplicity, let $\boldsymbol{\Theta}$ be the estimated parameters and latent variables in the model. Thus, a good model would be one that provides a large value of $p(z_{new}|\boldsymbol{z},\boldsymbol{\Theta})$. Proper rules for comparing a data value z_{new} with its predictive distribution involve the logarithm of the height of $p(z_{new}|\boldsymbol{z},\boldsymbol{\Theta})$, or $log(p(z_{new}|\boldsymbol{z},\boldsymbol{\Theta}))$ (Gneiting and Raftery 2007, Draper and Krnjajić 2010). This metric of predictive quality is known as the log-score (*LS*).

Ideally, we would estimate log($p(z_{new}|\boldsymbol{z},\boldsymbol{\Theta})$) via cross-validation; we would exclude some set of our observations from our model estimation procedure and predict those excluded values. This suggests we would need to run a number of MCMC models for each covariate and each run would have a different set of data points excluded from model estimation (e.g. Draper and Krnjajić 2010, Shelton et al. 2012). In practice, this is impractical due to the long computing times for models estimated with MCMC. Fortunately, with reasonably large sample sizes, we can use what is known as the "full sample" log-score that will approximate the cross-validation derived log-score (Draper and Krnjajić 2010). For each draw of the MCMC, g, we calculate the predicted probability of each observed data point, *i,* then

$$LS = \frac{1}{G}\sum_{g=1}^{G}\sum_{i=1}^{n}\log\left[p(z_i|\boldsymbol{z},\boldsymbol{\Theta^g})\right] \qquad \text{(A2.1.6)}$$

where *n* is the number of observations and *G* is the number of MCMC iterations. Larger log-scales indicate a higher overall match between prediction and observations. An alternative scoring criterion would be to divide the right side of eqn A2.1.6 by *n* to provide log-scores on a per observation basis.

Constructing Prediction Maps

After producing posterior distributions for model parameters and the spatial latent variables at the knot locations, we used draws from the joint posterior distribution to generate predictive map for probability of occurrence and for abundance. These two surfaces correspond to a surface for $\boldsymbol{\phi}$ and a surface for $\boldsymbol{\mu}$ in eqn A2.1.1, respectively. These two surfaces can be combined to provide a surface for the expected value of catch, ***E[Z]***.

We first generated a gridded (2x2 km) coast-wide map of the model spatial domain. The north/south extents of the domain approximated the U.S. border, while the shoreline and seaward boundaries were defined by a vector shoreline geospatial datalayer (NOAA 2001), and the 1,600 m isobath (3-arcsecond grain, [~86 m] NOAA 2003), respectively. We created the 2x2 km gridded polygon datalayer using “Generate Regular Points in ArcMap”, which is a Hawth’s Tools ArcGIS tool that runs in ArcMap (v. 9.3.1). We overlaid this gridded domain with the four habitat covariate datalayers and calculated the corresponding values for each of the grid cells. Since the covariates were continuous variables, each was expressed as an area weighted mean (AWM) for each of the grid cells.

We use $\boldsymbol{s_0}$ to denote the predicted grid centers along the coast. For depth, sediment grain size, and distance to rock outcrop the covariate values at each location were consistent across years.

For bottom temperature, we did not have a direct measure for each of the 2 X 2 km grid cells, so we used the trawl survey site bottom temperature data to interpolate a gridded surface of bottom temperature for each year (2003 – 2011). We used the “kriging” command ESRI ARC/INFO grid (v. 9.2) to interpolate bottom temperature. We interpolated bottom temperature on a 1 X 1 km grid for each year of the trawl survey data using the following kriging parameters: model domain polygon used as “barrier cover”; SPHERICAL semi-variogram model for kriging method; maximum of 12 neighboring input sample points; and, 100 km search radius to select neighboring points. We also used these interpolated bottom temperature datalayers to fill in missing bottom temperature in 272 of the bottom trawl survey sites.

We used a slightly different approach for calculating distance to nearest rocky habitat patch for the 2 X 2 km gridded datalayer. Calculating the distance from the centroids of each of the ~43k, 2 X 2 km grid cells to the nearest edge of each of the rocky habitat patches exceeded the capabilities of the "Nearest Features" tool that we used in generating the covariates for each of the bottom trawl survey sites, so we used the "NEAR" command in ESRI ARC/INFO (v. 9.2), which is a more robust software package.

Depending on the model used, each year modeled could also have a distinct offset (intercept) corresponding to a coastwide change in the probability of occurrence or abundance. Given these maps, we can generate predicted values for $\boldsymbol{s_0}$. For the probability of occurrence model, we generate predicted values at $\boldsymbol{s_0}$ for the g^{th} draw from the posterior,

$$\text{logit}(\boldsymbol{\phi^g}(\boldsymbol{s_0})) = \boldsymbol{X_1}(\boldsymbol{s_0})\boldsymbol{\beta_1^g} + Y_1 + \boldsymbol{c^T}(\boldsymbol{s_0},\theta^g)\boldsymbol{C^{*-1}}(\theta^g)\boldsymbol{\eta_1^{*g}} \quad \text{(A2.1.7)}$$

where the first term on the right side is the predicted value from the fixed habitat covariates, the second is the effort offset, and the third term is the linear interpolation of the spatial effect at each predicted point from the sampled knot locations (ie. the standard kriging projection). Here $\boldsymbol{C^*}$ is the covariance matrix for knot locations and $\boldsymbol{c}$ is a matrix describing the covariance between the prediction points and the knot locations (ie. $\boldsymbol{c}(\boldsymbol{s_0},\theta^g) = [\boldsymbol{C}(\boldsymbol{s_0}, \boldsymbol{s_j^{*g}},\theta^g)]_{j=1}^m$). An analogous model was constructed for the positive component of the model. For all predictions we use an effort offset of 1 hectare (0.01 km^2) swept for prediction. Recall that the offset for the positive part of the model we use the logarithm of area swept (so $Y_2 = log(0.01)$).

Each draw of the posterior distribution could thus provide predicted value of $logit(\boldsymbol{\phi})$ (or for the abundance portion of the model, $log(\boldsymbol{\mu})$) at each predicted location. Each component can then be back-transformed to generate a map of predicted probability of occurrence (bounded by 0 and 1) or the expected biomass caught. To calculate the across-year average map we created a mean prediction map for each year and then averaged across these year-specific maps. Thus the NWFSC maps shown in Figs A2.1 to A2.18 are the mean of the mean yearly predictions in each grid cell.

To save computing time, we selected 1,000 evenly spaced draws from the joint posterior distribution, produced a prediction from each of the 1,000 posterior draws. We then calculated the mean, median, and credible intervals for each prediction location.

Because the fixed and spatial components of the above model are additive, it is also possible to produce a map derived exclusively using the habitat covariates. This can be thought of as a predictive map for species occurrence based exclusively on the habitat characteristics unmodified by spatial clustering (we show an example using sablefish in 2010 in Figure A2.1.24). This map without spatial clustering is roughly analogous to earlier EFH efforts to identify suitable habitat (i.e. the HSP model; Anonymous 2005, 2008), though the HSP model was developed using substantially different methods. The spatial component (Figure A2.1.24) can be thought of as a smooth surface that adjusts the predicted probability of occurrence from the fixed habitat effect up or down to better match the observed data. We combine the spatial and habitat effects and back-transform them to the appropriate scale for the probability of occurrence and abundance. We can provide estimates of the average as well as estimates of uncertainty for each predicted point. We show the mean probability of occurrence for sablefish in a single year (2010; Figure A2.1.24) as well as the 5% and 95% predicted quantiles for the same year[2]. While we can provide such maps for each species in each year, to be concise we report an across-year average of for probability of occurrence and abundance in the main text and this appendix (Figs A2.1.1 to A2.1.18).

It is also possible to construct across year averages for the habitat effects and the spatial effects (Figure A2.1.25). The across year average of the spatial component has a particularly intuitive and potentially useful interpretation. Since the spatial component contains the information in the data that is not explained by the habitat model, we can compare the predicted spatial component across years to identify areas that persistently have higher probability of occurrence or abundance than is predicted by underlying habitat. By identifying areas that are persistently different, the spatial effect provides an alternative method for identifying areas of interest where habitat variables do a poor job of predicting occurrence or abundance. We show an example of this average, across-year spatial structure for sablefish in Fig A2.1.25.

Acknowledgments:

We thank T. Jagielo and B. Tissot, for providing raw submersible survey data and R. Hannah for discussing camera drop surveys on Stonewall Bank, OR.

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[2] Because the posterior distributions were generated using MCMC, the retained parameter estimates are not independent draws from the posterior distribution; the posterior draws are autocorrelated. This is not a serious problem. Using only 1,000 draws to generate predictions lessened the autocorrelation, but it is important to note that any remaining autocorrelation in the parameter estimates will produce an underestimate of the uncertainty of the predictions at each point. The magnitude of the underestimation will be quite small in most cases

Table A2.1: Habitat covariates included in the preferred NWFSC probability of occurrence model for the six focal species. "X" indicates the covariates included in the preferred model. All columns are habitat covariates except "Year" which designates a categorical offset for each year, and "Single Variance?" which designates if a single spatial variance parameter was estimated for all years ("Y") or if a spatial variance parameter was estimated for each year ("N").

Species	Year	Log (Depth) and log (Depth^2)	Bottom Temperature	(Bottom Temperature)^2	Sediment Grain Size	(Sediment Grain Size)^2	Sqrt(km to rock)	Single Variance?
Sablefish	X	X	X	X	X	X	X	N
Yelloweye rockfish		X	X		X		X	Y
Petrale sole	X	X	X	X				N
Longspine thornyhead		X	X	X	X	X	X	Y
Greenstriped rockfish	X	X	X	X	X		X	N
Darkblotched rockfish		X	X	X	X	X	X	N

Table A2.2: Habitat covariates included in the preferred NWFSC abundance model. "N/A" indicates that the abundance model was not estimated. See Table 2.1 for more explanation.

Species	Year	Log (Depth) and log (Depth^2)	Bottom Temperature	Bottom Temperature^2	Sediment Grain Size	(Sediment Grain Size)^2	Sqrt(km to rock)	Single Variance?
Sablefish	X	X	X	X	X		X	N
Yelloweye rockfish	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petrale sole		X	X	X				N
Longspine thornyhead		X	X	X	X	X	X	Y
Greenstriped		X	X				X	N
Darkblotched rockfish	X	X	X					Y

2.2 SPATIAL MODEL OF SPECIES-HABITAT RELATIONSHIPS (NCCOS MODEAL)

2.2.1 Model Description (Non-technical)

The statistical model used by NCCOS differs from the one used by the NWFSC. The model was chosen to generate predictions at the highest possible spatial resolution (sacrificing the ability to resolve temporal changes for improved spatial resolution. i.e. finer scale "texture," in model outputs). In contrast to the NWFSC model, the NCCOS model is constructed from a frequentist (rather than Bayesian) approach. Practically speaking, this allows the NCCOS model to incorporate more potential predictor variables and interactions among variables and an exact representation of spatial autocorrelation, while still estimating the model in a reasonable amount of time.

Similar to the NWFSC model, NCCOS's models have two distinct components ("stages"), one for predicting the probability of occurrence, and another for predicting relative abundance given presence. The predicted probability of occurrence (Stage I) is multiplied by the predicted abundance conditional on occurrence (Stage II) to produce the final estimate of relative abundance, which is the expected long-term average catch per unit effort (CPUE). The long-term average can be considered the estimated mean from repeated bottom trawls scattered between 2003 and 2010. Within each stage of the model, relationships among groundfishes and their environment were used to predict a trend surface using transformed Generalized Linear Models (GLMs), and spatial autocorrelation in GLM residuals was modeled using geostatistical modeling (kriging). For each species and each stage a model selection routine was used to select which environmental variables would be used in generalized linear models and which ones would be omitted. Final models were selected based on a statistic that balanced model fit to the training dataset with model complexity, and tested on a cross-validation set not included in model fitting. Tables 2.3 and 2.4 identify environmental variables selected for models for each species.

NCCOS's models were developed using fishery-independent groundfish observations and a range of environmental data sets spanning the large marine ecosystem (e.g., depth, slope, surface chlorophyll, bottom temperature). -Outputs from the models show continuous gridded predictions of species occurrence, and relative abundance at a spatial resolution of 1km (4x finer resolution than the 2km NWFSC models) along the West Coast from the Washington-Canada border to the California-Mexico border.

2.2.1.1 Groundfish survey observations

NCCOS models used tows extracted from the West Coast Groundfish Bottom Trawl Survey dataset that were taken between 2003 and 2010, and identified as "Fisheries

Assessment Acceptable" or "Station Removed From Survey Pool". This subset passed quality control standards based on post-collection analysis of bottom contact, net performance, and other metrics (Stauffer 2004). Stations removed from the survey pool and which passed quality control standards were also included in the analysis to increase sample size and the spatial dispersion of tow sites. All tows meeting our temporal and quality control criteria were merged. This dataset was used in spatial models for each investigated species and resulted in predictions representing the long-term average spatial distribution of the examined species (i.e., a spatial climatology). This approach allows for the maximum possible resolution of spatial differences in the long-term average spatial pattern of species' abundance. The tradeoff (and a key difference from the NWFSC model) is that it does not allow for analysis of temporal changes over time. Any temporal changes that do occur over the period of analysis will be represented as a long-term composite average in this kind of spatial climatological model.

2.2.1.2 Environmental variables

Eleven environmental variables were used as potential independent predictor variables for each species' spatial model (Table A2.2.1). It is important to note that the eleven predictors were only candidates and a model selection process was used to narrow down the set of predictor variables that contributed to any particular species model.

Table A2.2.1: A description of predictors variables used in NCCOS groundfish models

Dataset	Description
Depth	The base bathymetry used in the 2005 EFH review aggregated from 500 m to 1km resolution. Downloaded from PACOOS
Depth Polynomial	A species-specific nonlinear function fit between CPUE and depth. Function is a second order polynomial.
Alongshore distance	The distance from the most southerly point in the study area measured along a generalized representation of the coastline.
Region	Lines drawn perpendicular to shoreline at Point Conception and Cape Mendocino used to divide study into three categorical regions.
Bathymetric Position Index	Position on seafloor relative to surrounding seafloor
Rugosity	A measure of variations in depth within a 3x3 km neighborhood
Slope	Maximum change in depth represented by a gradient
Near-bottom temperature climatology	Seasonal climatology of long-term average bottom temperature; new geostatistical model developed from FRAM trawl temperature logger dataset
Surface temperature climatology	Seasonal climatology from POES AVHRR and MODIS Aqua datasets
Surface Chlorophyll climatology	Seasonal climatology from MODIS Aqua dataset
Distance to hardbottom	Distance derived from hardbottom habitats delineated in West Coast benthic habitat maps.

Long-term average seasonal climatologies were developed for bottom temperature, sea surface temperature, and chlorophyll a concentration predictors, because we expected these to have large intra-annual seasonal variation. Data for these predictors collected between May and October were used to prepare seasonal climatologies. These months correspond to the months of data acquisition by the West Coast Groundfish Bottom Trawl Survey and during the timing of upwelling and wind relaxation periods for the study area (Bograd et al. 2009).

Near-bottom temperature was interpolated from the average temperature collected during most FRAM trawls (N=4881). Near-bottom temperate represents the average temperature when the net was on the bottom and positioned at the midpoint of each tow. A new geostatistical predictive model was created to generate a gap-free gridded prediction of bottom temperature from point samples. Data were first detrended using a second order polynomial and then ordinary kriging was applied to the residuals. Ordinary kriging was used because data exhibited approximately stationary spatial autocorrelation (though geometrically anisotropic) over the study area after trend removal. An anisotropic model with a 4 sector neighborhood was applied in ArcGIS 10 (ESRI, Inc.), with a 20 km search neighborhood bandwidth and Gaussian kernel weights to smooth variation in predictions due to the sliding local search neighborhood. Leave one out crossvalidation of the bottom temperature model indicated a root mean square error of 0.58 deg C, suggesting that the model is suitable for predicting thermal habitat at broad scales.

Depth at 500 meter resolution for the entire west coast was downloaded from the PACOOS website (http://pacoos.coas.oregonstate.edu/datasets.html). The model was created by the Active Tectonics and Seafloor Mapping Lab (COAS, Oregon State University) and previously used in spatial models for the 2005 NMFS essential fish habitat review. This dataset was chosen because it has been vetted and widely used, and because it had the best available resolution at the desired spatial extent (i.e., consistently covering the entire study region).

The 500 m bathymetry model was bilinearly resampled to 1000 m and values greater than 0 (values on land) were removed. The new 1000 m bathymetry model was used to derive bathymetric slope and rugosity estimates using the ArcGIS Spatial Analyst and the Jenness DEM Surface Tools extensions for ArcGIS, respectively. A low pass smoothing filter (10km-mean) was applied to the slope model to create a second broader spatial scale slope layer. Preliminary tests examining the correlation of both slope layers with species' CPUE indicated that the slope layer showing broader spatial scale patterns was better correlated to CPUE and it was used in all subsequent analysis. A custom raster script was used to derive a bathymetric position index from the 1000 m bathymetry raster: BPI = Int((depth - focalmean), where the focal mean was in an annulus with an inner radius of 1 cell and outer radius of 3 cells.

Since many species distributions were nonlinearly related to bathymetry, species-specific nonlinear bathymetry predictors from a second order polynomial fit between depth and CPUE were developed. Only records where presence was greater than zero were used in the fit and only significant models (F ratio, $p<0.05$) were used as candidate predictors. Species-specific coefficients were applied to the 1000 m bathymetry model to derive new layers.

Geographic position was defined using a metric to quantify alongshore distance relative to the southern-most extent of the FRAM survey domain and a categorical variable representing distinct regions. Alongshore distance was measured from the most southerly point in the study area along a generalized representation of the coastline given by an elliptical arc. Alongshore distances of all points along a line perpendicular to the arc were identical. The study area was also divided into three regions separated by Point Conception and Cape Mendocino. The alongshore variable was useful to show gradual changes in species' spatial distribution whereas the regional variable was useful for abrupt changes in species' spatial distribution. We had originally used latitude and longitude as spatial predictors, but found the alongshore gradient and regional categories vastly improved model performance.

Chlorophyll a concentration and sea surface temperature (SST) predictors were derived from POES AVHRR and MODIS Aqua sensors. Monthly composites were downloaded from the CoastWatch ERDDAP server. Monthly chlorophyll a concentration composites for 2003-2010 were taken from the MODIS Aqua sensor. When available, monthly SST composites were downloaded (mid-2007-2010) from the POES AVHRR sensor (better resolution than MODIS), but for the earlier portion of the time series, either daily composites were downloaded and used to calculate monthly means (2004-2007), or monthly SST composites were collected from the MODIS Aqua sensor (2003). Monthly composites for both chlorophyll a concentration and SST were averaged for years 2003 - 2010 to develop monthly climatologies and then monthly climatologies for the trawl season (May-October) were averaged to develop seasonal climatologies.

A seamless benthic habitat map was developed for the 2005 EFH review process from two datasets (NMFS 2005). 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. We attempted to use the same benthic habitat map and habitat categories applied in the 2005 EFH review process, but found early on that the spatial modeling approach we were using did not work with the 35 unique benthic habitat types used previously. There were too few observations in some categories to correlate groundfish observations to benthic habitat. We then attempted to classify benthic habitat into two categories based on habitat induration: hardbottom and softbottom. Early draft spatial models used two habitat categories, but after viewing draft results a reviewer suggested that we use distance to hardbottom. We changed the categorical two-level habitat variable into a signed continuous variable indicating distance to hardbottom habitats. We measured distance from the hardbottom-softbottom habitat edge, where distance into hardbottom habitats was positive and distance away from hardbottom habitats was negative. Our preliminary tests showed improvements in spatial model diagnostic measures for several species and we decided to us the continuous benthic habitat variable instead of the categorical one.

Newer versions of the benthic habitat map are available from different sources, including Active Tectonics and Seafloor Mapping Lab, but we did not use them. Newer map versions include updates where new seafloor survey information has been collected since 2005. These updates are meant to communicate the best available information. Due to survey costs and scientific priorities there is a bias towards resolving nearshore and hardbottom habitats in more detail. This bias can be difficult to disentangle from species distribution preferences and can lead to spurious predictions. We examined newer benthic habitat maps and decided to use the older 2005 version, because it provided a map classified at more consistent spatial scales across our entire spatial domain.

All predictor processing was carried out using ArcGIS 10 (Environmental Systems Research Group [ESRI], Redlands, CA), with the Spatial Analyst and Geostatistical Analyst extensions.

2.2.1.3 Spatial analytical framework

All predictor grids were co-registered on the same 1 km-resolution sampling grid projected using UTM 10N. We chose a transverse projected coordinate system to keep constant lengths, angles, and areas across the height and width of the predictor grids, and because the projection maps a region of large north-south extent with low distortion. The study area is distributed in both the UTM 10N and UTM 11N zones, but for simplicity we use only the 10 N zone. By using only one UTM zone we incur an area distortion less than 0.5% within our study area, and given the size of the study area and resolution of our analysis this distortion seems negligible.

Groundfish survey data is coupled to all predictors on the same 1 km co-registered grid. Given the ~500 m (5min x 2.2 knots) minimum distance of FRAM tows, the minimum length scale that can be resolved is approximately 1 km or two times the minimum transect length. Thus, the 1 km grid resolution chosen for spatial predictors approaches the finest possible resolution for detecting spatial patterns given the limits of the trawl sampling design data. Most spatial predictors were collected at scales shorter than 1 km and were resampled up to the 1 km scale. Some older satellite chlorophyll and SST data were at coarser resolutions (~4km) and had to be down-sampled to the 1km grid.

Horizontal positional errors are present in both tows and spatial predictor data, but these errors are likely to be small relative to 1 km. All tow positions were collected using a DGPS system with accuracy greater than 10 m or 1% of the sampling resolution. Estimating and integrating horizontal positional errors in spatial models is outside the scope of this analysis, but cross-validation accuracy assessment provides an integrated measure of the uncertainty arising from horizontal positional errors as well as other sources such as error in environmental predictor layers.

2.2.2 Model Description (Technical)

NCCOS adopted a two-stage approach that separates a model of the presence probability of a species from a model of its relative abundance when it is present. This approach has been successfully used to model highly zero-inflated marine distribution data (e.g., Stefánsson, 1996; Ver Hoef and Jansen, 2007). This technique is also referred to in the statistical literature as a hurdle model or a delta model (Cragg, 1971; Potts and Elith, 2006; Ver Hoef and Jansen 2007). In our case we refer to the two parts of the model as Stage I and Stage II. Stage I models the probability, $p_i(x,y)$, that species i is observed in a survey at location (x,y):

$$p_i(x,y) \equiv \text{Prob}[i \text{ observed at } (x,y) \text{ in a single trawl}] \quad \text{(A2.2.1; Stage I)}$$

Here, $p_i(x,y)$ is treated as a spatial random variable whose value is a probability; the details of how it is modeled are discussed below. We do not distinguish between observation and presence; the probability $p_i(x,y)$ is assumed to be equal to the probability that the species was actually present during a single tow conducted over the 8-year study period. In other words, probability of detection when the species is present is assumed to be 1; consequences of this assumption are discussed later.

Stage II models $E\{Z_i(x,y) \mid P_i(x,y)=1\}$, the long-term mean of the observed relative abundance (CPUE), $Z_i(x,y)$, of species i at location *(x,y) when the species is present:*

$$E\{ Z_i(x,y) \mid P_i(x,y)=1\} \qquad \text{(A2.2.2; Stage II)}$$

Here $Z_i(x,y)$ is a continuous random variable representing relative abundance (species specific catch weight per square kilometer of trawl-swept area), and $P_i(x,y)$ is a Bernoulli random variable whose probability of success in a single trial is given by $p_i(x,y)$. Note that $E\{A|B\}$ represents the conditional expectation operator, which returns the expected value (arithmetic average over many trials) of the random variable A, given the value of the random variable B. This expected value can be thought of as the average CPUE that would have been recorded if the same location had been visited many times, instead of only once, during the 8-year survey period, and only non-zero values were included in the average. In this model, the observed value of CPUE at each location is our single observation of the random variable $Z_i(x,y)$, conditional on the outcome of $P_i(x,y)$ at that location (0 if species *i* is absent, 1 if present). Over a 8-year period, assuming 6 hours of potential survey per day, approximately 18,000 temporally non-overlapping 15-minute trawl surveys *could have been* conducted at each location. If hypothetical repeat surveys were conducted and averaged (excluding zero observations) and if the relevant assumptions outlined later are also met, then the value of that average would approach the value given by eqn A2.2.2 with repeat surveys, although it may take many surveys for the predicted and observed means to converge.

The groundfish data are conceptually modeled as a set of outcomes of the purely spatial (non-temporal) random variables $P_i(x,y)$ (Stage I) and $Z_i(x,y)$ conditional on $P_i(x,y)=1$ (Stage II). This relies on the basic assumption that the parameters that define these random variables (described in more detail below) do not vary over time among survey years. Implications of this assumption are discussed later. The use of spatial random variables without an explicit temporal component is termed a spatial climatological approach and has been used elsewhere to map "hotspots" and "coldspots" in long-term average patterns of species distribution (e.g., Santora and Reiss, 2011). The word climatology in this context means long-term average.

Both Stage I and Stage II of the model are themselves comprised of two sub-models: a trend model and a residual model, described in more detail below. The trend models are implemented as generalized linear models (GLMs), and predict large-scale variation in a species' distribution from environmental variables. The residual models are implemented as geostatistical models (kriging) to account for spatial autocorrelation in the residuals from the trend (Cressie, 1993; Pebesma, 1998).

The GLM trend component was necessary because exploratory data analysis showed that both probability of presence (Stage I) and abundance when a species is present (Stage II) showed large-scale trends that were related to environmental variables. Notably, presence/absence often showed different large-scale spatial patterns than abundance when the species was present, motivating the two-stage approach. Other types of trend models are possible, and could be explored in future work (e.g., generalized additive models, classification and regression trees).

The geostatistical component was necessary because the data are clustered and unevenly distributed in space, and preliminary analysis after removal of large-scale trends with GLM revealed autocorrelation in the spatial pattern of residuals. When this is the case, spatial dependence must be explicitly modeled to obtain unbiased estimates of GLM coefficients, as well as to properly model uncertainty at unsampled locations (Cressie, 1993; Chiles and Delfiner, 1999). A major advantage of the hybrid GLM-geostatistical approach is that predictions are accompanied by spatially explicit estimates of uncertainty, because spatial dependence in error fields is explicitly modeled (Pebesma, 1998).

The final model prediction of CPUE is the product of Stage I and Stage II maps, which gives the unconditional expected value of $Z_i(x,y)$:

$$E\{ Z_i(x,y) \} = p_i(x,y) * E\{Z_i(x,y) \mid P_i(x,y)=1\} \qquad \text{(A2.2.3; Stage I x II)}$$

This result follows directly from application of laws of probability and conditional expectation for random variables (Cragg, 1971; Ross, 2007). The final predicted value represents the average species catch per unit effort (kg/ha) that would be observed if a site was surveyed repeatedly (using the same standardized tows), including times when the species was not seen as values of 0.

The modeling process can be summarized as follows:

1. Transform dependent variables and potential predictor variables for linearity.
2. Divide data into training and validation (“holdout”) subsets for cross-validation purposes.
3. Stage I trend model: Use a GLM (binomial distribution, logit link) to generate a predictive map of the mean probability of species occurrence.
4. Stage I residual model: Use ordinary indicator kriging (OIK) to predict the “residual” probability map, where “residual” is defined as the probability that the regression model leads to an incorrect classification of the presence state ($P_i(x,y)$) of a given location.
5. Final Stage I model: Adjust the trend-predicted probability map using the kriged residual probability map from step 4. The trend from step 3 and residual from step 4 are combined using probability laws.
6. Stage II trend model: Use a GLM (normal distribution, Box-Cox link) to generate a predictive map of the mean abundance of a species when it is present. The Box-Cox link indicates that data were transformed for normality for this part of the analysis using a Box-Cox type transformation (Box and Cox 1964), described further below, and back-transformed for final maps.
7. Stage II residual model: Use Simple Kriging (SK) to predict residual map of the regression model of abundance.
8. Final Stage II model: Add the trend map from step 6 and the residual map from step 7.
9. Final Stage I x II model prediction: Multiply the predicted probability of occurrence at each location by the predicted abundance if present to produce the final prediction of the expected value (long-term average) of abundance at each location.
10. Relative uncertainty calculation: scaled relative uncertainty values were calculated for the trend, residual, and final models for Stage I and Stage II, and for the final Stage IxII prediction.
11. Model evaluation, cross-validation, and relative uncertainty calibration.
12. Post-processing

The sections below describe each of these steps in detail.

Unless otherwise noted, all predictive modeling analyses were carried out in Matlab R2011b (The Mathworks, Natick, MA), with the Statistics, Mapping, and Image Processing toolboxes (Mathworks), mGstat (Hansen 2009, http://mgstat.sourceforge.net/), ROC (Cardillo 2008), partest (Cardillo 2008), lowess (Burkey 2009), ploterr (Zörgiebel 2008), boxcoxlm (Dror 2006), and additional custom code available by contacting the authors. Geostatistical algorithms (kriging, generalized least squares estimation of trend model coefficients, variogram estimation, and variogram model fitting) were implemented by calling the program gstat (standalone version 2.5.1; Pebesma and Wesseling 1998; http://www.gstat.org/) from within Matlab, with the help of the mGstat toolbox. GLM model selection was carried out by calling the R package glmulti (Calcagno and Mazancourt 2010, Calcagno 2011, http://cran.r-project.org/web/packages/glmulti/index.html) from within Matlab. All Matlab code is available for review.

Step 1: Transformation of variables

Transforming independent variables in a multiple linear regression context for normality, centrality, and homogeneity of variance is often desirable for stabilizing estimates of regression parameters, and can also help to linearize relationships between predictors and response (Sokal and Rohlf, 1995). The family of power-law transformations studied by Box and Cox (1964) is particularly useful for improving both normality and linearity. A Box-Cox transformation is defined as follows, where X denotes the original variable and X* the transformed variable:

$$X^* = \begin{cases} X^{\lambda}, \text{if } \lambda \neq 0 \\ \ln(X), \text{if } \lambda = 0 \end{cases} \qquad \text{(A2.2.4)}$$

Catch per unit effort at non-zero locations were first transformed for normality using a Box-Cox power transform whose parameter λ was chosen by a maximum likelihood procedure (Box and Cox, 1964; Dror, 2006).

We investigated linearizing the relationship between the each transformed species' catch per unit effort and each independent variables using the Box-Tidwell procure (in R CAR package), but found widely different transformations were selected. We chose not to use different transformations, although in the future one could have a different transformation for each species that maximized linearity between predictors and responses. Instead, we transformed chlorophyll a concentration using a logarithmic transformation [Log10(X+1)] and converted depth from negative to positive values to follow convention. Note that the bathymetry transformation changes the sign of the linear relationship between the variable and response; care must therefore be taken in interpreting the signs of regression coefficients for transformed predictors.

Transformed predictor variables were centered and standardized prior to each GLM fit, using the set of values of each predictor variable at the data locations under consideration (centering and standardization was performed each time just prior to running the GLM, because different patterns of missing predictor data could cause different data points to be used, requiring re-centering and re-standardization).

Step 2: Selection of cross-validation data

50% of the observation locations were selected at random to be used in subsequent model-fitting (henceforth referred to as the training set), with the remaining 50% withheld for cross-validation (henceforth referred to as the validation or holdout set). All model selection and model fitting was carried out using only the training set. Cross-validation statistics were calculated by comparing model predictions at the holdout locations to the true data values at the holdout locations. Final predictive maps, however, used all available data by applying the models selected and fit based on training data to the entire original dataset. Cross-validation error estimates are thus conservative in the sense that they were derived from a model fit to a dataset one half the size of the final dataset.

Step 3: Stage I trend model

The trend component of the Stage I model, $\mu_i^I(x,y)$, was estimated as follows.

Observed data $Z_i(x,y)$ were first transformed to a binary indicator variable $P_i(x,y)$, whose value was 1 if $Z_i(x,y)>0$ and 0 otherwise. The initial set of 11 potential predictor variables was then pre-screened to remove any predictors whose pattern of missing values would too greatly influence the data points that could be used to estimate the GLM. Pre-screening criteria are given in Table A2.2.3.

Predictor variables not excluded in the pre-screening process were centered, standardized, and the R package 'glmulti' (Calcagno and Mazancourt, 2010; Calcagno, 2011) was used to search for the model with lowest AICc from the set of possible generalized linear models, allowing two-way interaction effects to be included, but requiring that both corresponding main effects be in the model if an interaction term were to be included (marginality requirement). GLM model used a binomial distribution with a logit link function (Fox, 2008).

The search method used depended on the size of the possible model space, which was restricted by the elimination of some potential predictors in the pre-screening stage (above) and by an upper bound on the number of terms determined by the number of observations. The number of terms in a model (not including the intercept) was restricted to be no greater than the number of observations divided by 10 (Sokal and Rohlf, 1995; Fox, 2008). If the number of predictors and/or maximum number of terms was sufficiently small, then the model space was searched exhaustively for the model with the lowest corrected Akaike's Information Criterion (AICc; Sokal and Rohlf, 1995). If the number of predictors and/or maximum number of terms was intermediate, then a genetic algorithm with the default parameters and stopping criteria of deltaM=0.5, conseq=5 was used (Calcagno and Mazancourt, 2010; Calcagno, 2011). If the number of predictors and/or maximum number of terms was too large for the genetic algorithm to enumerate the model space, then an exhaustive search was performed of all possible models with 5 or fewer main effects (allowing for two-way interactions within each subset).

The selected model structure was then fit to the data using Matlab Statistics Toolbox function 'glmfit', which implements standard Generalized Linear Model fitting by iteratively re-weighted least-squares (Bjorck, 1996; Fox, 2008). As before, a binomial distribution and logit link function were used. Use of binomial distributions and logit link functions involves assumptions that are discussed later. Parametric ± 1 standard error confidence bounds on GLM estimates were calculated using Matlab function 'glmval' (following equations in Fox, 2008).

A standard array of GLM diagnostics was produced, including effect tests, deviance goodness-of-fit tests, several 'pseudo-R^2' measures designed for logistic regression, residual leverage and influence plots, and a variety of other diagnostic measures. An ROC curve analysis was also performed to assess accuracy of the Stage I trend prediction.

Step 4: Stage I residual model

The residual component of the Stage I model, $\varepsilon_i^I(x,y)$, was estimated as follows. First, ROC curve analysis was used to determine the optimal cutoff value of the trend probability, $\mu_i^I(x,y)$, to use for classifying the presence/absence data (Cardillo, 2008). ROC curve analysis identifies the cutoff probability for classification that optimizes the tradeoff between sensitivity and specificity, given a training dataset. This cutoff was then applied to transform the trend prediction map $\mu_i^I(x,y)$ into a binary classification map (0=predicted absence, 1=predicted presence). Use of this ROC curve method to classify the trend can result in global bias of the classification toward the less-common class (usually presences), and the implications of this bias are discussed later.

A binary indicator variable (the "misclassification indicator") was then created that took the value 1 if the binary classification map based on the trend was correct at a data location, and 0 if not. Indicator variograms were estimated and modeled from this misclassification indicator, and Ordinary Indicator Kriging (OIK) was used to produce a map of predicted misclassification probabilities. Kriging predictions >1 or <0 were set to 1 or 0, respectively, to satisfy order relations for probabilities (Deutsch and Journel, 1998; Pebesma, 1998), and the resulting map was the residual component of Stage I, $\varepsilon_i^I(x,y)$. Because misclassification of 0's as 1's and 1's as 0's were considered equivalent, the OIK geostatistical model makes the assumption that the spatial patterns of misclassification of 1's and 0's are equivalent (symmetry). Implications of this symmetry assumption are discussed later.

Variogram models were fit automatically by a non-linear weighted least-squares minimization algorithm (Pebesma, 1998; Pardo-Igúzquiza, 1999), using weights proportional to N/h^2 (the number of pairs of observations used to estimate each observation divided by the square of the lag distance), as described by Pebesma (1998). Following standard geostatistical practice, the functional form of the variogram and an initial-guess parameter set was specified prior to the least-squares minimization by inspection of the empirical variogram (Issaks and Srivistava, 1989; Cressie, 1993; Deutsch and Journel, 1998; Chiles and Delfiner, 1999).

OIK produces parametric estimates of uncertainty (kriging standard error) for each location in the residual prediction map (Pebesma, 1998; Deutsch and Journel, 1998). An ROC curve analysis was also performed to assess accuracy of the Stage I residual prediction.

Step 5: Final Stage I model

Because the trend and residual components of the Stage I model are probabilities, they can be combined using the laws of conditional probability to arrive at the full Stage I model as follows (Ross, 2007):

$p_i\,(x,y)$ = Prob([trend model predicts *i* is present AND trend model is not wrong] OR [trend model predicts *i* is not present AND trend model is wrong]) (A2.2.5)

which can be translated to,

$$p_i(x,y) = \mu_i^I(x,y) \cdot (1-\varepsilon_i^I(x,y)) + (1-\mu_i^I(x,y)) \cdot \varepsilon_i^I(x,y) \qquad \text{(A2.2.6)}$$

which simplifies to the final Stage I model:

$$p_i(x,y) = \mu_i^I(x,y) + \varepsilon_i^I(x,y) - 2 \cdot \mu_i^I(x,y) \cdot \varepsilon_i^I(x,y) \qquad \text{(A2.2.7)}$$

Parametric ± 1SE confidence intervals for the final Stage I model, $p_i(x,y)$, were derived by applying eqn A2.2.7 to the parametric confidence intervals for $\mu_i^I\,(x,y)$ and $\varepsilon_i^I\,(x,y)$ calculated using the GLM model and the geostatistical (OIK) model, respectively.

Step 6: Stage II trend model

The trend component of the Stage II model, $\mu_i^{II}\,(x,y)$, was estimated as follows. Data at non-zero locations were first transformed for normality using a Box-Cox power transform whose parameter λ was chosen by a maximum likelihood procedure (Box and

Cox 1964, Dror 2006). The initial set of 11 potential predictor variables was then pre-screened to remove any predictors whose pattern of missing values would too greatly influence the data points that could be used to estimate the GLM. Pre-screening criteria are given in Table A2.2.3 .

The predictor variables were centered, standardized, and the R package 'glmulti' (Calcagno and Mazancourt, 2010; Calcagno, 2011) was used to search for the model with lowest AICc in the same way described for Stage I (above), except that in this case the GLM model used a normal distribution with a Box-Cox link function (Fox, 2008) (in practice, we applied a Box-Cox transformation prior to GLM modeling, used an identity link, and then back-transformed to the original scale).

The selected model structure was then fit to the data using Matlab Statistics Toolbox function 'glmfit', which implements standard Generalized Linear Model fitting by iteratively re-weighted least-squares (Bjorck, 1996; Fox, 2008). A normal distribution and identity link function were used. Use of the normal distribution here involves assumptions that are discussed later. Parametric ± 1 standard error uncertainty bounds on GLM estimates were calculated using Matlab function 'glmval' (following equations in Fox, 2008).

Because spatial autocorrelation biases the estimation of GLM parameters, we followed an iterative procedure to fit the final GLM in gstat (Pebesma, 1998; Chiles and Delfiner,1999).

1. Calculate residuals and estimate residual variogram
2. Re-calculate fit with gstat, using residual variogram
3. Re-calculate residuals and repeat fitting with gstat (steps 2 and 3) until residual variogram has converged (determined by inspection).

A standard array of GLM diagnostics was produced, including effect tests, goodness-of-fit F tests, R^2 and several 'pseudo-R^2' measures to allow comparison with the Stage I logistic regression, residual leverage and influence plots, and a variety of other diagnostic measures.

Step 7: Stage II residual model

The residual component of the Stage II model, $\varepsilon_i^{II}(x,y)$, was estimated as follows. First, residuals from the trend model fit were calculated by subtracting the observed values from predicted values. Residuals were calculated in Box-Cox transformed space to satisfy normality assumptions of geostatistical methods. Residual variograms were then estimated and modeled using gstat, and Simple Kriging (SK) was used to produce a map of predicted residuals. The resulting map was the residual component of Stage II, $\varepsilon_i^{II}(x,y)$.

Variogram models were fit automatically by a non-linear weighted least-squares minimization algorithm (Pebesma, 1998; Pardo-Igúzquiza, 1999), using weights proportional to N/h^2 (the number of pairs of observations used to estimate each observation divided by the square of the lag distance), as described by Pebesma (1998). Following standard geostatistical practice, the functional form of the variogram and an initial-guess parameter set was specified prior to the least-squares minimization by inspection of the empirical variogram (Issaks and Srivistava, 1989; Cressie, 1993; Deutsch and Journel, 1998; Chiles and Delfiner, 1999).

SK was also used to produce parametric estimates of uncertainty (kriging standard error) for each location in the residual prediction map (Pebesma, 1998; Deutsch and Journel, 1998).

Step 8: Final Stage II model

In Box-Cox transformed space, the final Stage II model is simply the sum of trend and residual components:

$$\mathrm{E}\{Z_i^{Transformed}(x,y)|\,P_i(x,y)=1\}=\mu_i^{II}(x,y)+\varepsilon_i^{II}(x,y) \qquad \text{(A2.2.8)}$$

The result can be back-transformed to yield a prediction in the original units of CPUE:

$$\mathrm{E}\{Z_i\ (x,y)\,|\,P_i(x,y)=1\}=\begin{cases}(\mathrm{E}\{Z_i^{Transformed}(x,y)\,|\,P_i(x,y)=1\})^{1/\lambda}, \text{if } \lambda\neq 0\\ \exp(\mathrm{E}\{Z_i^{Transformed}(x,y)\,|\,P_i(x,y)=1\}), \text{if } \lambda=0\end{cases} \qquad \text{(A2.2.9)}$$

Back-transforms were constrained to lie between 0 and 110% of the observed data maximum. Back-transformation in this way yields an estimate of the mean that is biased to produce lower values than the true arithmetic mean on the original scale; the bias is proportional to the magnitude of the abundance prediction and to the prediction variance. Effectively, the highest and most uncertain values are downweighted, resulting in more conservative (lower) predictions of expected abundance. This systematic bias can be corrected with a simple formula, although in this version the uncorrected back-transformed estimates are shown, resulting in systematic underestimation of very high abundances, especially in places where model predictions are very uncertain.

Parametric ± 1SE confidence intervals for the final back-transformed Stage II model, $\mathrm{E}\{\,Zi(x,y)\mid P_i(x,y)=1\}$, were derived by applying eqn A2.2.8 and A2.2.9 to the parametric confidence intervals for μ_i^{II} *(x,y)* and ε_i^{II} *(x,y)* calculated using the GLM model and the geostatistical (SK) model, respectively.

Step 9: Final Stage I x II model

Stage I and Stage II models were combined as described in eqn A2.2.3 to produce each predictive map of the unconditional expected value of CPUE, which we will refer to as the “Stage I x II” prediction map or $E\{Z_i(x,y)\}$. Specifically, $E\{Z_i(x,y)\}$ is equal to the product of eqn A2.2.9 (the final back-transformed Stage II prediction) and eqn A2.2.7 (the final Stage I model prediction). Note that the Stage I x II predictions are in back-transformed units (CPUE).

Parametric uncertainty bounds (± 1SE) for the final Stage I x II maps were obtained by plugging the confidence intervals for μ_i^{I} *(x,y)*, ε_i^{I} *(x,y)*, μ_i^{II} *(x,y)*, and ε_i^{II} *(x,y)* described above into eqn A2.2.7 and A2.2.9 and multiplying eqn A2.2.7 by eqn A2.2.9 for each set of uncertainty bounds.

Step 10: Relative uncertainty calculations

In order to simplify comparison of uncertainties among different model components, uncertainties were converted to relative values that fall between 0 and 1, with 0 representing low uncertainty (high certainty) and 1 representing high uncertainty (low certainty). The implications of a particular relative uncertainty value for model performance can be determined by examining the diagnostic tables, which give cross-validation error statistics for each certainty class, and the cross-validation relative uncertainty calibration plots.

Stage I

The relative uncertainty of Stage I model predictions is expressed as the scaled negative log (odds ratio), *SNLOR*. The negative log odds ratio, *NLOR*, is the negative natural logarithm of the ratio of the odds of correct binary classification (absence= 0, presence= 1) using the Stage I model to the odds of correct binary classification under a null model:

$$NLOR = -\ln\left(\frac{Odds_{model}}{Odds_{null}}\right) \qquad \text{(A2.2.10)}$$

To calculate the odds of correct classification under the Stage I model, $Odds_{model}$, we first consider uncertainty of the Stage I model prediction relative to the cutoff probability *c* used for binary classification (in this case, the optimal cutoff probability determined by ROC curve analysis). The uncertainty around the Stage I model prediction *p* can be modeled by a normal curve on the logit scale, with mean equal to the Stage I prediction and standard deviation equal to the larger of the upper and lower 1SE confidence intervals:

$$z_p \sim N(\text{logit}[p], \max(\text{logit}[p^{+1SE}] - \text{logit}[p], \text{logit}[p] - \text{logit}[p^{-1SE}]))$$
(A2.2.11)

Then the probability of the true predicted value lying above the cutoff probability c is given by

$$p_{above} = \text{Prob}(z_p > \text{logit}(c)) \qquad \text{(A2.2.12)}$$

and the probability of the true predicted value falling below the cutoff probability is

$$p_{below} = \text{Prob}(z_p < \text{logit}(c)) \qquad \text{(A2.2.13)}$$

The classifier itself is subject to error, which we estimate by its performance in cross-validation: the true positive ($\hat{p}_{TP}$), true negative ($\hat{p}_{TN}$), false positive ($\hat{p}_{FP}$), and false negative ($\hat{p}_{FN}$), rates of the classifier from the cross-validation confusion matrix at cutoff value c. The odds of correct classification using the Stage I model can then be calculated as:

$$Odds_{model} = \frac{p_{above} \cdot \hat{p}_{TP} + p_{below} \cdot \hat{p}_{TN}}{p_{above} \cdot \hat{p}_{FP} + p_{below} \cdot \hat{p}_{FN}} \qquad \text{(A2.2.14)}$$

To calculate the odds of correct classification under a null model, $Odds_{null}$, we consider a null model in which the true and predicted presence/absence (1/0) states are given by Bernoulli random variables with probabilities p_1 (equal to the global prevalence of the species) and c (equal to the optimal cutoff probability from ROC curve analysis), respectively. Then the null odds of correct classification are:

$$Odds_{null} = \frac{(1 - p_1) \cdot c + p_1 \cdot (1 - c)}{(1 - p_1) \cdot (1 - c) + p_1 \cdot c} \qquad \text{(A2.2.15)}$$

For a given set of cross-validation error rates ($\hat{p}_{TP}$, $\hat{p}_{TN}$, $\hat{p}_{FP}$, and $\hat{p}_{FN}$), the minimum and maximum possible values of the *NLOR* are:

$$Odds_{model}^{min} = \min\left(\frac{\hat{p}_{TP}}{\hat{p}_{FP}}, \frac{\hat{p}_{TN}}{\hat{p}_{FN}}\right), \; Odds_{model}^{max} = \max\left(\frac{\hat{p}_{TP}}{\hat{p}_{FP}}, \frac{\hat{p}_{TN}}{\hat{p}_{FN}}\right) \qquad \text{(A2.2.16)}$$

The scaled *NLOR*, *SNLOR*, is calculated so that *SNLOR*=0 at the minimum possible value of the *NLOR* and *SNLOR*=1 at the maximum possible value of the *NLOR*:

$$SNLOR = \frac{\ln(\frac{Odds_{model}^{\max}}{Odds_{null}}) - \ln(\frac{Odds_{model}}{Odds_{null}})}{\ln(\frac{Odds_{model}^{\max}}{Odds_{null}}) - \ln(\frac{Odds_{model}^{\min}}{Odds_{null}})} \quad \text{(A2.2.17)}$$

Values of *SNLOR* closer to 0 indicate model predictions that have relatively high odds of being correct compared to a null model (high certainty), whereas values closer to 1 indicate model predictions that have relatively low odds of being correct compared to a null model (low certainty). Relative uncertainties were calculated in this way for the Stage I trend, Stage I residual, and the final Stage I model, using the cross-validation ROC curve cutoff *c* and cross-validation error rates ($\hat{p}_{TP}$, $\hat{p}_{TN}$, $\hat{p}_{FP}$, and $\hat{p}_{FN}$) determined from the ROC analysis of trend, residual, and final Stage I predictions, respectively. Below, the final Stage I relative uncertainty is denoted $\sigma^{I,rel}(x,y)$, and is equal to the value of SNLOR for the final Stage I model for species *i* at location *(x,y)*.

Stage II

Relative uncertainty of Stage II trend, residual, and final model predictions were calculated as the ratio of prediction variances to the appropriate error variance (trend prediction variance: total sample variance minus residual variogram sill; residual variance: residual variogram sill; final prediction variance: total sample variance). Below, the final Stage II relative uncertainty is denoted $\sigma^{II,rel}(x,y)$.

Stage IxII

The relative uncertainty of final Stage IxII model predictions was calculated by combining the relative uncertainties of final Stage I and Stage II models as follows:

$$\sigma_i^{IxII,rel}(x,y) = p_i(x,y) \cdot [\sigma_i^{II,rel}(x,y)] + (1 - p_i(x,y)) \cdot \sigma_i^{I,rel}(x,y) \quad \text{(A2.2.18)}$$

The rationale behind eqn A2.2.18 is that the Stage II relative uncertainty applies if the species is present (which is true with probability $p_i(x,y)$), whereas the Stage I relative uncertainty applies if the species is absent (which is true with probability $[1- p_i(x,y)]$).

Step 11: Model evaluation and uncertainty calibration

In addition to the standard GLM effect tests and diagnostics, model predictive performance was evaluated in and out of the training set using a variety of error statistics, error plots and ROC curve analysis. As a final summary of model performance in cross-validation and aid to the user in interpreting relative uncertainty values for the final Stage IxII model, an uncertainty calibration plot was produced. For each location in the holdout set, the model developed from training data was used to predict the value at that location, and the magnitude of the difference between actual and predicted values (absolute error) was plotted versus the Stage I x II relative uncertainty value. Robust linear loess smoothing lines (Burkey, 2009) are plotted to show how actual out-of-set average prediction errors relate to parametric relative uncertainty estimates. Separate lines are plotted for overall error, and error when the species was present (since most species are relatively rare in any given survey, presences are harder to predict than absences). Similar relative uncertainty calibration plots are produced for Stage I predictions (presence/absence).

Uncertainty calibration plots, ROC analyses, error statistics, and other model evaluation diagnostics are included in the diagnostic table at the end of this report, and in the Online Supplements for each species.

Model Diagnostics and Display

Model predictions were evaluated using model diagnostic measures, visual comparisons with input observations and reviewer expertise. In some cases model predictor sets were modified to exclude potential predictors, because of evidence of overfitting (gauged by the degradation of model performance in cross-validation). The models were rerun without the selected predictors and if model overfitting was reduced the new model was used to make groundfish predictions. Excluded predictors are identified for each species in Table A2.2.3.

Model predictions were clipped by relative uncertainty, known latitude and depth limits for each species and the area of the NMFS trawl survey sampling domain. Relative uncertainty was calculated as part of the modeling process and was used to eliminate predictions with relative uncertainty estimates greater than 1.1 in Stage I, and 2.0 in stage II and stage IxII outputs. Species specific depth and latitude limits were taken from published literature including: Love et al. (2002), Love and Yoklavich (2008), and the Habitat Use Database (HUD) fish species details compiled by the Northwest Fisheries Science Center, Fishery Resource Analysis & Monitoring Division. Predictions within known depth and latitude limits are shown and predictions outside the limits were eliminated. Predictions outside of the NMFS trawl sampling domain were eliminated, such as the Cowcod Conservation Areas or in areas hazardous to fish in.

As part of the model validation process, probability of occurrence (Stage I) predictions were assessed for bias. Bias was computed by applying the GLM and spatial autocorrelation parameters fitted to the training trawl dataset to predict probability of occurrence at testing dataset locations. The difference between the predicted and observed probability of occurrence was used to compute a bias correction multiplier which was then used to correct probability of occurrence predictions for all final models. Table A2.2.4 shows the bias correction factor for each species. It should be noted that this bias correction corrects for the bias in Stage I (occurrence probability), but not for any bias that may be present in Stage II (conditional abundance), which is discussed above.

Table A2.2.4: Bias correction factors applied to the final species predictive models.

Species	**Bias Correction Factor**
Sablefish	1.12
Yelloweye rockfish	0.10
Petrale sole	0.92
Longspine thornyhead	0.98
Greenstriped rockfish	0.77
Darkblotched rockfish	0.61
Dover sole	1.13
Lingcod	0.75
Shortspine thornyhead	1.00
Pacific ocean perch	0.40
Chilipepper	0.61

NCCOS Results

Overall, diagnostic statistics indicated that most models were successful in describing aspects of species distribution, although model performance varied over space and from species to species. Tables A2.3, A2.4, A2.2.5, and A2.2.6 summarize the relative importance of different environmental predictor variables across the predictive models, and model variance components, respectively. The relative importance of different model components (trend, spatial model, 'white noise' error term) varied from Stage I to Stage II and among species. Model performance also varied, and any application of these models should consider the performance metrics most relevant to the application in question. Table A2.2.6 summarizes several selected cross-validation performance diagnostics from predictive models and gives a qualitative assessment (e.g., poor, good, excellent) of each model based on a combination of the Area under Curves (AUC), Spearman's rank correlation coefficients and mean absolute error calculated on cross-validation holdout datasets.

We present the predicted probability of occurrence and abundance maps for the six focal species and five additional species in Figs. A2.1 to A2.23.

Table A2.2.5: Variance components (percentages of all variance) for 10 groundfish species models developed by NCCOS.

	Stage I			Stage II		
Species	Trend	Spatial Noise	White Noise	Trend	Spatial Noise	White Noise
Sablefish	80.44	4.78	14.78	30.51	0.00	69.49
Yelloweye rockfish	93.15	4.26	2.59	40.26	0.00	59.74
Petrale sole	97.75	0.00	2.25	21.12	7.43	71.45
Longspine thornyhead	99.29	0.00	0.71	72.50	9.96	17.55
Greenstriped	99.06	0.13	0.80	41.24	10.90	47.86
Darkblotched rockfish	97.63	0.82	1.56	41.54	6.83	51.63
Dover sole	82.36	6.51	11.13	57.28	14.71	28.01
Lingcod	98.85	0.20	0.96	28.73	2.64	68.63
Shortspine thornyhead	93.89	0.00	6.11	27.40	27.17	45.42
Pacific ocean perch	98.99	0.38	0.63	53.17	8.48	38.35

Table A2.2.6:

	Qualitative		R	% correct within 1SD	Mean Absolute Error	AUC	
Species	Stage I	Stage IxII	Stage IxII	Stage IxII	Stage IxII	Stage I	Stage IxII
Sablefish	Excellent	Good	0.56	80.10	1.75	0.88	0.79
Yelloweye rockfish	Excellent	Poor	0.27	52.94	0.70	0.85	0.65
Petrale sole	Excellent	Poor	0.39	72.36	1.15	0.96	0.69
Longspine thornyhead	Excellent	Excellent	0.87	75.53	2.38	0.99	0.94
Greenstriped rockfish	Excellent	Good	0.65	72.81	5.56	0.93	0.80
Darkblotched rockfish	Excellent	Fair	0.57	68.83	0.86	0.92	0.76
Dover sole	Excellent	Good	0.74	71.57	4.92	0.90	0.87
Lingcod	Excellent	Fair	0.45	72.59	1.26	0.89	0.71
Shortspine thornyhead	Excellent	Good	0.62	76.50	0.93	0.97	0.80
Pacific ocean perch	Excellent	Fair	0.49	67.65	4.18	0.94	0.73

2.2.3 Summary and implications of model assumptions

The predictive modeling approach described above makes a number of assumptions. To the extent these assumptions are violated, accuracy of predictions and uncertainty estimates may suffer. In this section we briefly review the major assumptions and their implications. The degree to which violations of model assumptions affect the performance of any given model can be assessed by considering the cross-validation performance statistics and reported in diagnostic tables.

2.2.3.1 Important general assumptions

Stationarity of pattern over time among years

Statistically, stationarity in this context means that the region-wide mean, variance, and spatial structure of abundance and occurrence patterns do not change over the time period we studied. Ecologically, stationarity implies that the ecosystem has not undergone any fundamental shifts in patterns and processes (e.g., climate trends, ocean climate regime shifts, introduced species, changes in patterns of human activities like fishing). If this assumption is violated, temporal variation will show up as non-spatially structured error ("white noise") in the model result. Model parameters and predictions may also be biased (cross-validation errors will not be centered at 0). The predicted spatial pattern may be an amalgam of different patterns that occurred at different time periods (e.g., "smearing" of hotspots that moved from year to year). If there are major changes in the underlying processes, the model will also be less generalizable to other time periods.

Stationarity of environmental predictor climatologies

The use of long-term climatologies of time-varying environmental predictors (such as SST and stratification), assumes that the long-term mean spatial patterns of these variables have not changed over time. Major changes in the underlying environmental patterns and processes will make the model less generalizable to other time periods.

Perfect detectability; freedom from other kinds of sample bias

To the extent that a given species is not perfectly detectable by the sampling protocol, relative occurrence and abundance indices will be biased compared to true abundance and occurrence values. Given the diversity of fishes, life-history characteristics and habitats in the study area, the survey did not equally detect and enumerate species. Unequal biases, systematized by the standard survey protocol, arise from a combination of factors including: gear type, mesh size, tow length and speed, surveyed and omitted habitats, and species life-history characteristics. Predictions from this model should be considered relative, rather than absolute, estimates of occurrence and abundance. Severely undersampled species or life-stages may require other survey and modeling approaches to improve information.

Constant relationship between sampling effort, relative indices of occurrence and abundance, and true values of occurrence and abundance

Not only are species unlikely to be perfectly detectable, the relationship between our relative indices of occurrence and abundance and the true values of occurrence and abundance could vary in time and space, depending on differences in observers, weather conditions, animal behavior, etc. Such variation introduces an unaccounted for source of measurement error into data.

Important Stage I assumptions

Binomial distribution and logit link function

To the extent that these distributional assumptions are violated, trend predictions may be biased and parametric confidence intervals inaccurate.

Use of receiver operating characteristic (ROC) curve optimal cutoff analysis to classify residuals from the trend model

Use of the ROC classifier may introduce bias into the final presence probability estimates at the expense of balancing overall sensitivity and specificity. We have estimated this bias using cross-validation and corrected for it in final presentation of model results.

Symmetry assumption for misclassification probability field

Misclassification of absences as presences may not show the same spatial pattern as misclassification of presences as absences; if that is the case, then model predictions may be biased and the model may perform better for one type of misclassification than for others, even though parametric uncertainty estimates are the same.

Important Stage II assumptions

Normality and linearity of Box-Cox transformed predictors and responses in the Stage II trend model

We assume that the Box-Cox transform in Stage II is sufficient to achieve normality of residual variances and linearity of underlying response-predictor relationships. Since the underlying fish relative abundance data are based on counts (divided by area swept to create a quasi-continuous density estimate), this requires that we assume the continuous Box-Cox transformed Gaussian distribution used to represent non-zero relative abundance is an adequate approximation to the underlying discrete probability distribution. The appropriateness of these assumptions is difficult to test directly and the reader should rely on cross-validation performance statistics to judge the extent to which these assumptions were approximately correct.

Trans-Gaussian assumption in the Stage II residual (geostatistical) model

Simple Kriging also assumes approximate normality; therefore the adequacy of the Box-Cox transformation to achieve normality of the residual distribution is also important to the accuracy of the kriging prediction (especially the validity of the kriging variance).

Back-transform issues (extrapolation of the CDF tail)

When back-transforming Stage II predictions, we have arbitrarily cut off the upper end of the distribution at 110% of the data maximum, which may not always be appropriate. This is only expected to influence the highest predicted values.

Important Stage IxII assumptions

Separability of abundance and presence/absence patterns

We have assumed that abundance is conditionally independent of presence/absence (that is, abundance can be modeled independently of presence probability). If this assumption is violated, then the Stage IxII estimates will be biased. The direction of this bias will depend on the sign of the dependence, and on the Box-Cox transformation parameter. The degree of bias in predictions can be assessed (and corrected for) by examining cross-validation bias statistics in the diagnostic tables.

Table A2.3: Probability of occurrence parameters included in the plotted NCCOS models. "X" indicates a covariate used as a main effect, "Y" indicates a covariate used as part of an interaction term, and "N/A" indicates a term that was omitted from the model.

Species	Depth	Depth Polynomial	Alongshore distance	Region	Bathymetric Position Index	Rugosity	Slope	Near-bottom temperature	Surface temperature	Surface Chlorophyll	Distance to hardbottom
Sablefish	X	X	Y	X	Y	Y	Y	X	Y	Y	
Yelloweye rockfish	X		X		X				X	X	
Petrale sole	X	Y	Y	X	Y	Y	Y	X	Y	X	Y
Longspine thornyhead	X	X	X	X	Y	X	X	X	X	Y	
Greenstriped rockfish	X	N/A	X	Y	X	X		X	Y	X	X
Darkblotched rockfish	X	X	X	X					X		
Dover sole	X	X	Y	X	X	Y	X	X	Y	X	X
Lingcod	X	Y	X	X	Y	X	X	X	X	X	
Shortspine thornyhead	X	X	X	X	Y		X	Y	Y	X	Y
Pacific ocean perch		X	Y	X				X			
Chilipepper	Y	X	X	X	X	Y		X	X		X

Table A2.4: Abundance parameters included in the plotted NCCOS models. “X” indicates a covariate used as a main effect, “Y” indicates a covariate used as part of an interaction term, and “N/A” indicates a term that was omitted from the model.

Species	Depth	Depth Polynomial	Alongshore distance	Region	Bathymetric Position Index	Rugosity	Slope	Near-bottom temperature	Surface temperature	Surface Chlorophyll	Distance to hardbottom
Sablefish	X	X	Y	Y			X		Y	Y	Y
Yelloweye rockfish			X		X		X	X			
Petrale sole	X	Y	Y	X	Y	X	Y	Y	X	X	Y
Longspine thornyhead	X	Y	Y	X	Y	X	X	X	X	Y	Y
Greenstriped rockfish	Y	N/A	Y	X	X		Y	X	X	X	X
Darkblotched rockfish	X	X			X			X			
Dover sole	X	X	Y	X		Y	X		Y	Y	X
Lingcod		X			X			Y	X	X	
Shortspine thornyhead	Y	Y	X		Y		Y	Y	X	X	Y
Pacific ocean perch		X	X				X	X	X		
Chilipepper	Y	X		X	X	Y		Y			

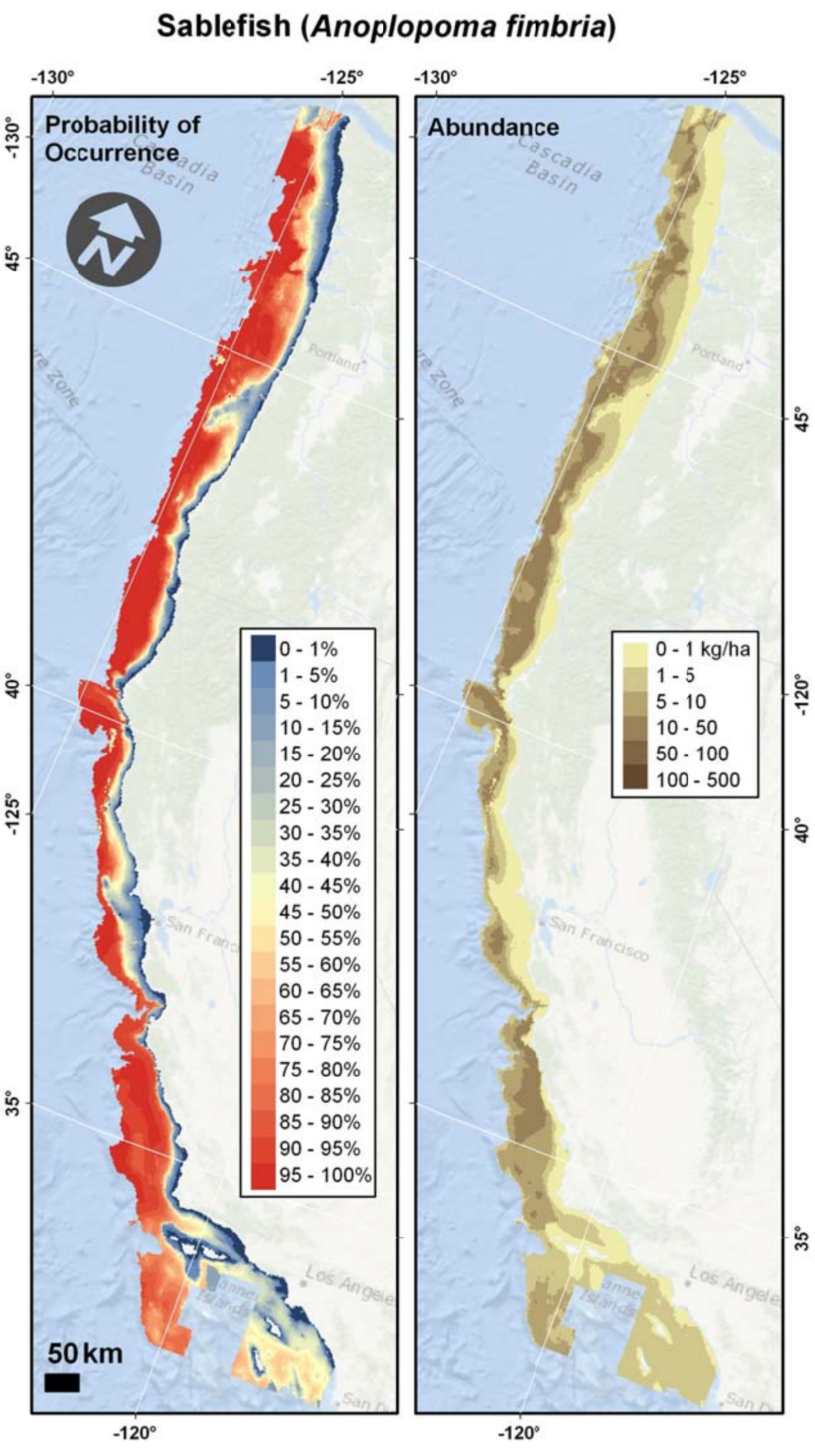

Figure A2.1: Sablefish mean predicted probability of occurrence and mean predicted abundance. NWFSC model projections.

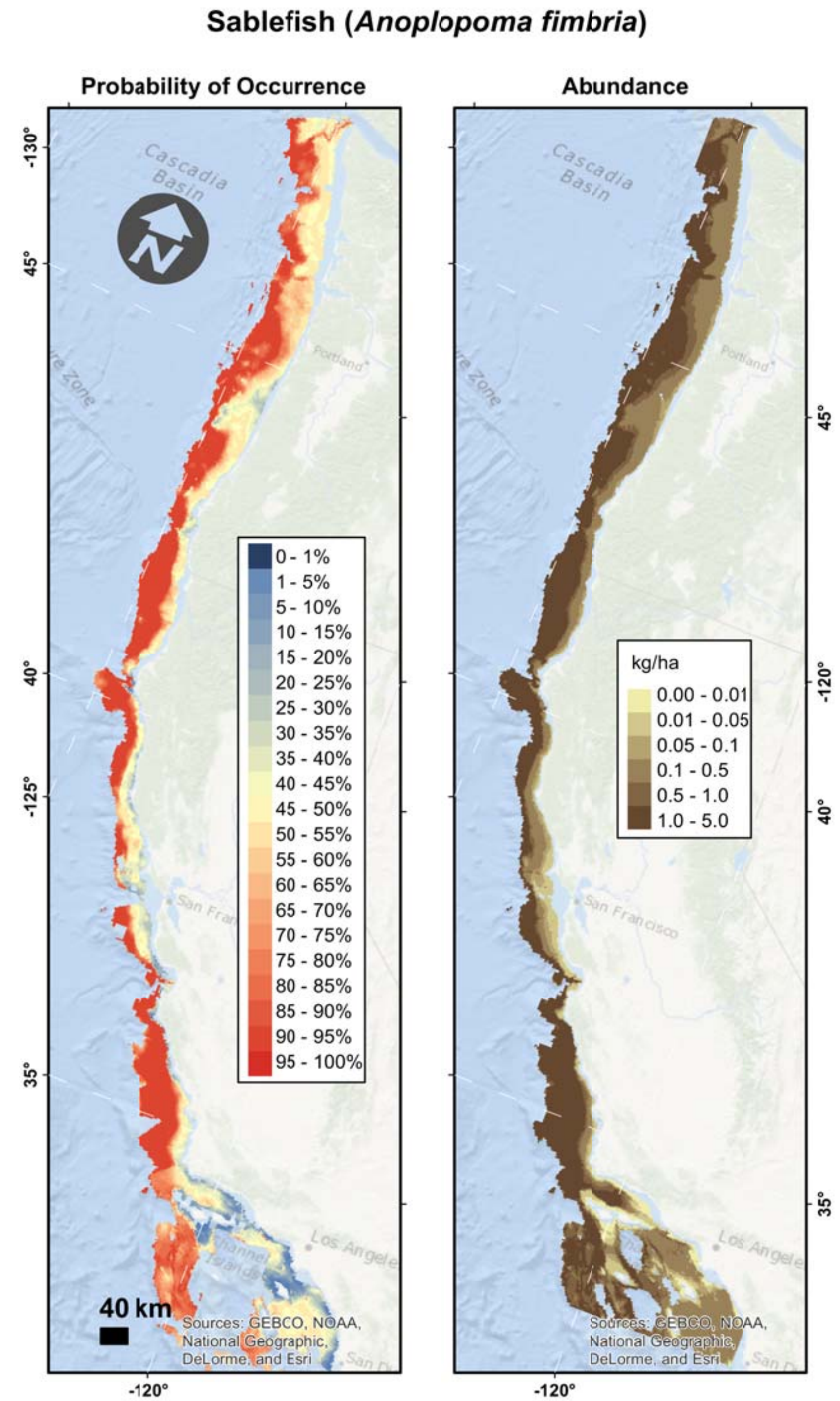

Figure A2.2: Sablefish mean predicted probability of occurrence and mean predicted abundance. NCCOS model projections.

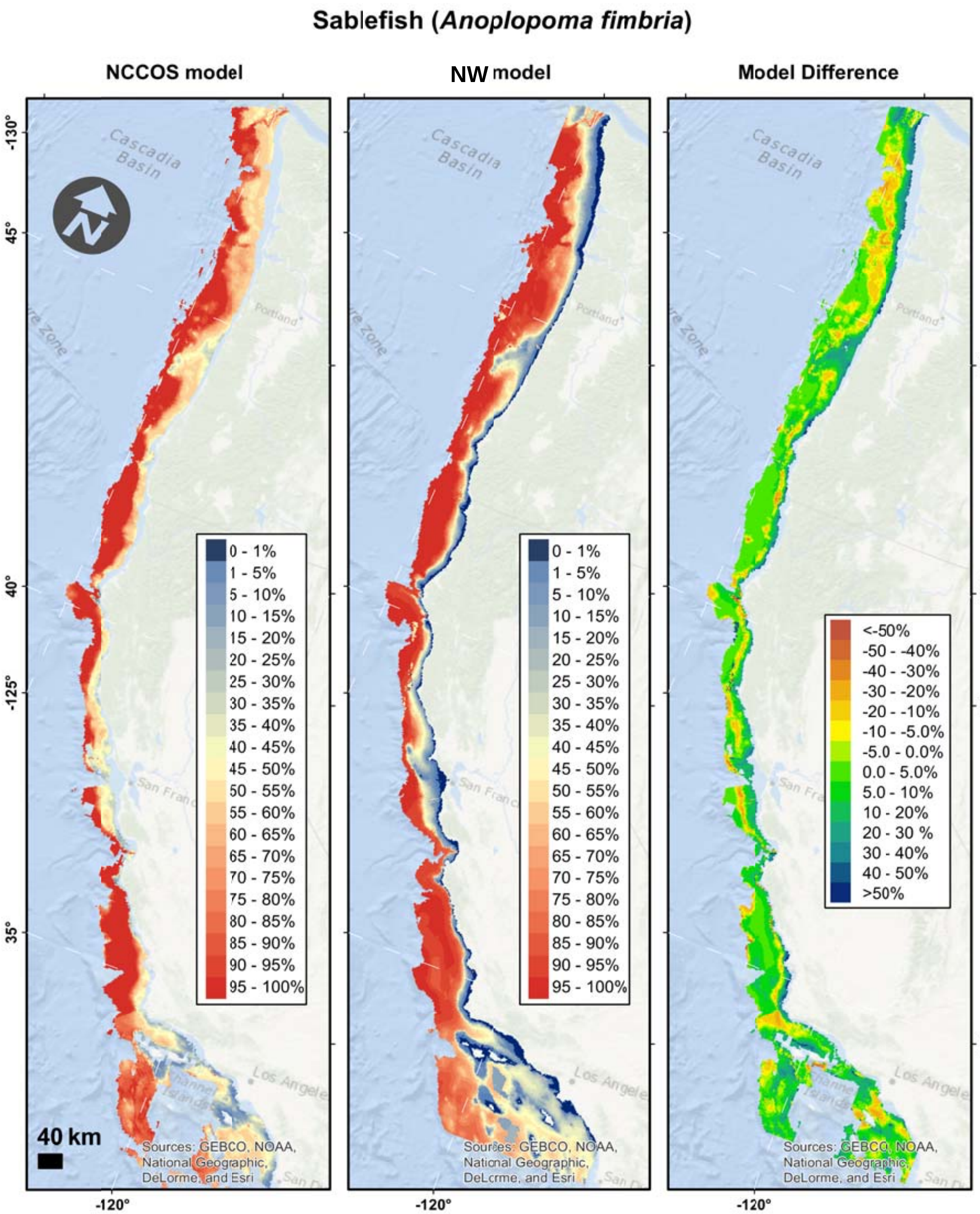

Figure A2.3: Sablefish predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS is greater than NWFSC

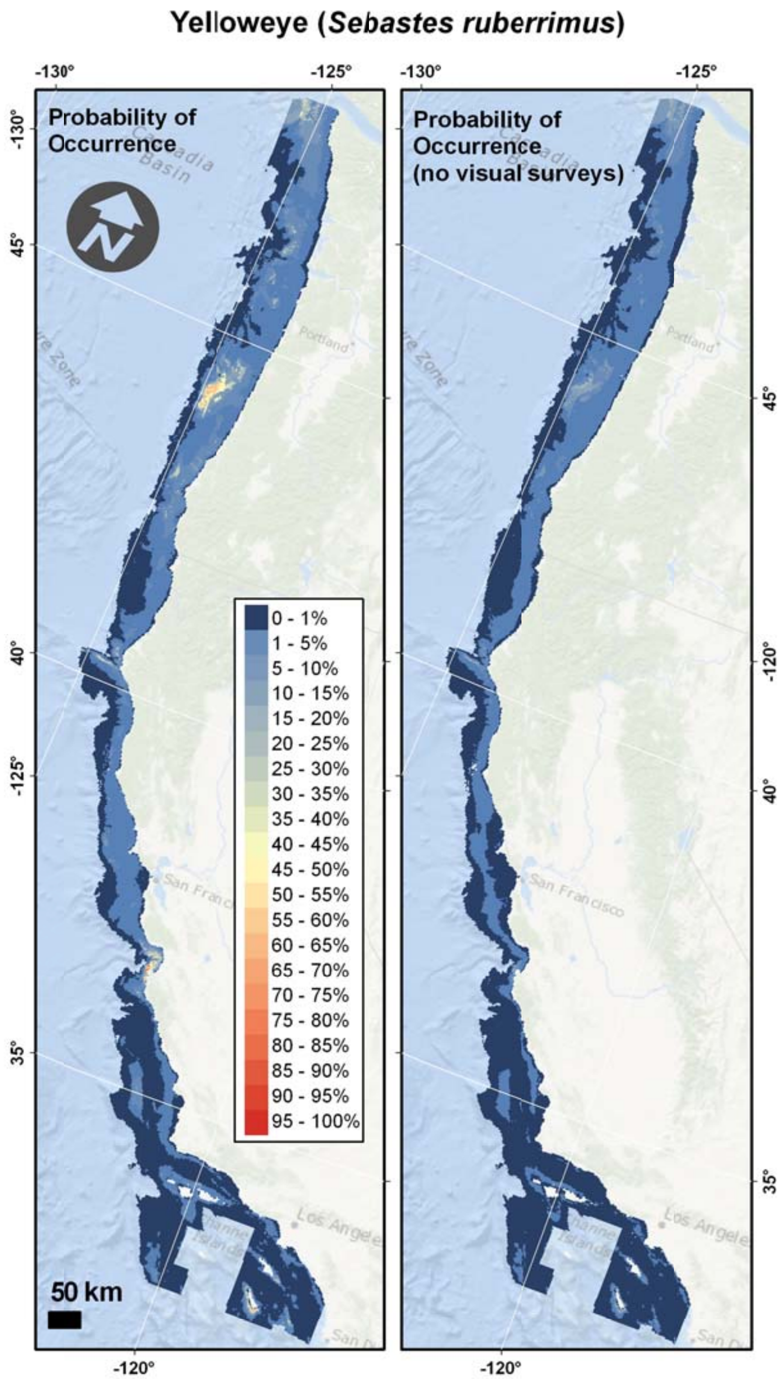

Figure A2.4: Yelloweye rockfish mean predicted probability of occurrence. NWFSC model projections. Left panel shows results using trawl survey data and visual survey data from submersible transects. Right panel shows results using only trawl survey data. We did not construct an abundance model for yelloweye rockfish.

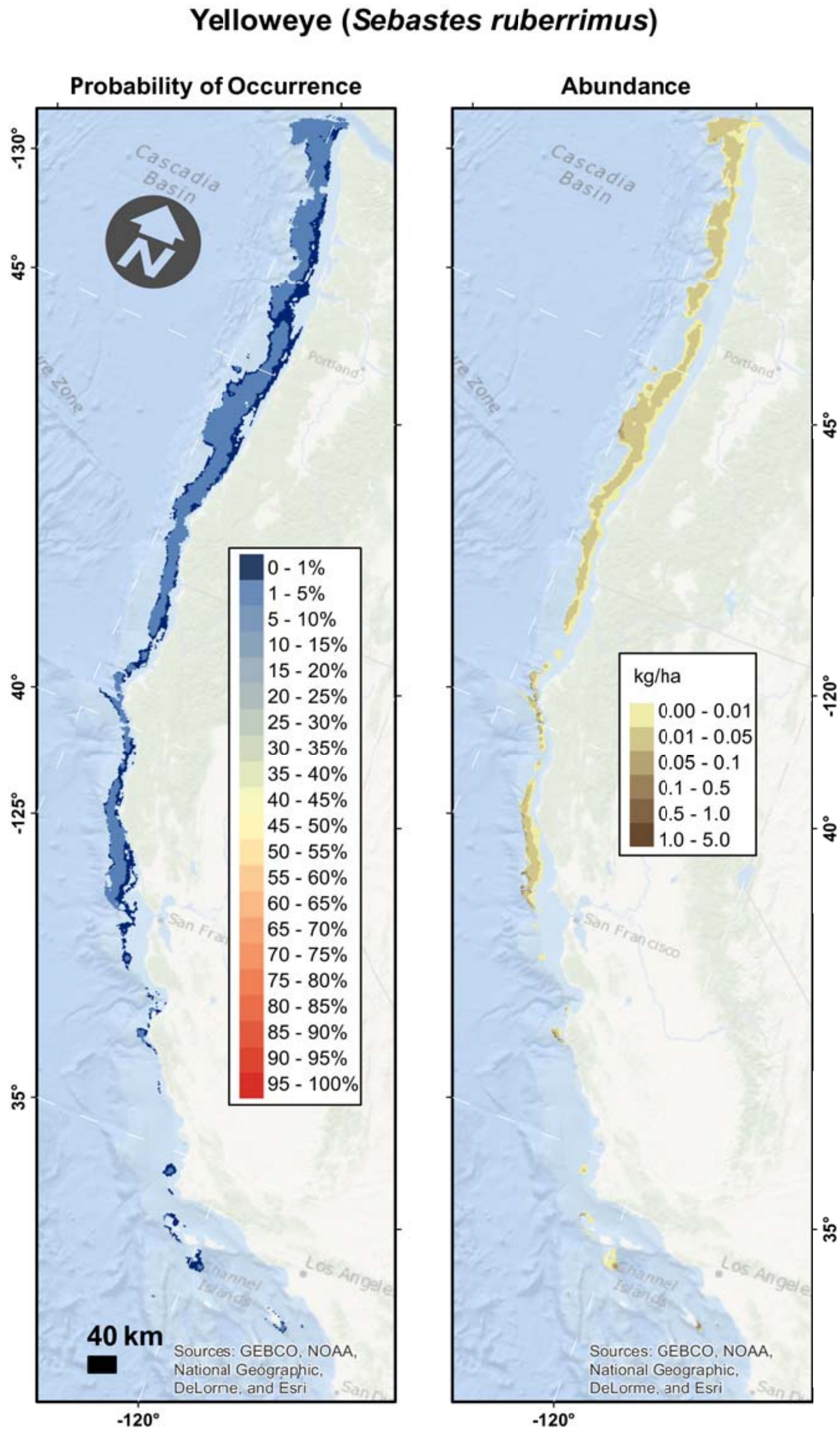

Figure A2.5: Yelloweye rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

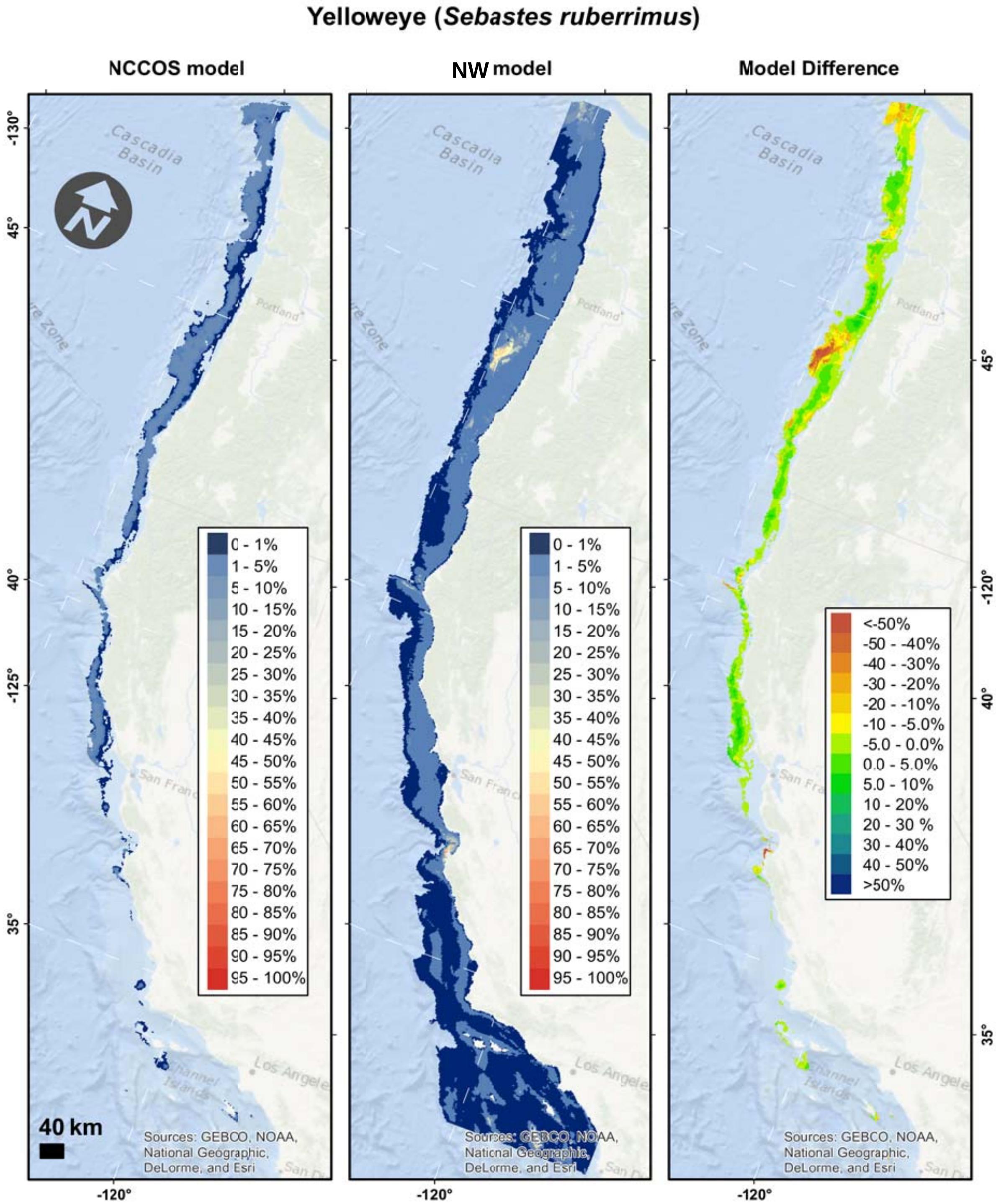

Figure A2.6: Yelloweye rockfish predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

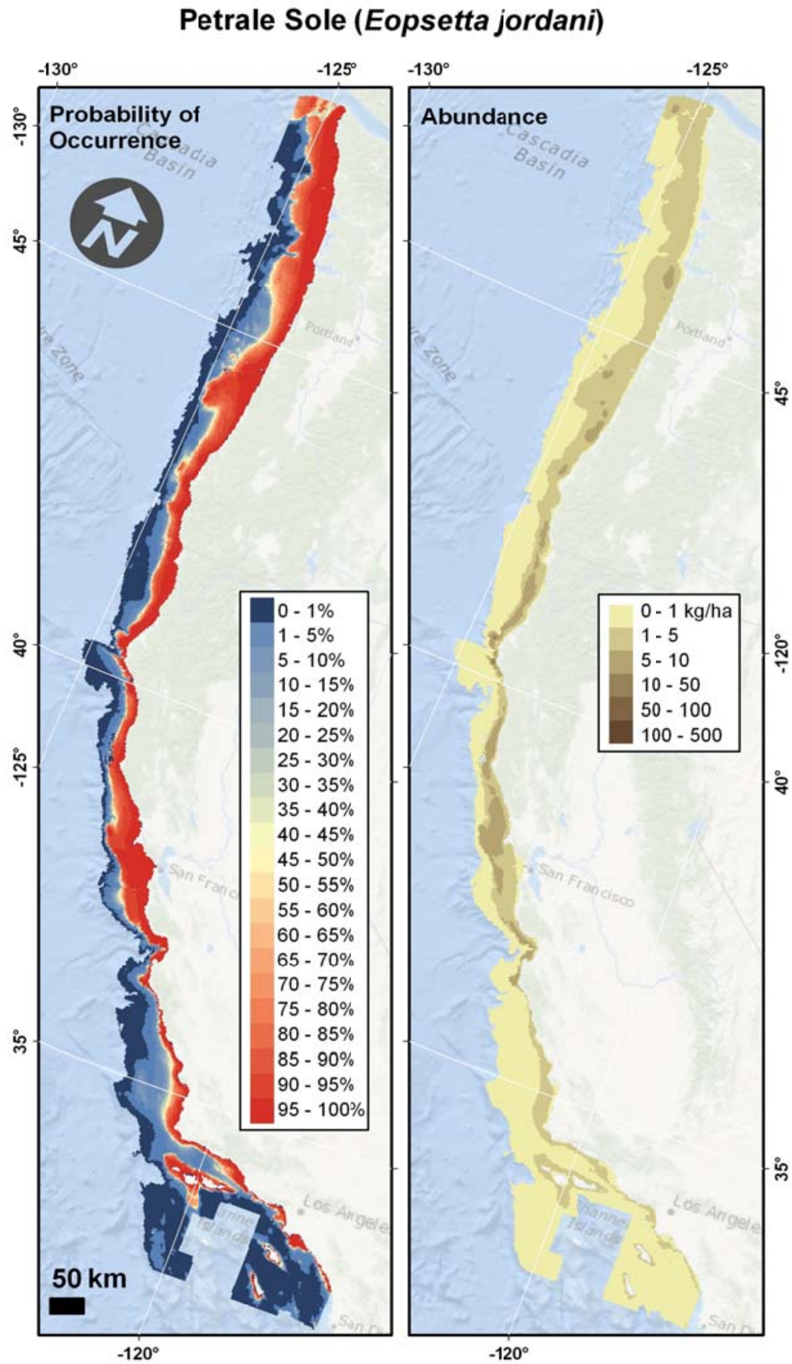

Figure A2.7: Petrale sole mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

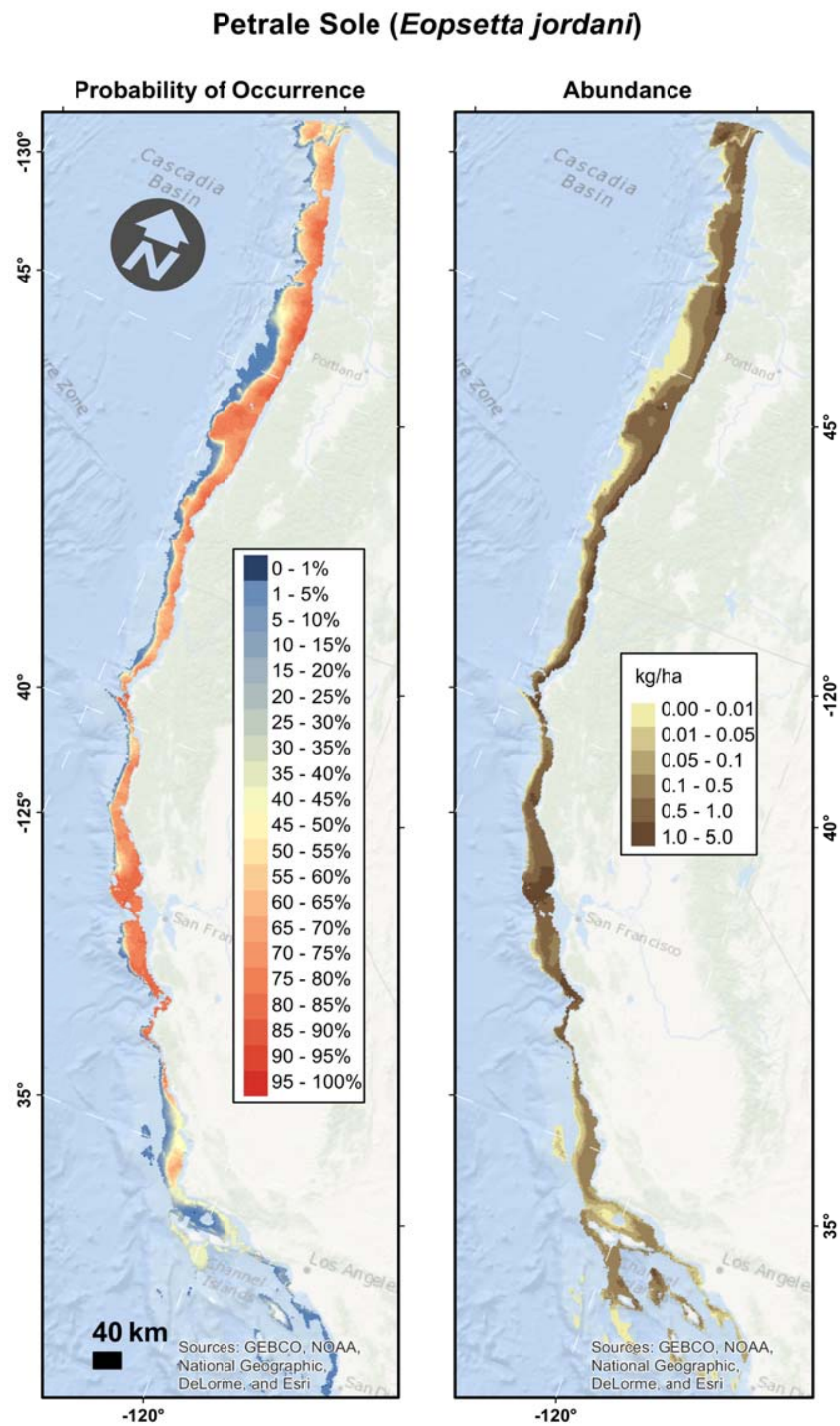

Figure A2.8: Petrale sole predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

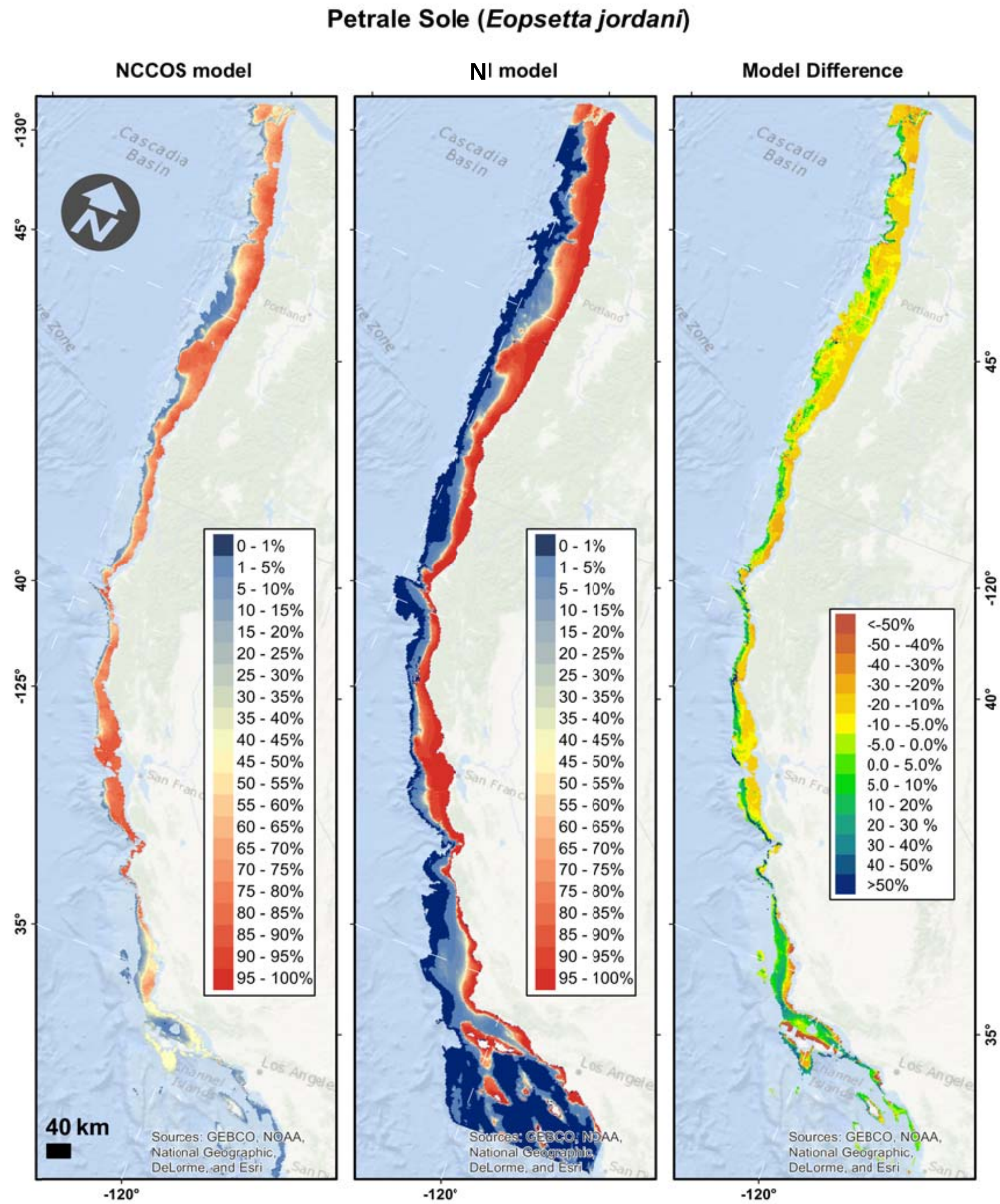

Figure A2.9: Petrale sole predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

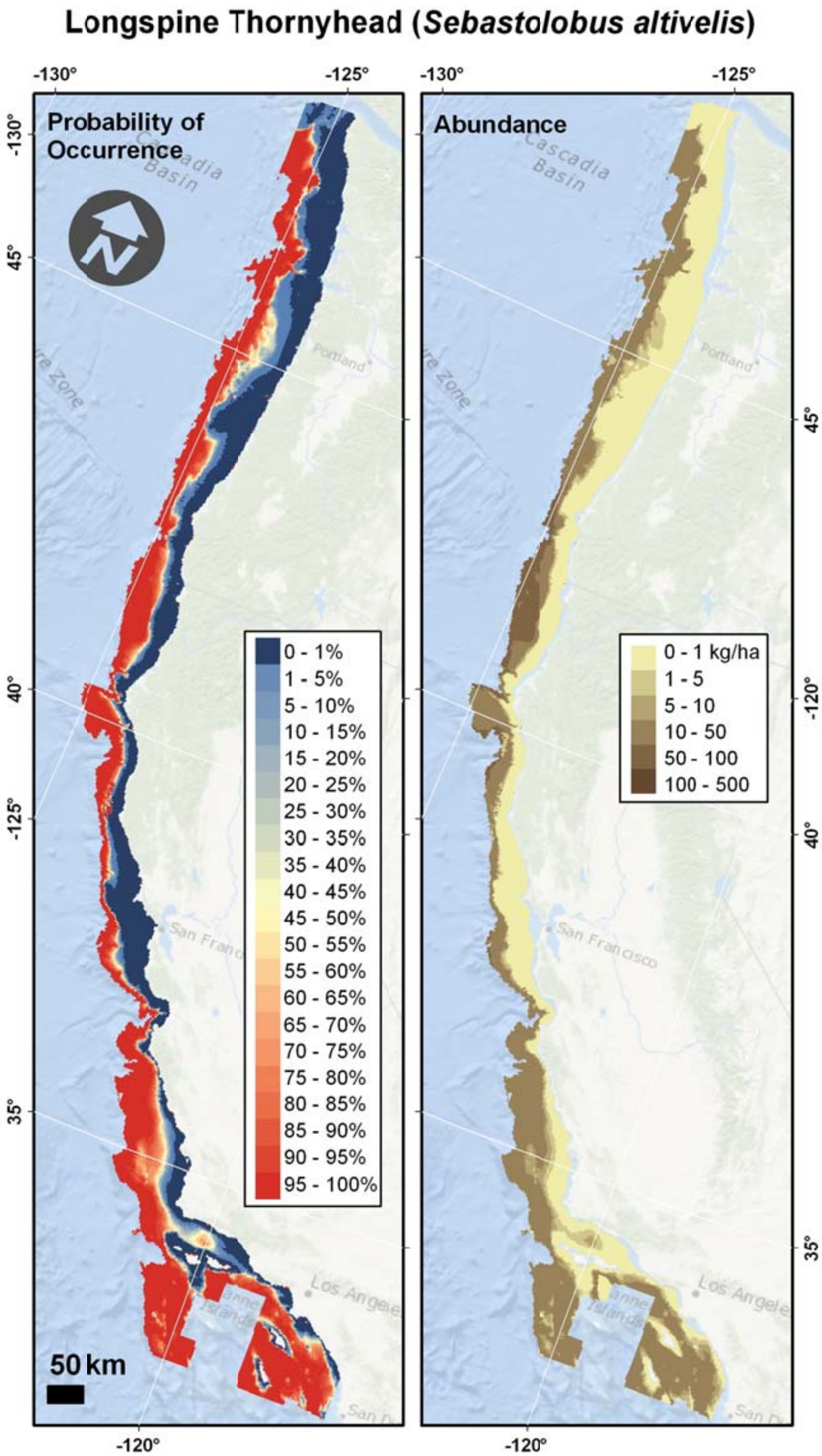

Figure A2.10: Longspine thornyhead sole mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

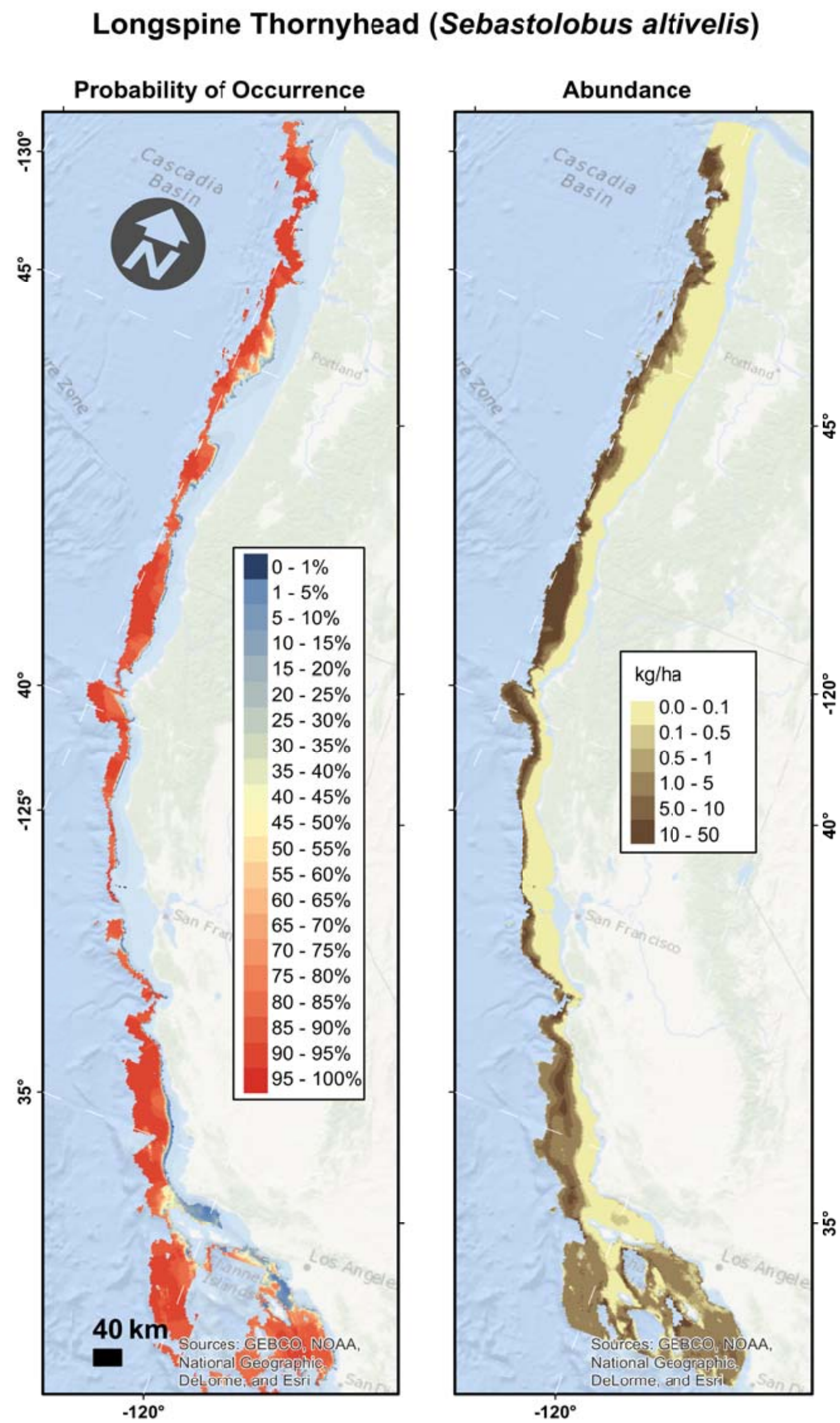

Figure A2.11: Longspine thornyhead predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

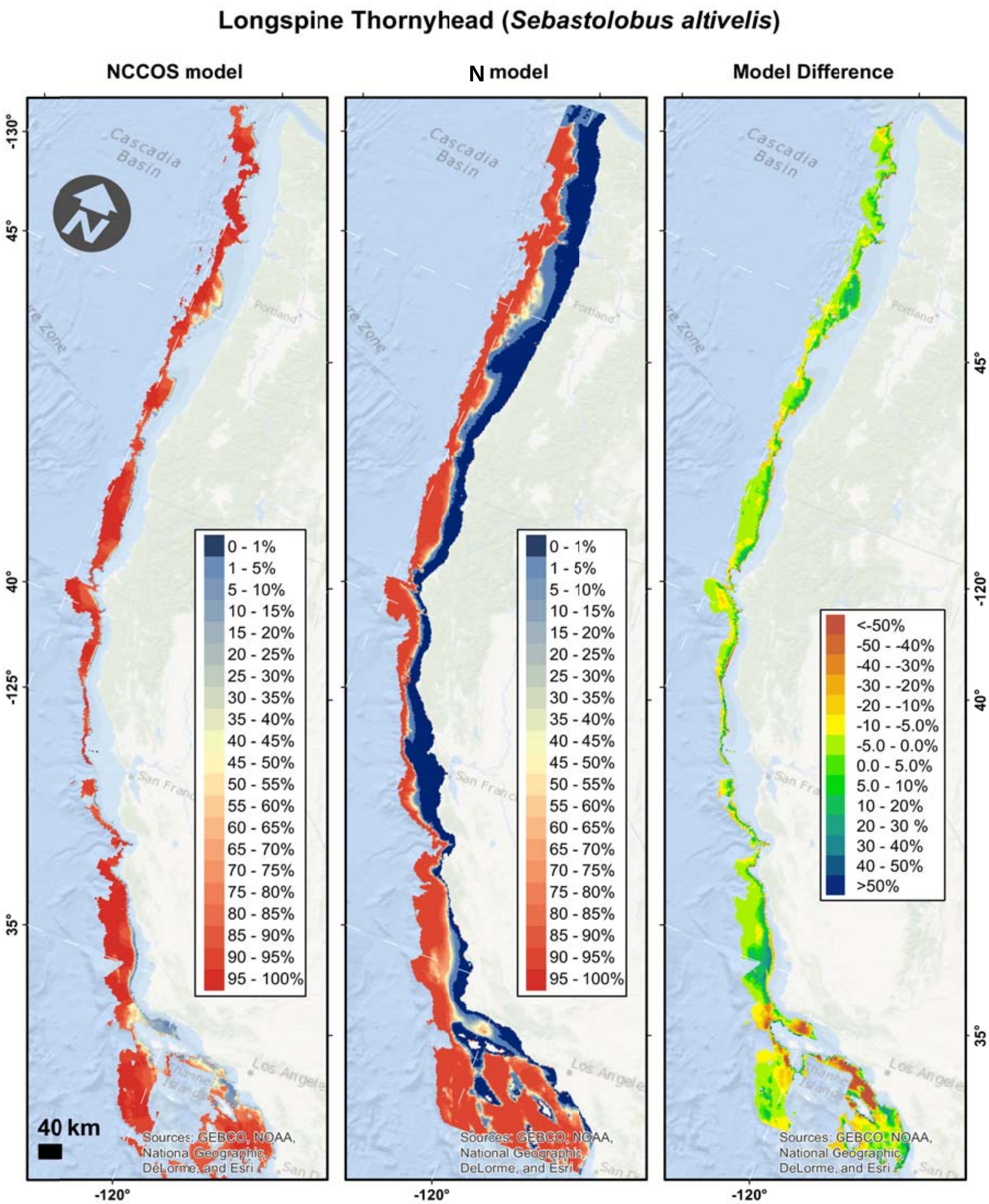

Figure A2.12: Longspine thornyhead predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

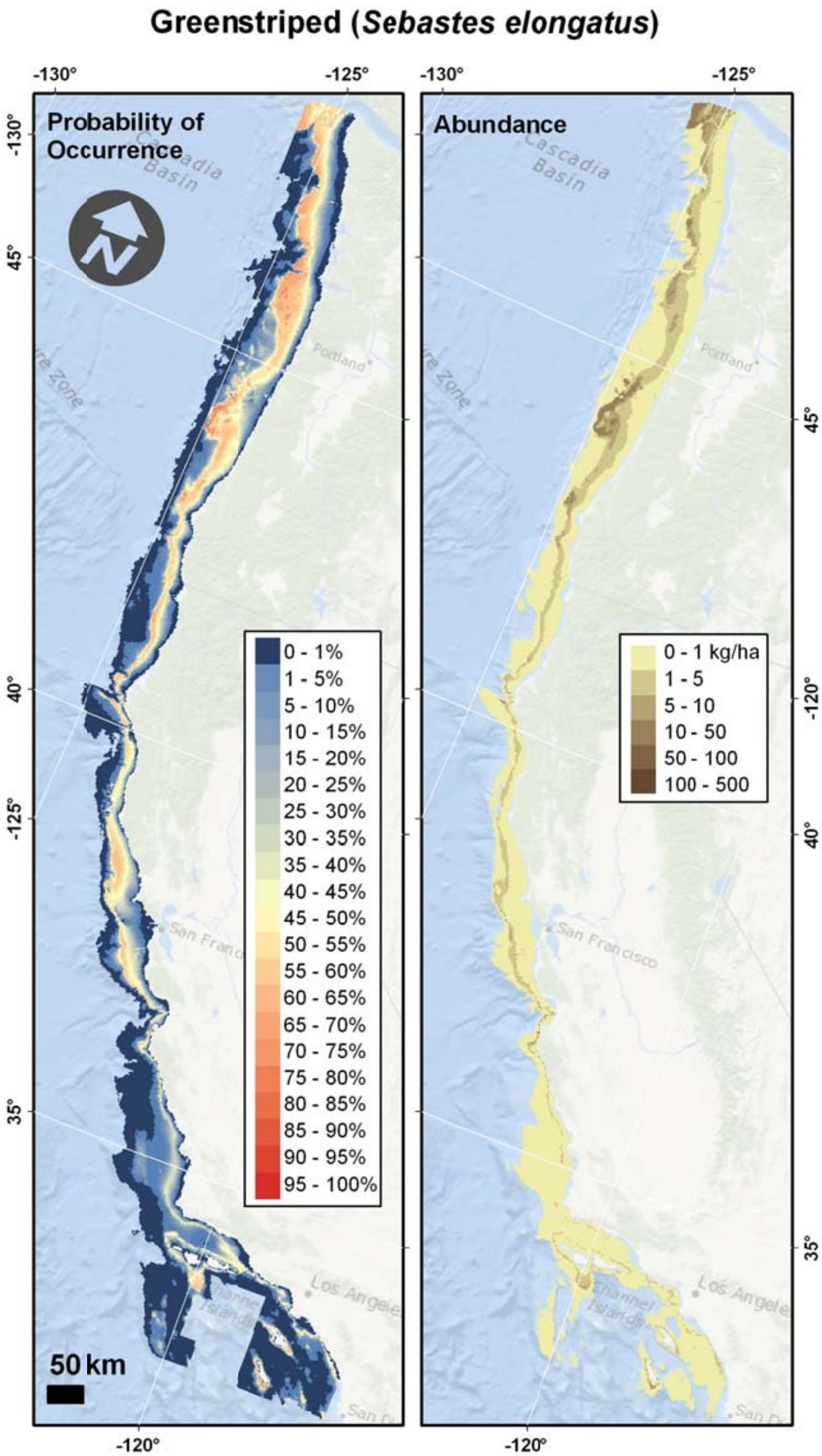

Figure A2.13: Greenstriped rockfish mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

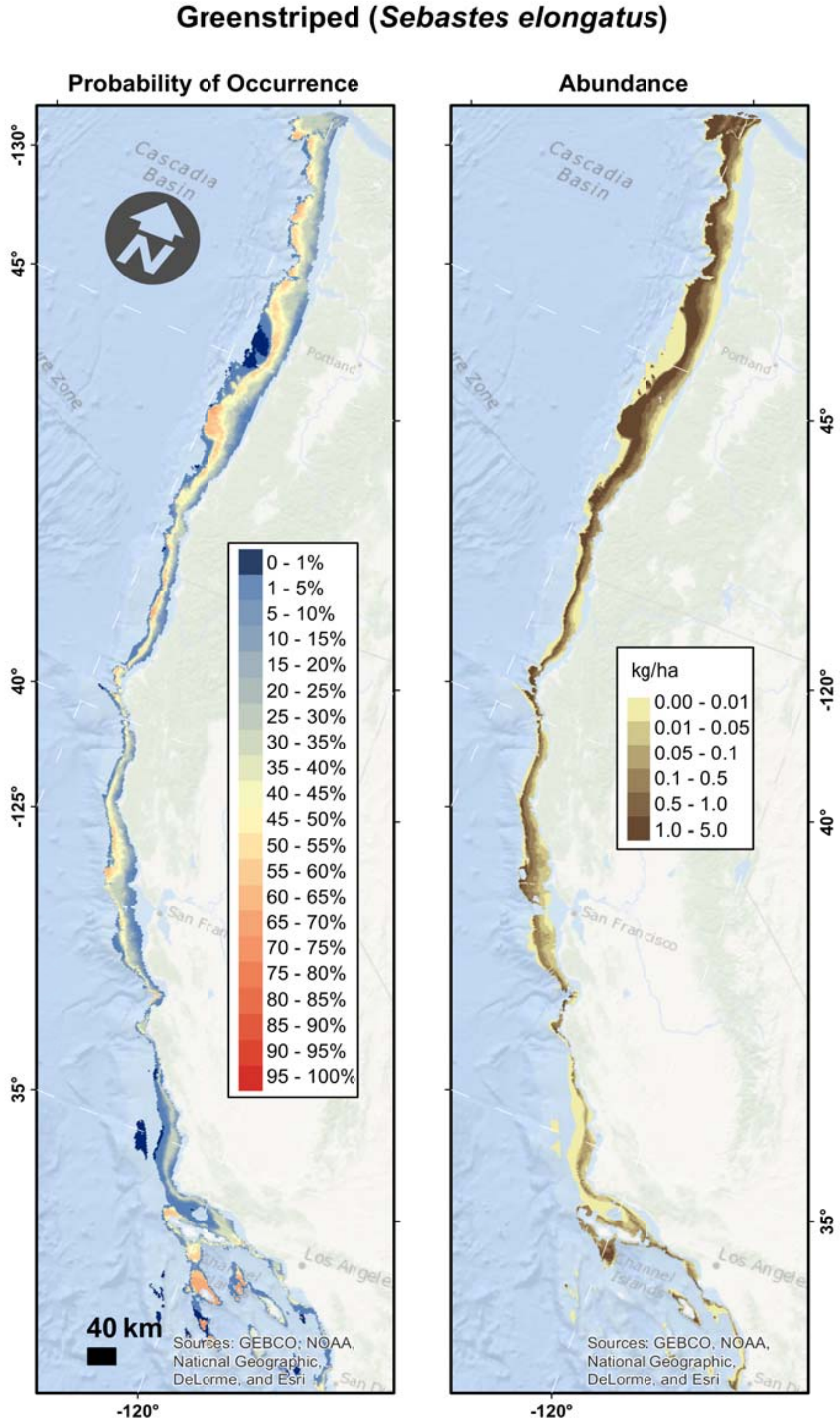

Figure A2.14: Greenstriped rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

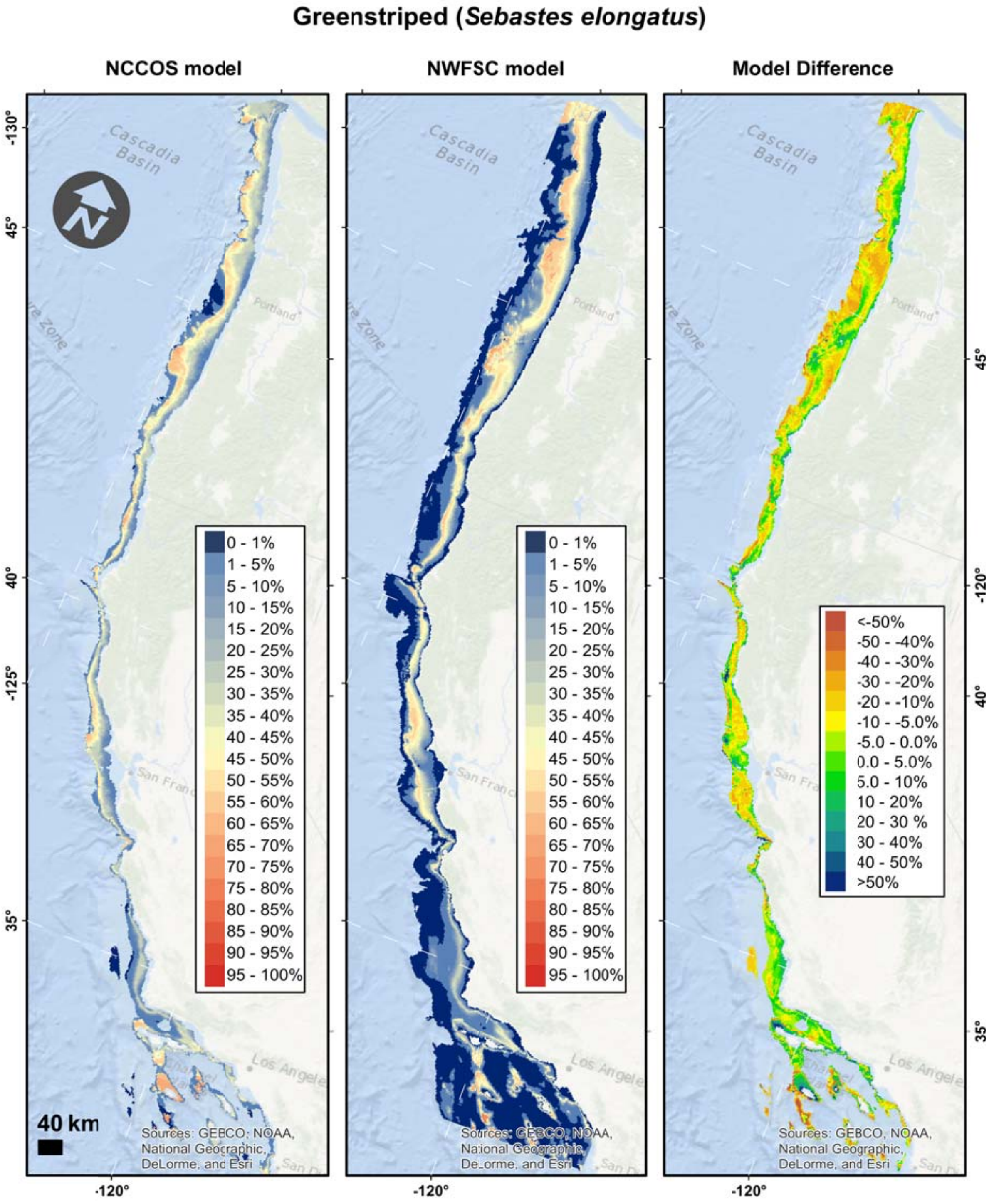

Figure A2.15: Greenstriped rockfish predicted mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

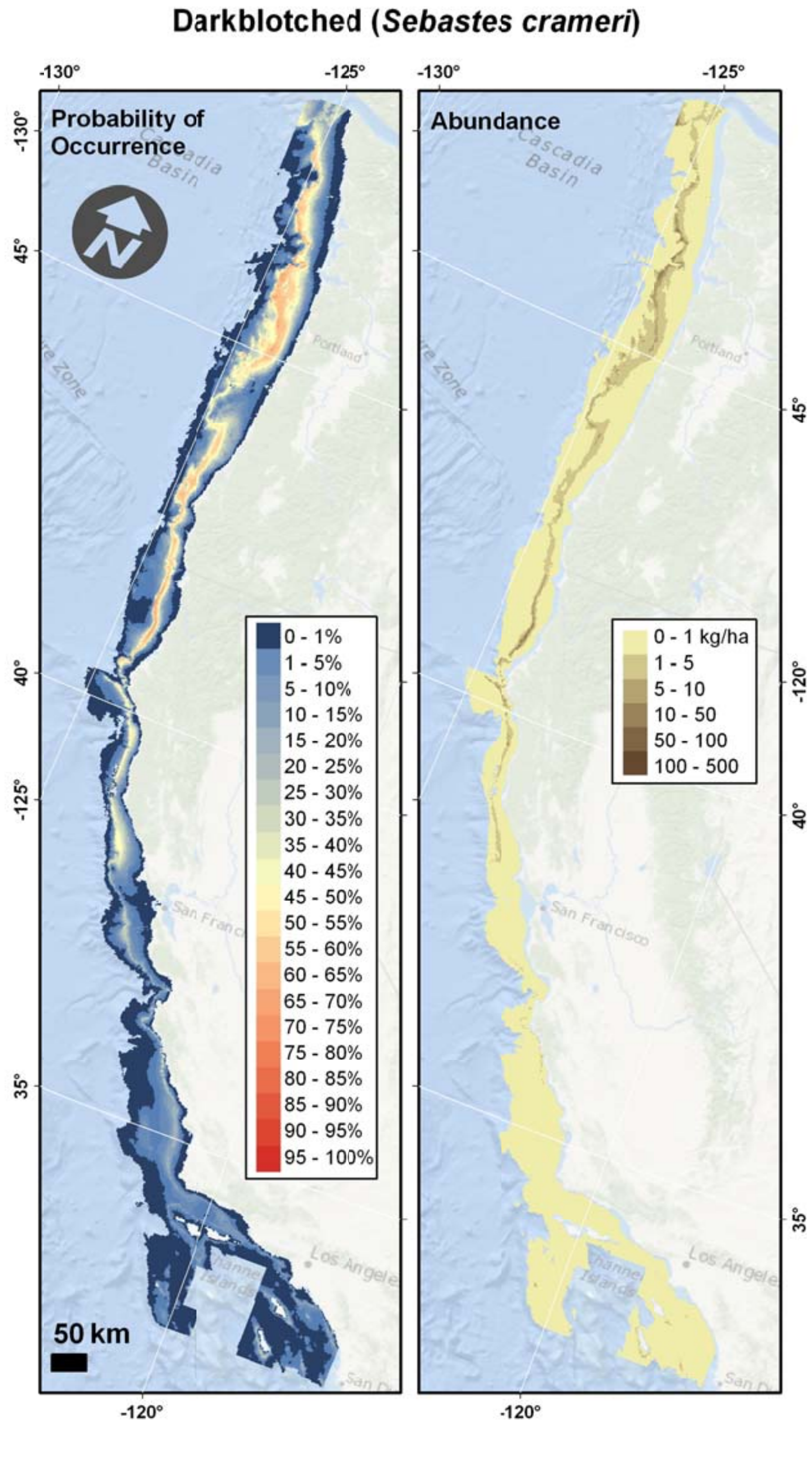

Figure A2.16: Darkblotched mean predicted probability of occurrence and predicted mean abundance. NWFSC model projections.

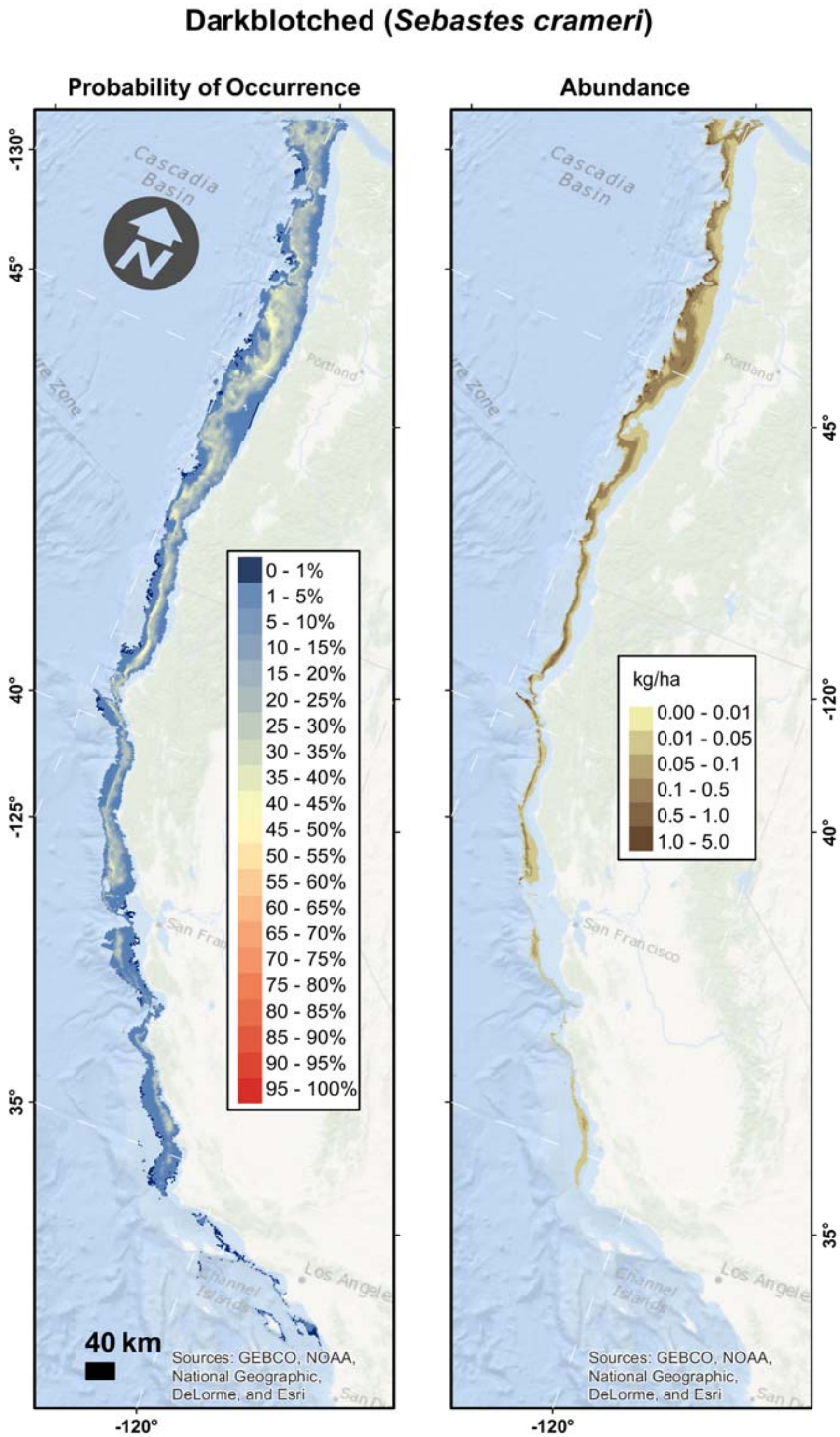

Figure A2.17: Darkblotched rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

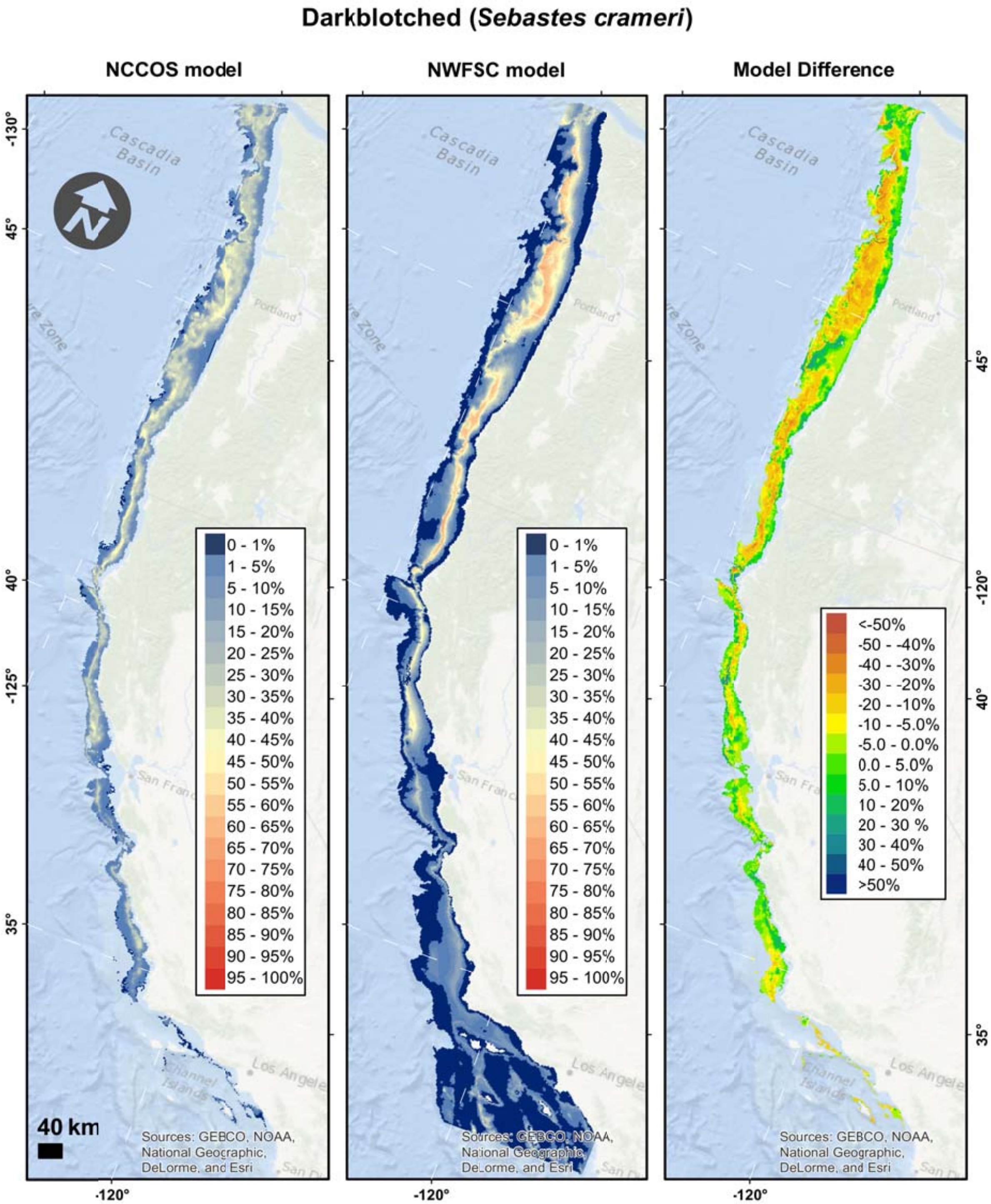

Figure A2.18: Darkblotched rockfish mean probability of occurrence from the NCCOS (left) and NWFSC (center) models. Right panel shows a plot of the difference between the NCCOS and NWFSC models (NCCOS – NWFSC). Positive values indicate NCCOS predicts higher probability of occurrence than NWFSC.

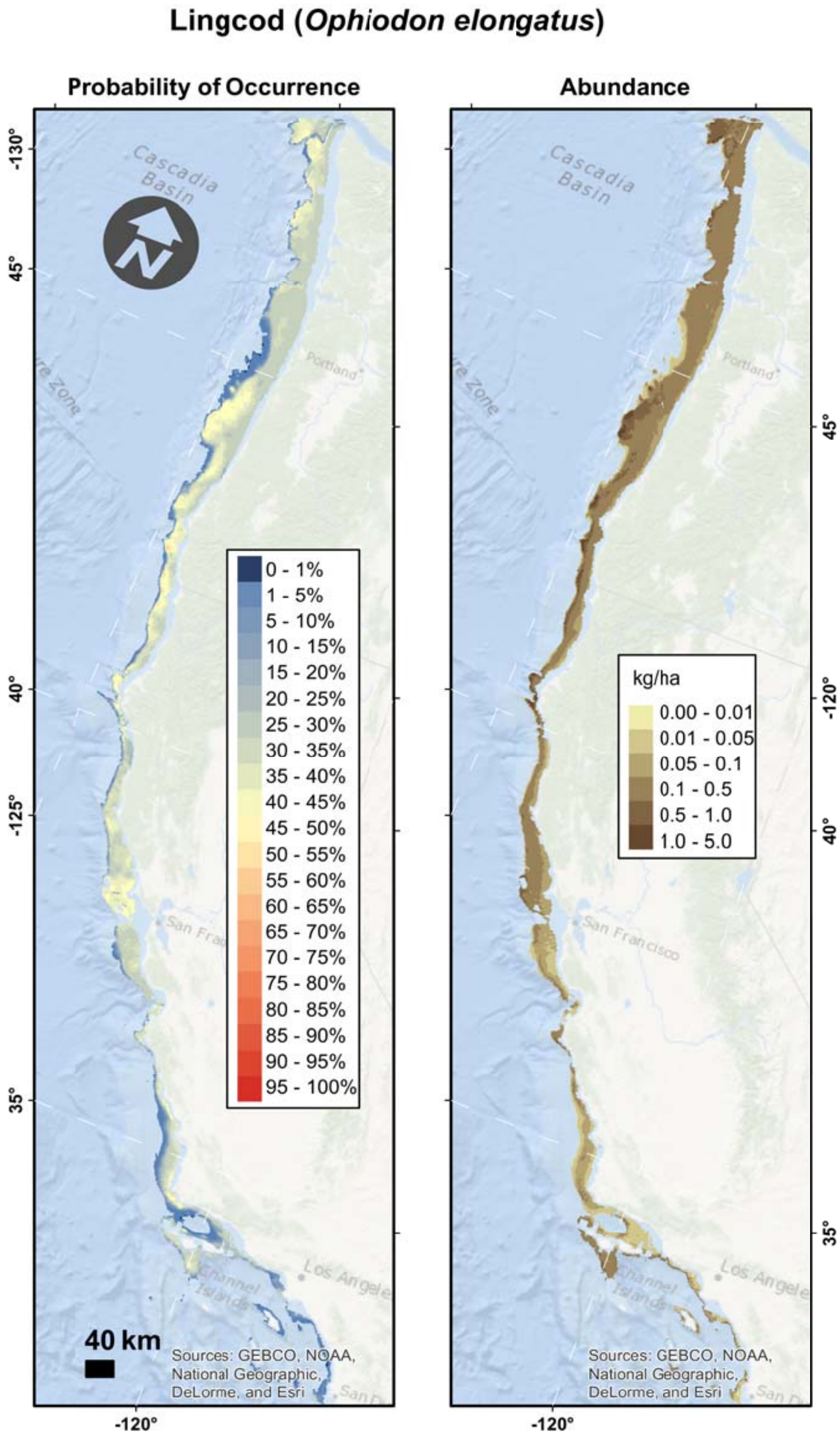

Figure A2.19: Lingcod predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

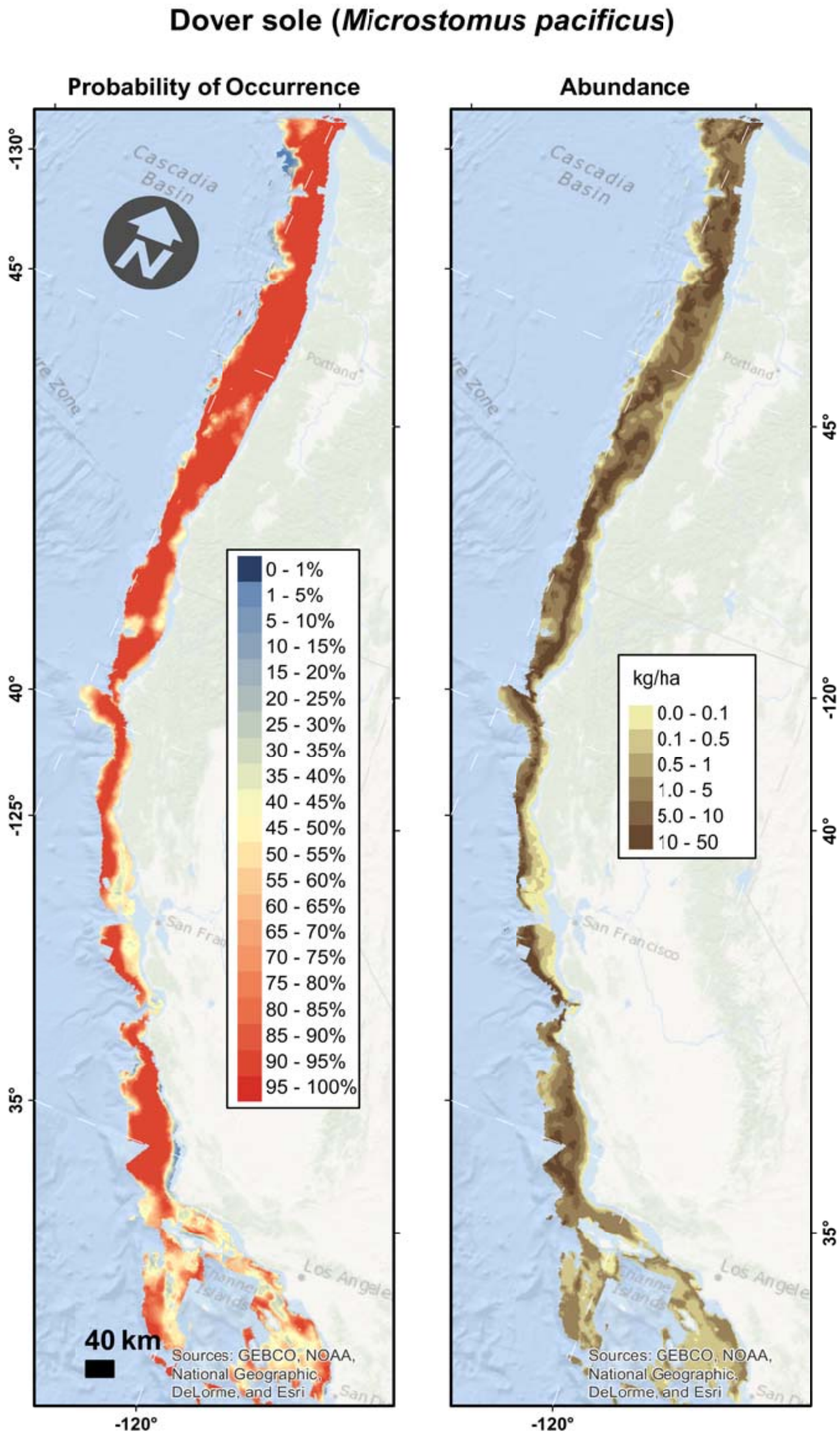

Figure A2.20: Dover sole predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

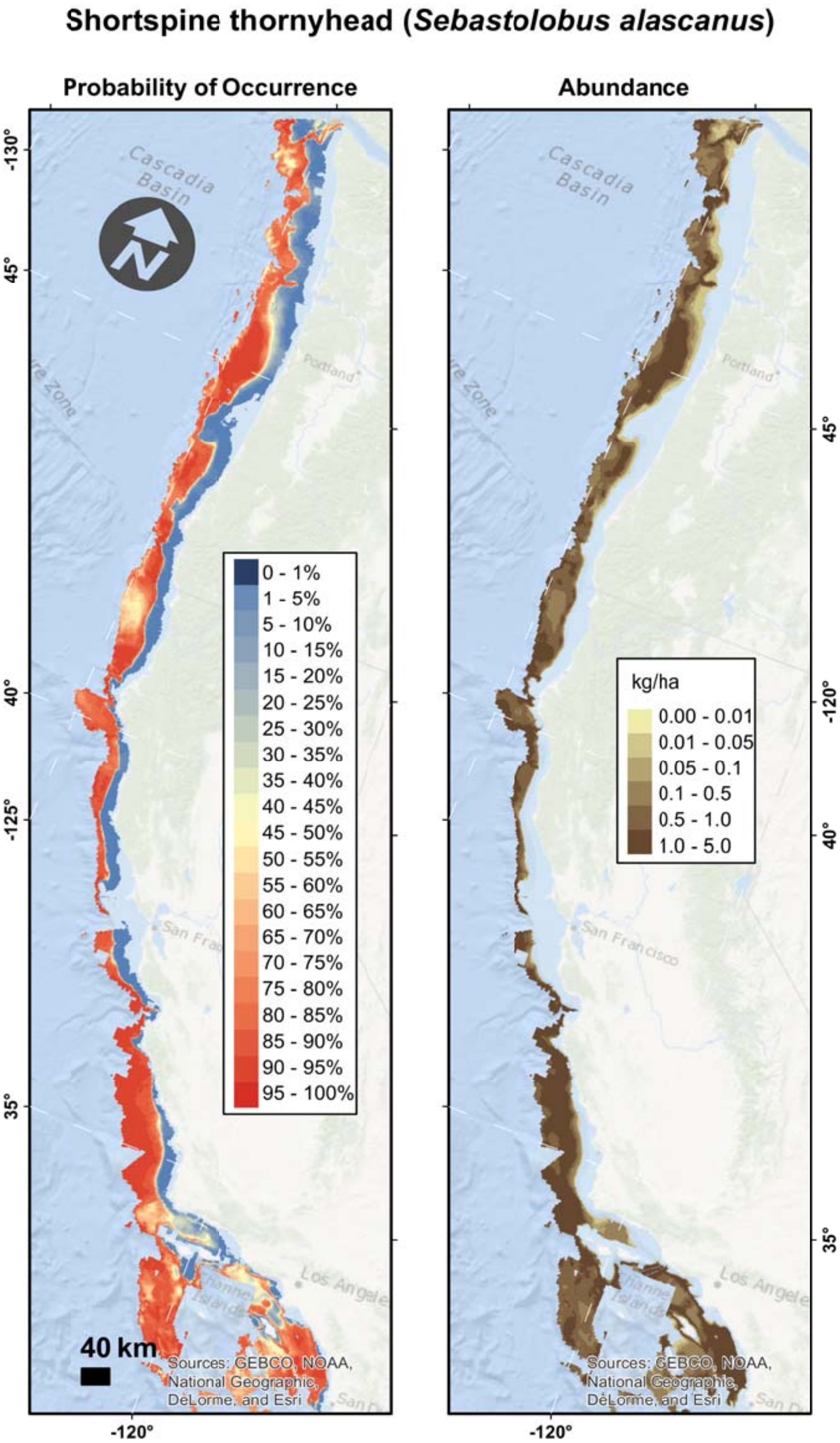

Figure A2.21: Shortspine thornyhead predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

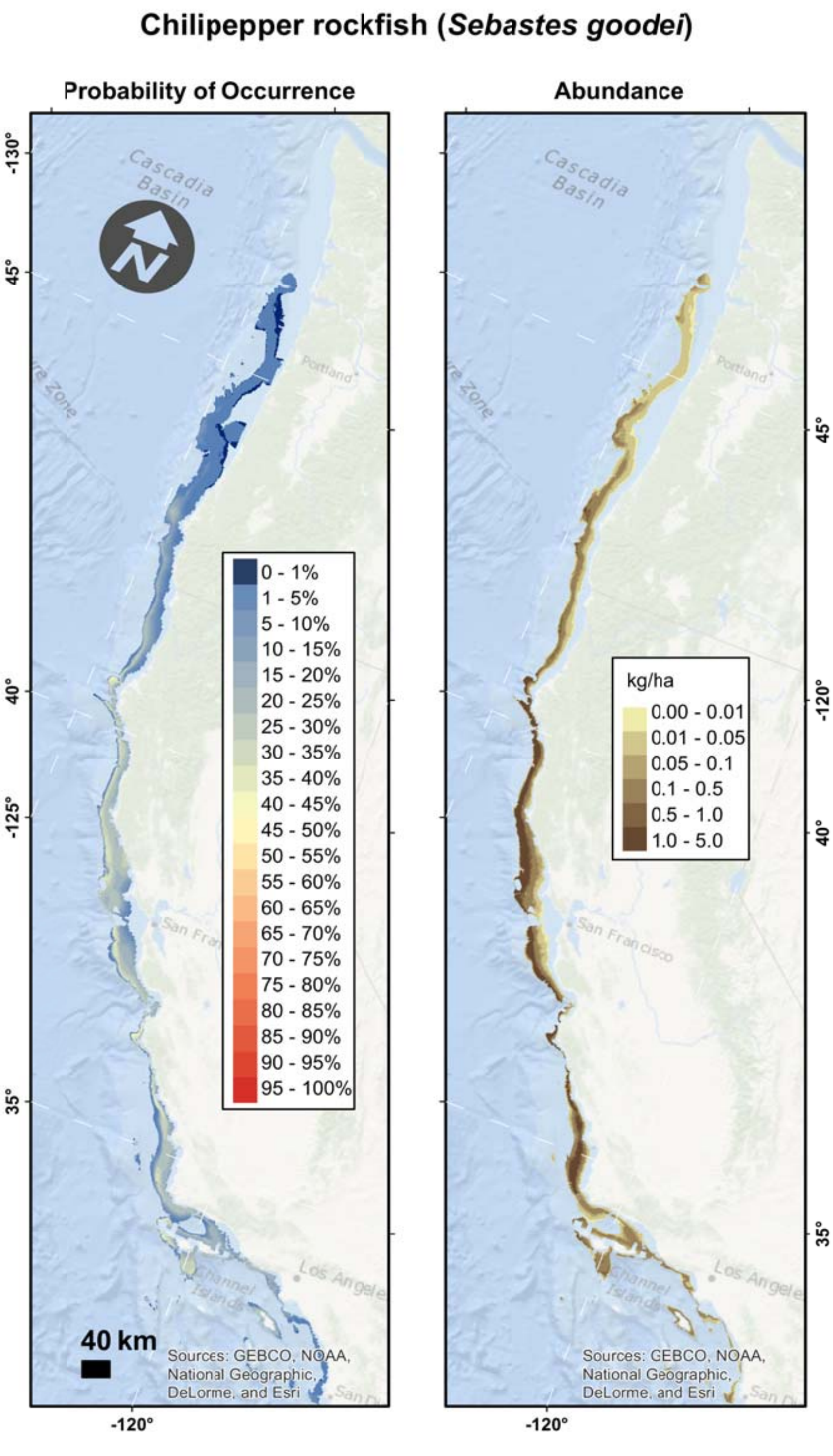

Figure A2.22: Chilipepper rockfish predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

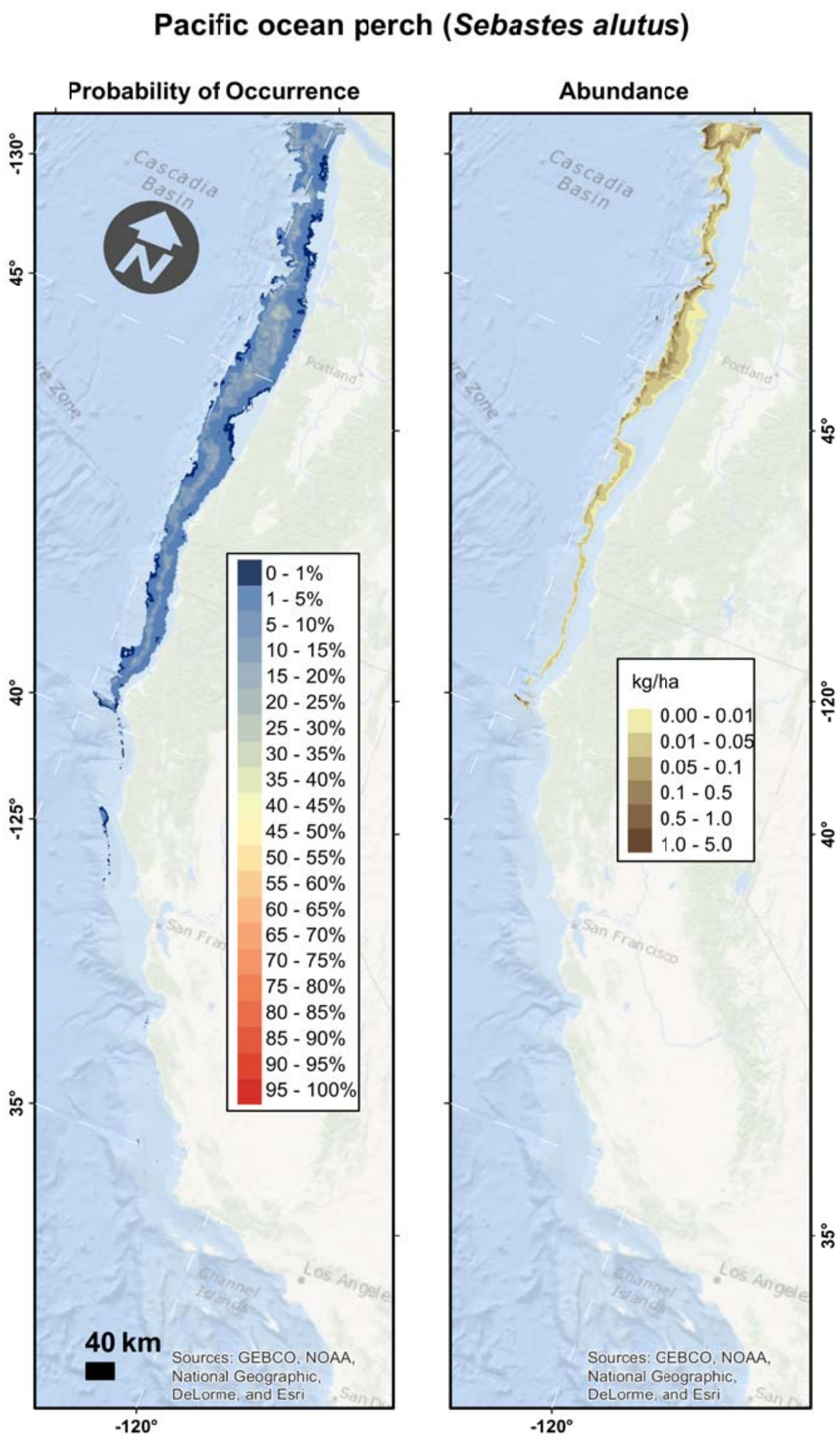

Figure A2.23: Pacific Ocean perch predicted mean probability of occurrence and predicted mean abundance. NCCOS model projections.

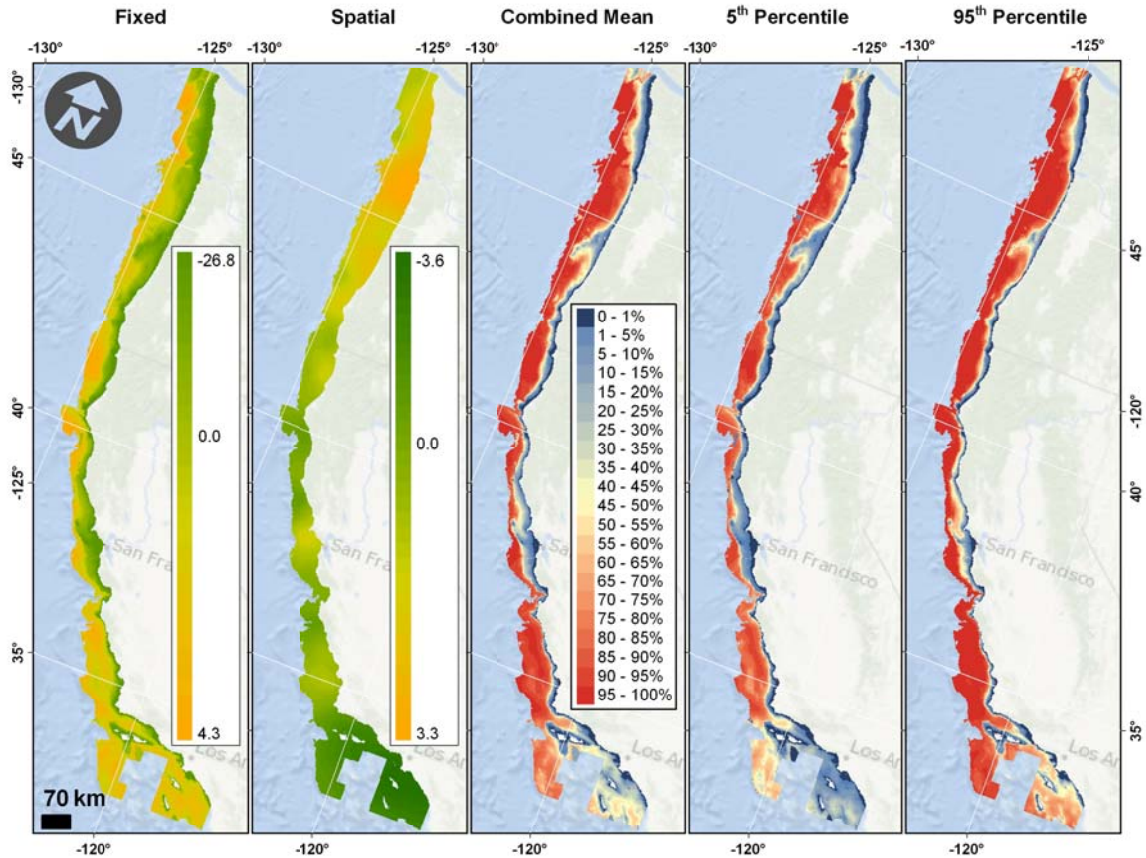

Figure A2.24: Components of the NWFSC probability of occurrence model for sablefish in 2010. Panels from left to right: A. Predicted mean habitat covariate fixed effect (logit scale), B. Predicted mean spatial effect (logit scale), C. Predicted mean probability of occurrence (ie. habitat + spatial effects; proportion scale); D. Predicted 5th quantile (proportion scale); E. Predicted 95th quantile (proportion scale). Together panels D and E bound the 90% credible interval.

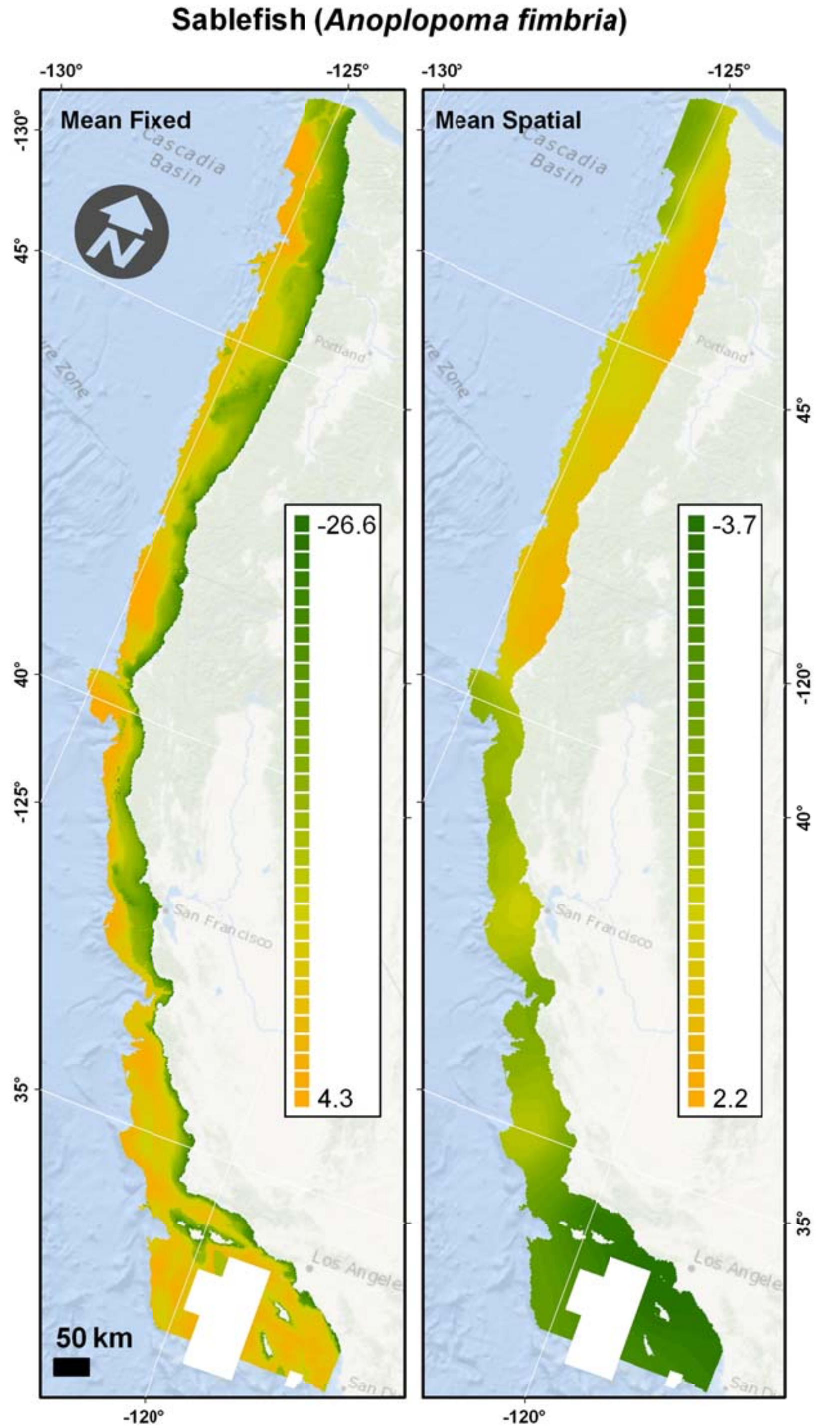

Figure A2.25: Mean of predicted, across-year fixed habitat effect (left panel). Mean of predicted, across-year spatial effect (right panel). Both are on the logit scale.

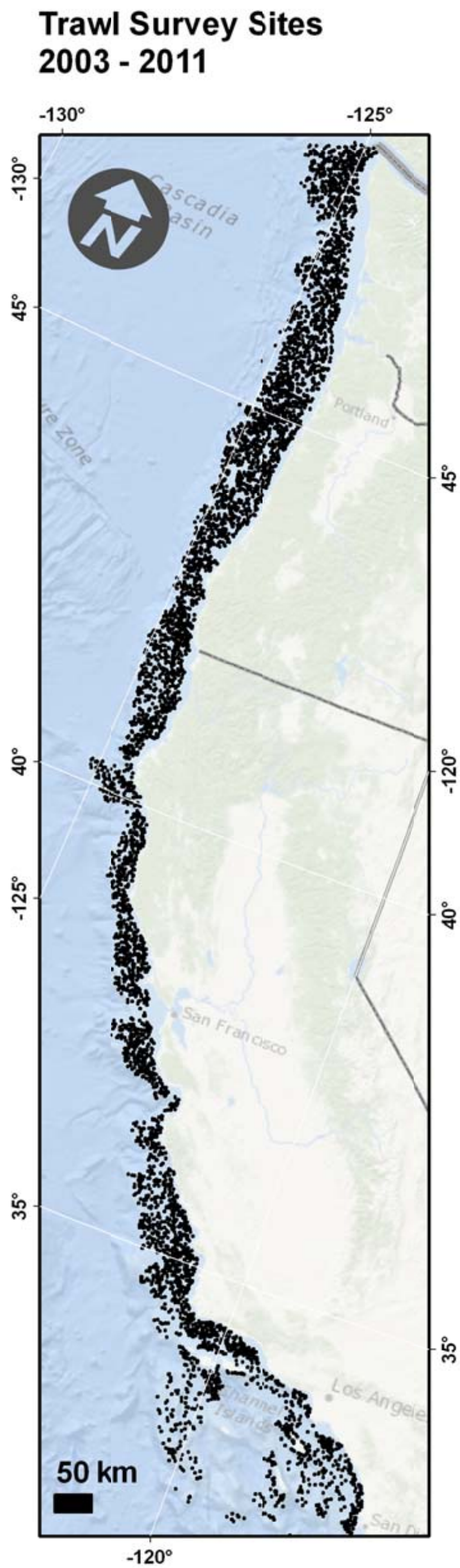

Figure A2.26: NOAA trawl survey locations 2003 to 2011.

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3.0 METHODS FOR EXAMINING STRESSORS TO EFH

3.1 FISHERY PRESSURES

Methodology used in this synthesis for reviewing fishing impacts is partially described in the EFH 5-year review Phase 1 document presented to the PFMC (PFMC 2012). Specific data was utilized as described in section 4.4 Magnuson Act Fisheries Effects, 4.4.1 Distribution of Commercial Fishing Effort for bottom trawl effort, midwater trawl effort, and fixed gear effort.

However, an update to the spatial representation of observed fixed gear data was made, related to specific concerns about weighting the level of impact which various fixed gear types exert on seafloor habitats. Rather than the spatial representation of fixed gear as points of both the deployment and retrieval locations as in the Phase 1 report, spatial representations were divided into a towline model or a single point of the average of deployment and retrieval coordinates, based on observed fishery and gear code. The following were represented as a towline model: fishing events using longline gear, fishing events in the limited entry sablefish-endorsed primary season using pot gear. The following were represented as an averaged point location: fishing events using hook-and-line gear codes (other than longline), and fishing events in the open access fixed gear or state-permitted nearshore fixed gear sectors using pot gear.

ArcGIS™ geographical information system software (Environmental System Research Institute, Incorporated, Redlands, California) was used to conduct overlays (“Identity” tool) of each fishing fleet’s spatial representation of either towlines or the average point of deployment and retrieval coordinates, and the stratification, spatial management boundaries, etc. summarized in this synthesis. A common, customized Transverse Mercator coordinate system specifically designed for the US Pacific west coast was used by all authors for any spatial analysis or mapping (see metadata). Subsequent analyses were carried out using R software (v. 2.8.1; R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

3.1.1 Cumulative fishery pressures

Fishing pressures act upon groundfish essential fish habitat collectively and thus quantifying a cumulative pressure index is an important tool in assessing overall fishing impacts. We used a weighted approach by assuming that fishing pressures were additive, but with a weighting scheme applied for the sensitivity of various habitat types to individual fishing gears. The weighting scheme was adapted from information summarized for a report on the effects of fishing gear on habitats developed for the 2005 groundfish EFH Environmental Impact Statement (PSMFC 2004, NMFS 2005). The report included the development of habitat sensitivity levels to gear impacts and recovery times for habitats impacted by fishing gears. The sensitivity scale consisted of four levels (0, 1, 2, and 3) representing relative sensitivity to gear impacts (Table A3a.1). The descriptors for the sensitivities at each level were based on the actual impacts reported in the literature and referenced in the report. The recovery scale was in units of time (years) with the values taken directly from each report cited (Table A3a.1).

For the current synthesis, indices of sensitivity were prepared by extracting the sensitivity levels from the 2005 groundfish EFH EIS for hard and soft substrates for the three seabed habitat depth zones; shelf, upper slope and lower slope, and four major gear types; bottom trawl, midwater trawl, fixed gear represented by a distance metric (i.e., longline gear and pot gear), and fixed gear represented by a point metric (i.e., hook-and-line gear other than longline gear and open access fixed gear or state-permitted nearshore fixed gear sectors using pot gear (Table A3a.2.). Sensitivity levels for mixed substrate were considered to be the mid-range between hard and soft substrates. In developing the sensitivity values, the ranges were considered in relation to several reviews (Dayton et al. 2002, NRC 2002, Chuenpagdee et al. 2003, Morgan and Chuenpagdee 2003, NEFMC 2011). For comparison, impact levels for four major gear types (out of ten considered), adapted from Morgan and Cheunpagdee (2003) are shown in Table A3a.3. The impacts shown in Table A3a.3. were derived from two sources: 1) an experts workshop where participants rated both physical and biological impacts and 2) a respondent survey where participants rated the severity of ecological impacts. A second set of impact levels ("vulnerabilities"), for relevant fishing gears, is shown for trawlable seabed substrates in Table A3a.4. This overview is drawn from a recent analysis of swept area seabed impact for the New England Fisheries Management Council (NEFMC 2011). Impact levels for three major gear types (out of five considered) is shown as vulnerability of geological and biological features, according to substrate type, and low and high energy environments.

References for Fishery Pressures

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Table A3a.1. Descriptions of sensitivity levels and recovery time (years) for gear impacts from PFMC 2004.

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.
Recovery Time	**Recovery Description**
0	No recovery time required because no detectable adverse impacts on seabed.
n	n = time (years) required for return to pre-impact condition; i.e. no significant differences between impact and control areas in any metrics.

Table A3a.2. Part A. Sensitivity level ranges for four major gear and three bottom types adapted from PFMC 2004 (0 = no detectable impacts, 1 = minor impacts, 2 = substantial changes, 3 = major changes in bottom structures).

Part A Sensitivity Levels	Bottom Trawl	Midwater Trawl	Fixed Gear Distance	Fixed Gear Point
Hard shelf	2.5	0.1	0.3	0.1
Hard upper slope	2.8	0.1	0.3	0.1
Hard lower slope	2.8	0.1	0.3	0.1
Mixed shelf	1.9	0.1	0.2	0.1
Mixed upper slope	1.9	0.1	0.2	0.1
Mixed lower slope	1.9	0.1	0.2	0.1
Soft shelf	1.2	0.1	0.1	0.1
Soft upper slope	1.0	0.1	0.1	0.1
Soft lower slope	1.0	0.1	0.1	0.1

Table A3a.2. Part B. Recovery time (years) for four major gear and and three bottom types adapted from PFMC 2004.

Part B Recovery Times	Bottom Trawl	Midwater Trawl	Fixed Gear Distance	Fixed Gear Point
Hard shelf	2.8	na	0.1	0.1
Hard upper slope	2.8	na	0.3	0.1
Hard lower slope	2.8	na	0.3	0.1
Mixed shelf	2.8	na	0.4	0.1
Mixed upper slope	2.8	na	0.4	0.1
Mixed lower slope	2.8	na	0.4	0.1
Soft shelf	0.4	na	0.4	0.1
Soft upper slope	1.0	na	0.4	0.1
Soft lower slope	1.0	na	0.4	0.1

Table A3a.3. Impact levels for four major gear types, adapted from Morgan and Cheunpagdee 2003, and Cheunpagdee et al. 2003.

	Bottom Trawl	Midwater Trawl	Fixed Gear Distance	Fixed Gear Point
Impact based on expert workshop (n = 13 experts; ave. physical & biological impacts; scale 1 = very low, 5 = very high)	5	1	2.3	1
Severity ranking of ecological impacts based on respondent survey (n= 70 respondents; scale of 0 = least severe to 100= most severe)	91	4	34	4

Table A3a.4. Impact levels (scale of 0-3) for three major gear types represented as vulnerability of geologiacal and biological features to trawl impacts according to substrate, and low and high energy environments, adapted from NEFMC 2011.

	Bottom Trawl		**Longline**		**Trap**	
Vulnerability (S) as percent reduction in "functional value" S = 0, 0-10%; S=1, 10-25%; S=2, 25-50%; S=3, 50-100%	**Geological**	**Biological**	**Geological**	**Biological**	**Geological**	**Biological**
High energy mud / sand	**1.8–2.0**	**1.3-1.5**	**0.3-0.4**	**0.0**	**0.6-1.0**	**0.6-0.8**
Low energy mud / sand	**1.8-2.0**	**1.4-1.6**	**0.3-0.4**	**0.0**	**0.8-1.0**	**0.7-0.8**
High energy pebble / cobble /boulder	**1.0-1.7**	**1.6-1.7**	**0.0-0.3**	**0.0-1.5**	**0.0-0.3**	**0.9-0.9**
Low energy pebble / cobble /boulder	**1.0-2.0**	**1.7-1.8**	**0.0-0.5**	**0.0-1.5**	**0.0-0.5**	**0.9-1.0**

Table A3a.5. Distribution of bottom trawl fishing effort (distance, meters) from 2002-2010 by seabed habitat type, and by depth zones both coastwide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Data source: PacFIN trawl logbooks, based on a towline model that depicts a line from the gear deployment to retrieval coordinates.

		BIOGEOGRAPHIC SUB-REGION								COASTWIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	***Substrate***	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*
Shelf[1]	**Total**	**465,744,267**	**34.5%**	**135,584,061**	**39.4%**	**57,556,112**	**98.2%**	**3,652,788**	**100.0%**	**662,537,227**	**37.7%**
	hard	4,168,770	0.3%	1,103,097	0.3%	281,647	0.5%	5,767	0.2%	5,559,281	0.3%
	mixed	3,730,922	0.3%	89,351	0.0%	238,597	0.4%	9,969	0.3%	4,068,840	0.2%
	soft	457,844,575	33.9%	134,391,612	39.1%	57,035,868	97.4%	3,637,052	99.6%	652,909,107	37.1%
	undefined	0	0.0%	0	0.0%	0	0.0%		0.0%	0	0.0%
Upper Slope[2]	**Total**	**884,755,328**	**65.5%**	**208,141,081**	**60.5%**	**1,026,193**	**1.8%**	**0**	**0.0%**	**1,093,922,602**	**62.2%**
	hard	22,508,956	1.7%	3,738,955	1.1%	14,917	0.0%	0	0.0%	26,262,828	1.5%
	mixed	32,343,926	2.4%	128,515	0.0%	1,393	0.0%	0	0.0%	32,473,835	1.8%
	soft	829,902,445	61.4%	204,273,611	59.4%	1,009,883	1.7%	0	0.0%	1,035,185,939	58.9%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**1,279,842**	**0.1%**	**198,966**	**0.1%**	**4,716**	**0.0%**	**0**	**0.0%**	**1,483,524**	**0.1%**
	hard	118,706	0.0%	1,155	0.0%	4,716	0.0%	0	0.0%	124,577	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	1,161,136	0.1%	197,812	0.1%	0	0.0%	0	0.0%	1,358,947	0.1%
	undefined	0	0.0%	0	0.0%		0.0%	0	0.0%	0	0.0%
Total		**1,351,779,436**	**100.0%**	**343,924,108**	**100.0%**	**58,587,021**	**100.0%**	**3,652,788**	**100.0%**	**1,757,943,353**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

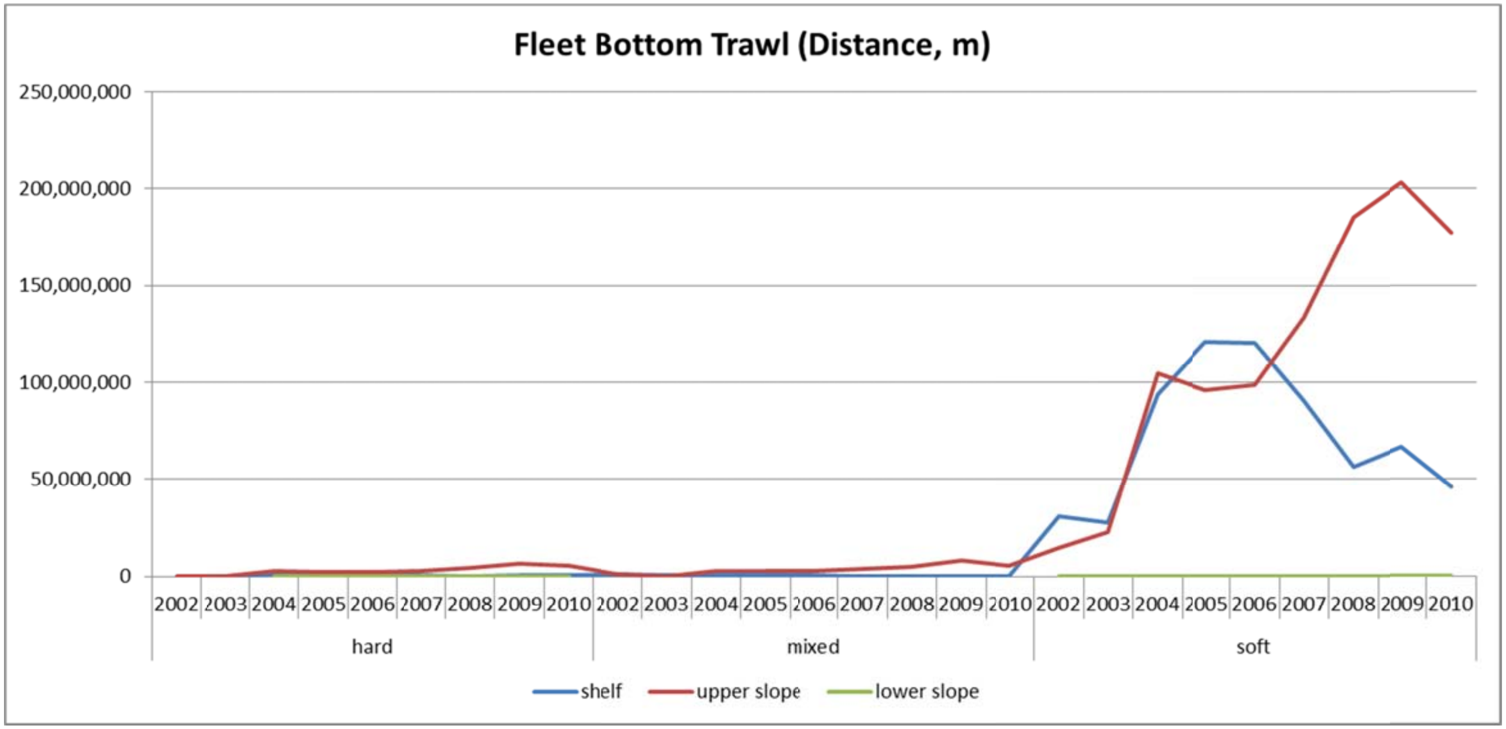


Figure A3a.1. Annual distribution of bottom trawl fishing effort (distance, meters) from 2002-2010, by seabed habitat type and depth zones.

Table A3a.6. Distribution of midwater trawl fishing effort (distance, meters) from 2002-2010 by seabed habitat type, and by depth zones both coastwide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Data source: At-Sea Hake Observer Program (NWFSC), based on a towline model which depicts a line from the gear deployment to retrieval coordinates.

		BIOGEOGRAPHIC SUB-REGION								COASTWIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	***Substrate***	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*	*Distance (m)*	*%*
Shelf[1]	**Total**	**26,732,815**	**14.1%**	**0**	**0.0%**	**0**	**0.0%**	**80,811**	**100.0%**	**26,813,626**	**14.1%**
	hard	406,100	0.2%	0	0.0%	0	0.0%	3,146	3.9%	409,246	0.2%
	mixed	2,356,373	1.2%	0	0.0%	0	0.0%	39,155	48.5%	2,395,528	1.3%
	soft	23,970,342	12.6%	0	0.0%	0	0.0%	38,510	47.7%	24,008,853	12.6%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Upper Slope[2]	**Total**	**161,885,915**	**85.2%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**161,885,915**	**85.2%**
	hard	5,807,496	3.1%	0	0.0%	0	0.0%	0	0.0%	5,807,496	3.1%
	mixed	10,502,163	5.5%	0	0.0%	0	0.0%	0	0.0%	10,502,163	5.5%
	soft	145,576,257	76.7%	0	0.0%	0	0.0%	0	0.0%	145,576,257	76.6%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**1,277,669**	**0.7%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**1,277,669**	**0.7%**
	hard	90,633	0.0%	0	0.0%	0	0.0%	0	0.0%	90,633	0.0%
	mixed	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	soft	1,187,036	0.6%	0	0.0%	0	0.0%	0	0.0%	1,187,036	0.6%
	undefined	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total		**189,896,400**	**100.0%**	**0**	**0.0%**	**0**	**0.0%**	**80,811**	**100.0%**	**189,977,211**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

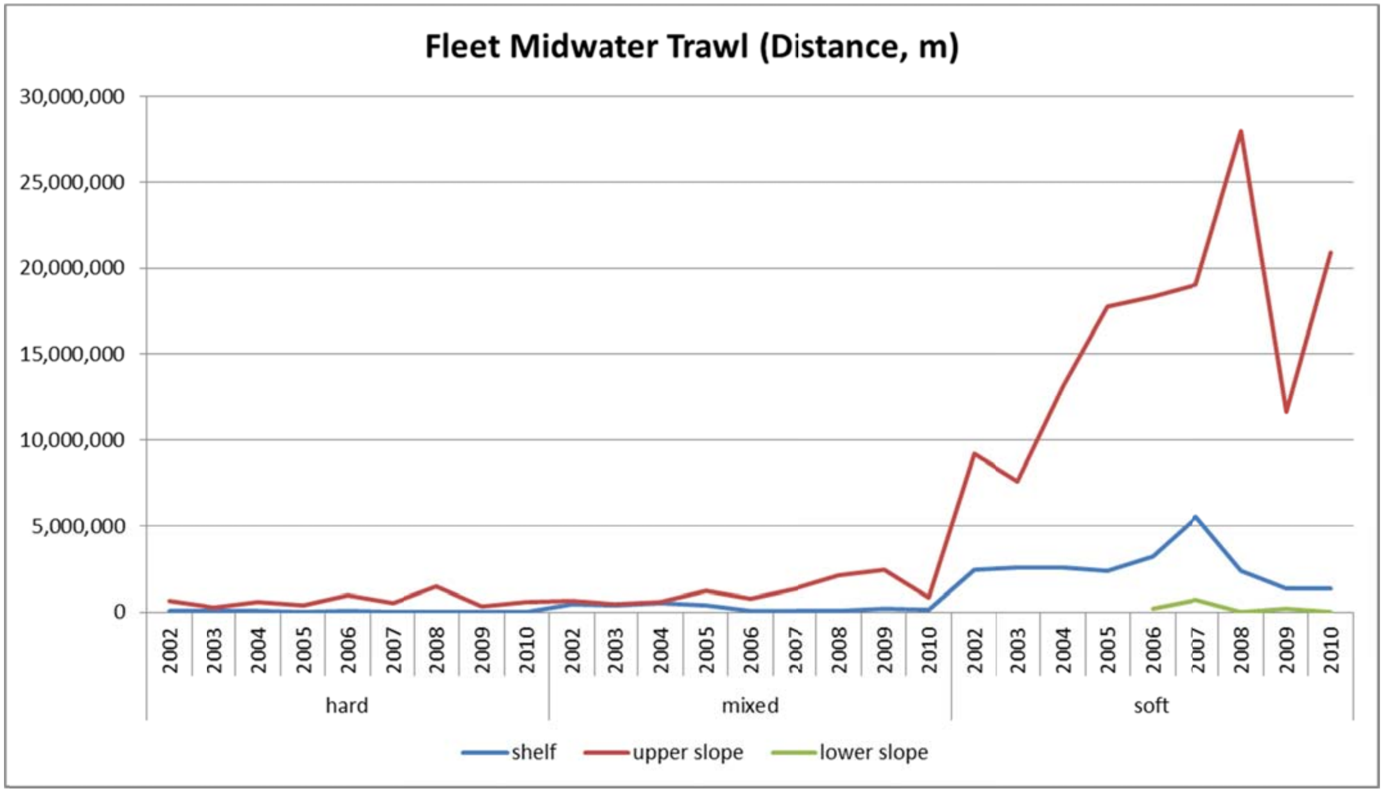


Figure A3a.2. Annual distribution of midwater trawl fishing effort (distance, meters) from 2002-2010, by seabed habitat type and depth zones.

Table A3a.7. Distribution of observed groundfish fixed gear fishing effort (# of fishing events) from 2002-2010 by seabed habitat type, and by depth zones both coastwide and in four biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Percentage values represent relative contribution to the sub-region. The "Salish Sea" only encompasses the shallowest ("shelf") depth zone. Data source: West Coast Groundfish Observer Program (NWFSC), based on either a towline model which depicts a line from the gear deployment to retrieval coordinates (longlines or pot strings), or on points representing the average of gear deployment and retrieval coordinates (other hook-and-line gears or pot/trap gears), depending on gear type.

		BIOGEOGRAPHIC SUB-REGION								COASTWIDE	
		Northern		Central		Southern		Salish Sea		Combined	
Depth Zone	***Substrate***	*# of Events*	*%*	*# of Events*	*%*	*# of Events*	*%*	*# of Events*	*%*	*# of Events*	*%*
Shelf[1]	**Total**	**3,459**	**32.4%**	**905**	**49.3%**	**319**	**14.0%**	**0**	**0.0%**	**4,683**	**31.7%**
	hard	825	7.7%	435	23.7%	108	4.7%	0	0.0%	1,368	9.3%
	mixed	462	4.3%	37	2.0%	2	0.1%	0	0.0%	501	3.4%
	soft	2172	20.4%	433	23.6%	209	9.2%	0	0.0%	2,814	19.0%
	undefined		0.0%		0.0%		0.0%	0	0.0%	0	0.0%
Upper Slope[2]	**Total**	**7,085**	**66.4%**	**911**	**49.7%**	**1,947**	**85.3%**	**0**	**0.0%**	**9,943**	**67.3%**
	hard	722	6.8%	119	6.5%	127	5.6%	0	0.0%	968	6.5%
	mixed	836	7.8%	3	0.2%	0	0.0%	0	0.0%	839	5.7%
	soft	5527	51.8%	789	43.0%	1820	79.7%	0	0.0%	8,136	55.0%
	undefined		0.0%		0.0%		0.0%	0	0.0%	0	0.0%
Lower Slope[3]	**Total**	**122**	**1.1%**	**18**	**1.0%**	**17**	**0.7%**	**0**	**0.0%**	**157**	**1.1%**
	hard	57	0.5%	2	0.1%	9	0.4%	0	0.0%	68	0.5%
	mixed	65	0.6%	13	0.7%	0	0.0%	0	0.0%	78	0.5%
	soft	0	0.0%	3	0.2%	8	0.4%	0	0.0%	11	0.1%
	undefined		0.0%		0.0%		0.0%	0	0.0%	0	0.0%
Total		**10,666**	**100.0%**	**1,834**	**100.0%**	**2,283**	**100.0%**	**0**	**0.0%**	**14,783**	**100.0%**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

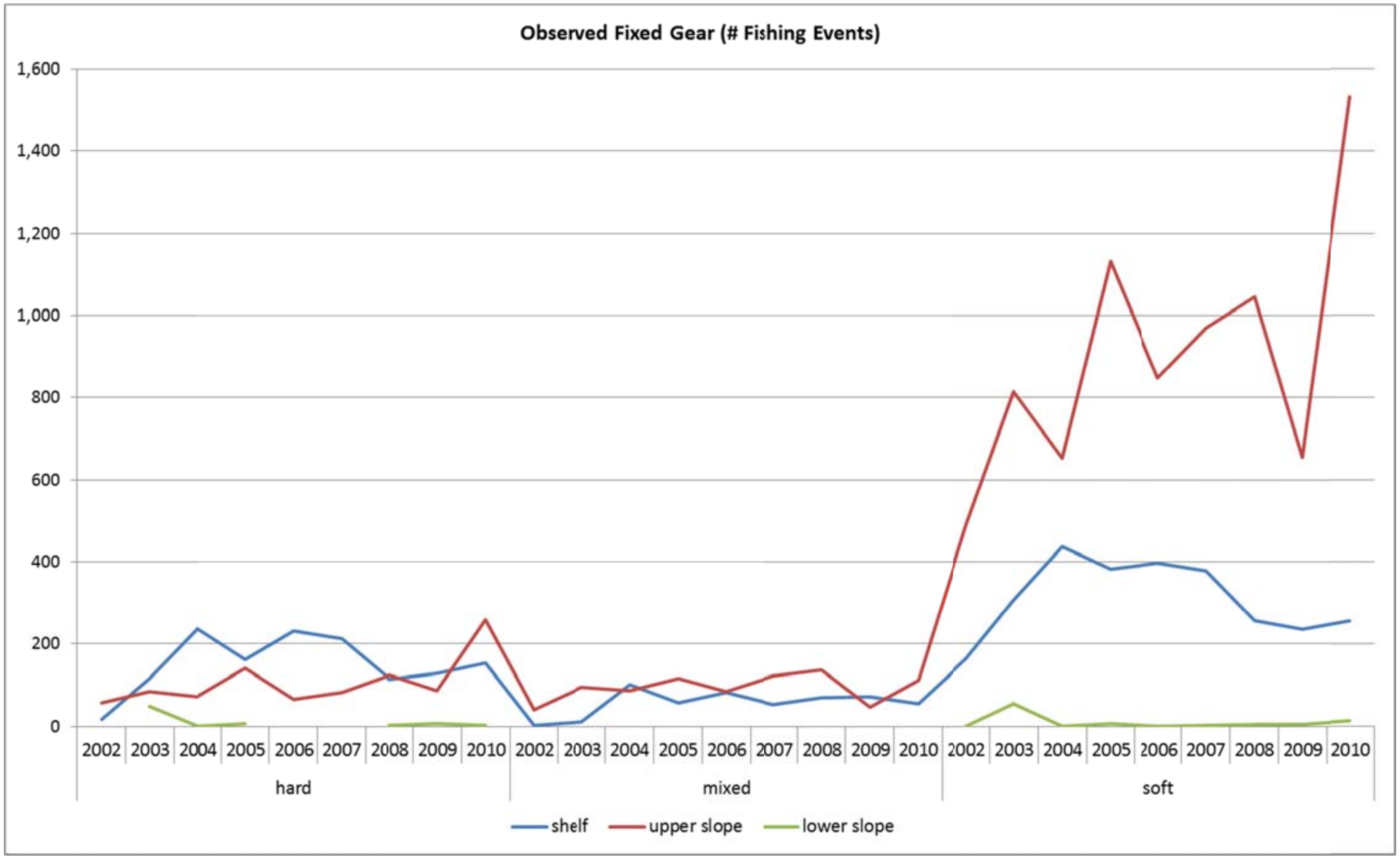
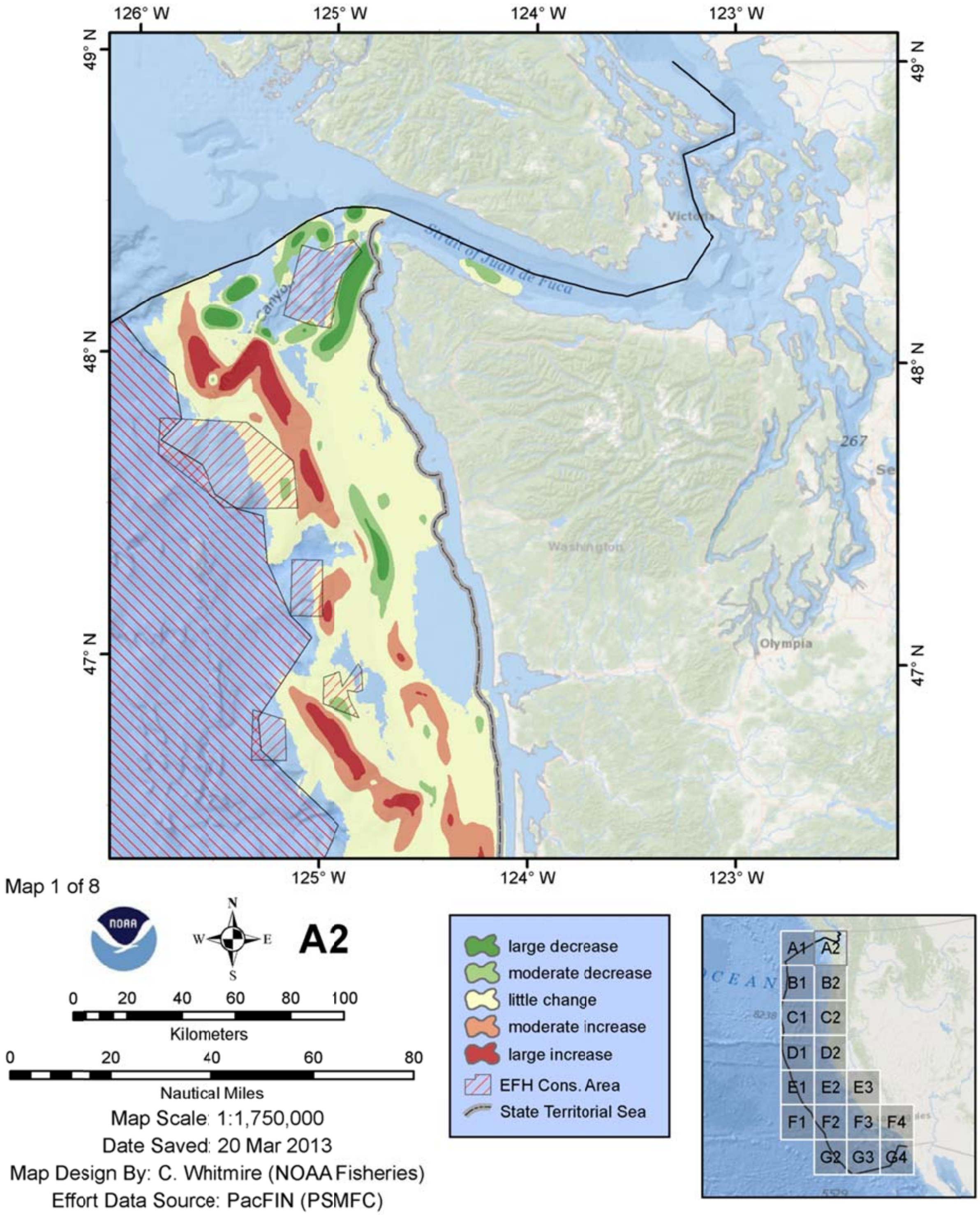


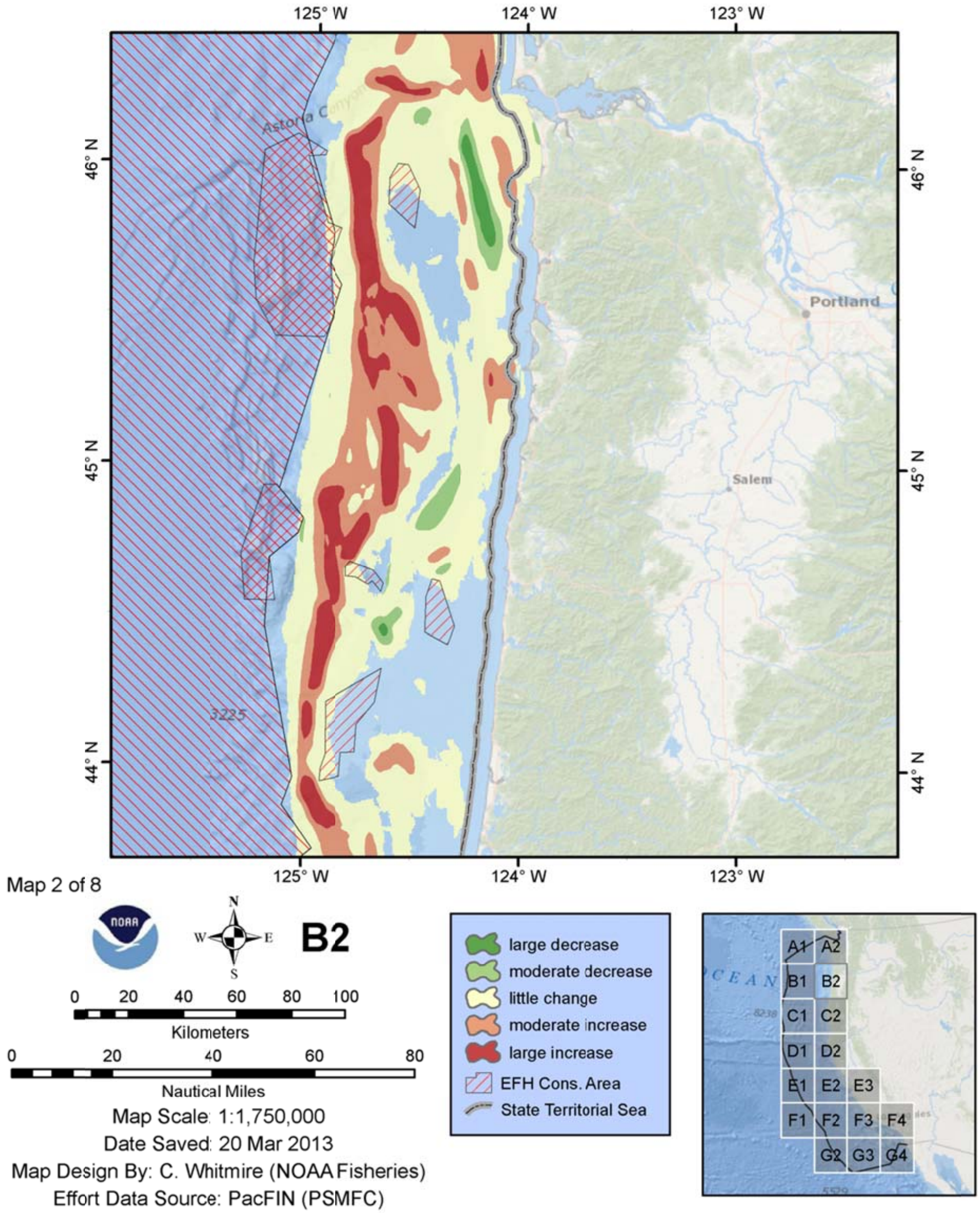
Figure A3a.3. Annual distribution of observed fixed gear fishing effort (# of fishing events) from 2002-2010, by seabed habitat type and depth zones.

Figure A3a.4. Map views (following pages; plates A2-F4) showing change in bottom trawl effort between two time periods: “before” (i.e., 1 Jan 2002 – 11 Jun 2006) and “after” (i.e., 12 Jun 2006 – 31 Dec 2010) implementation of Amendment 19 regulatory measures.

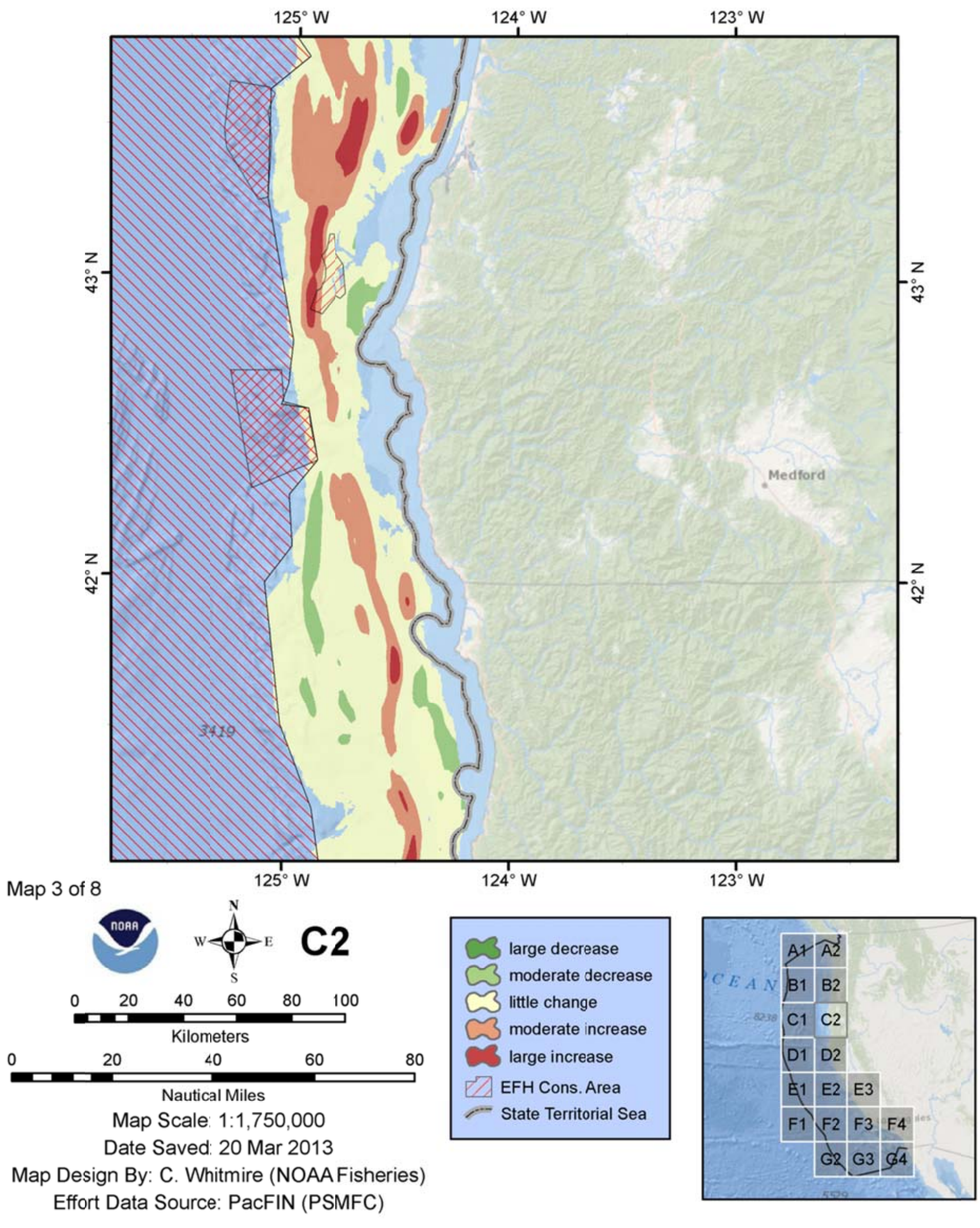
Bottom Trawl Effort (Temporal Change)



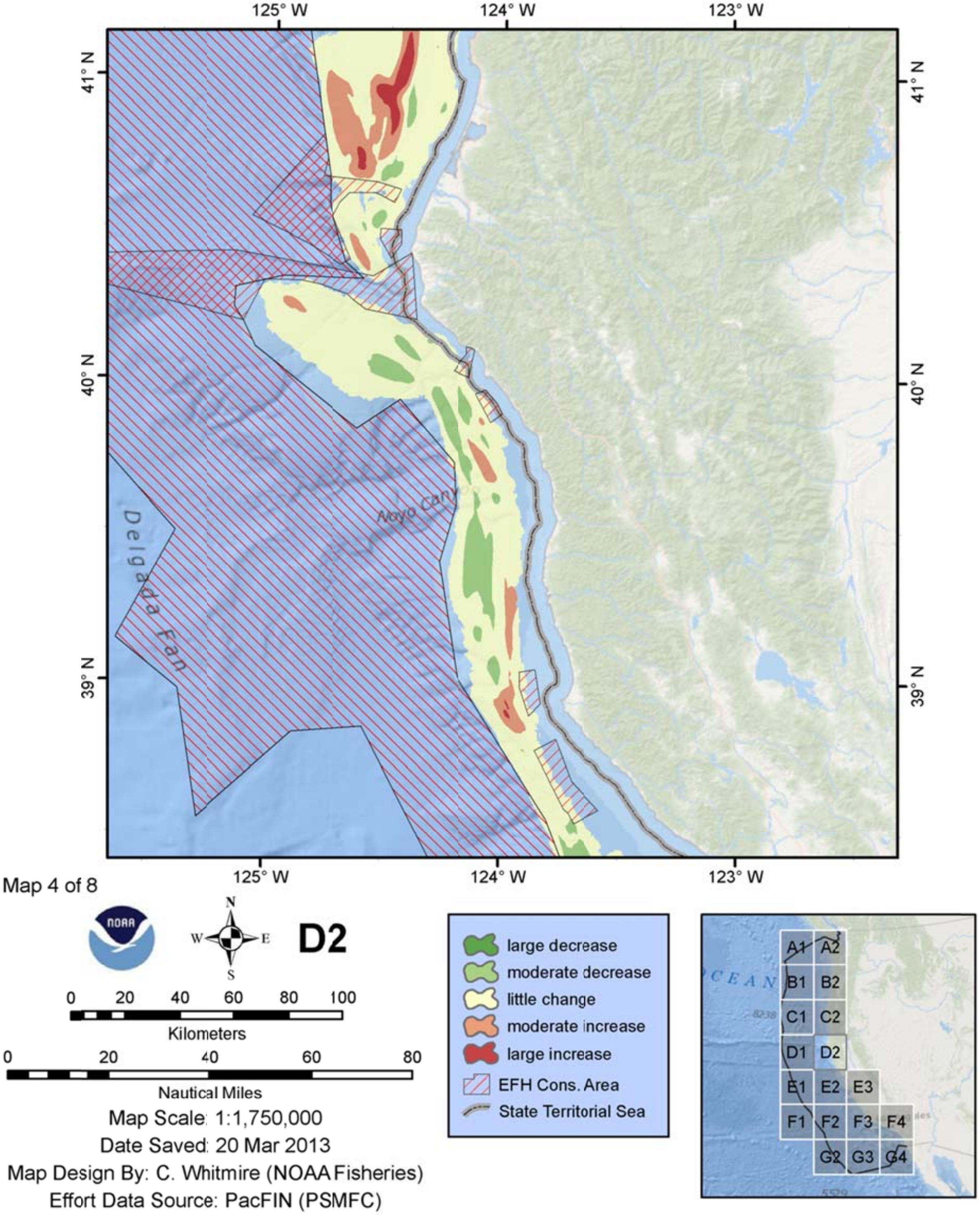
Bottom Trawl Effort (Temporal Change)



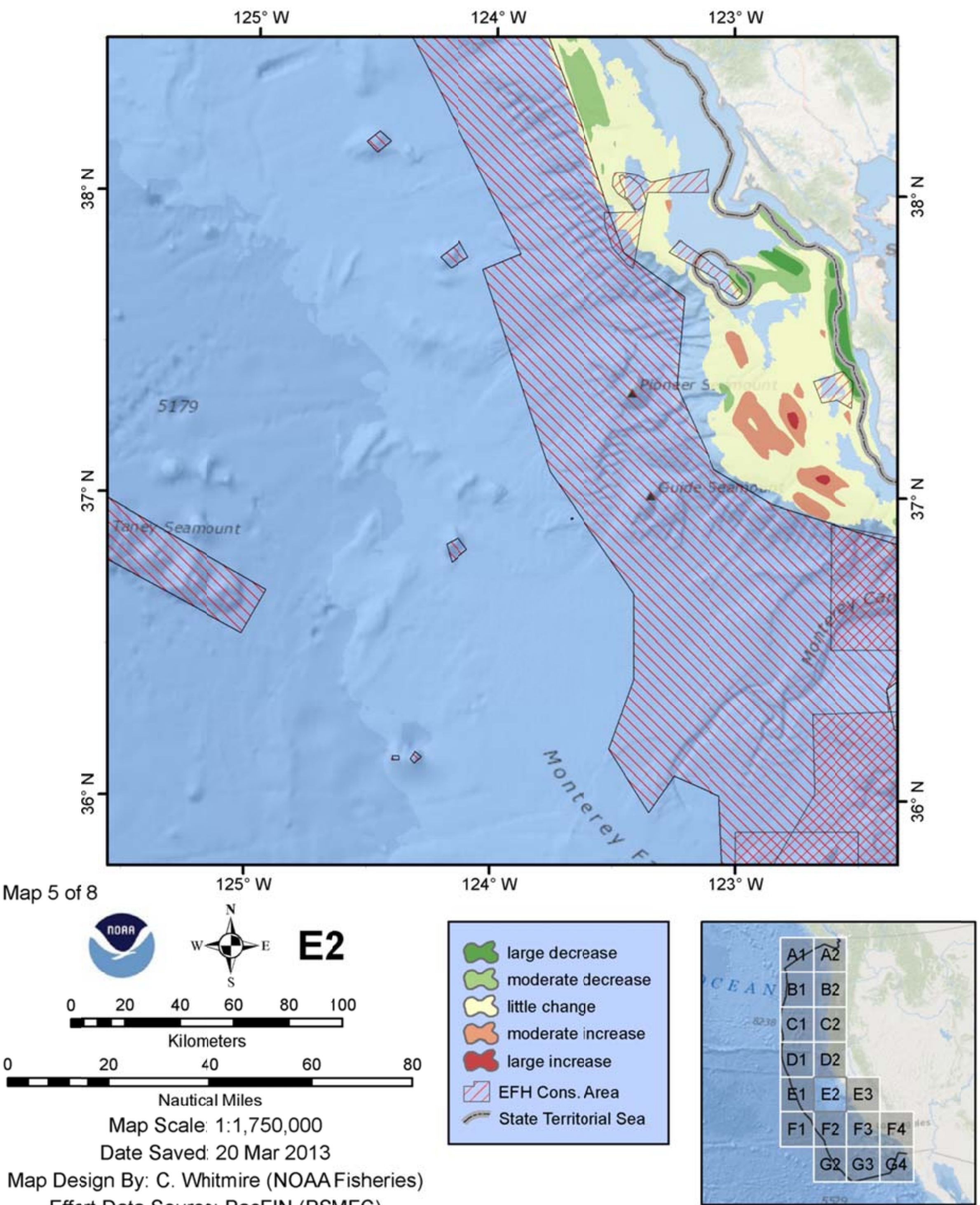
Bottom Trawl Effort (Temporal Change)



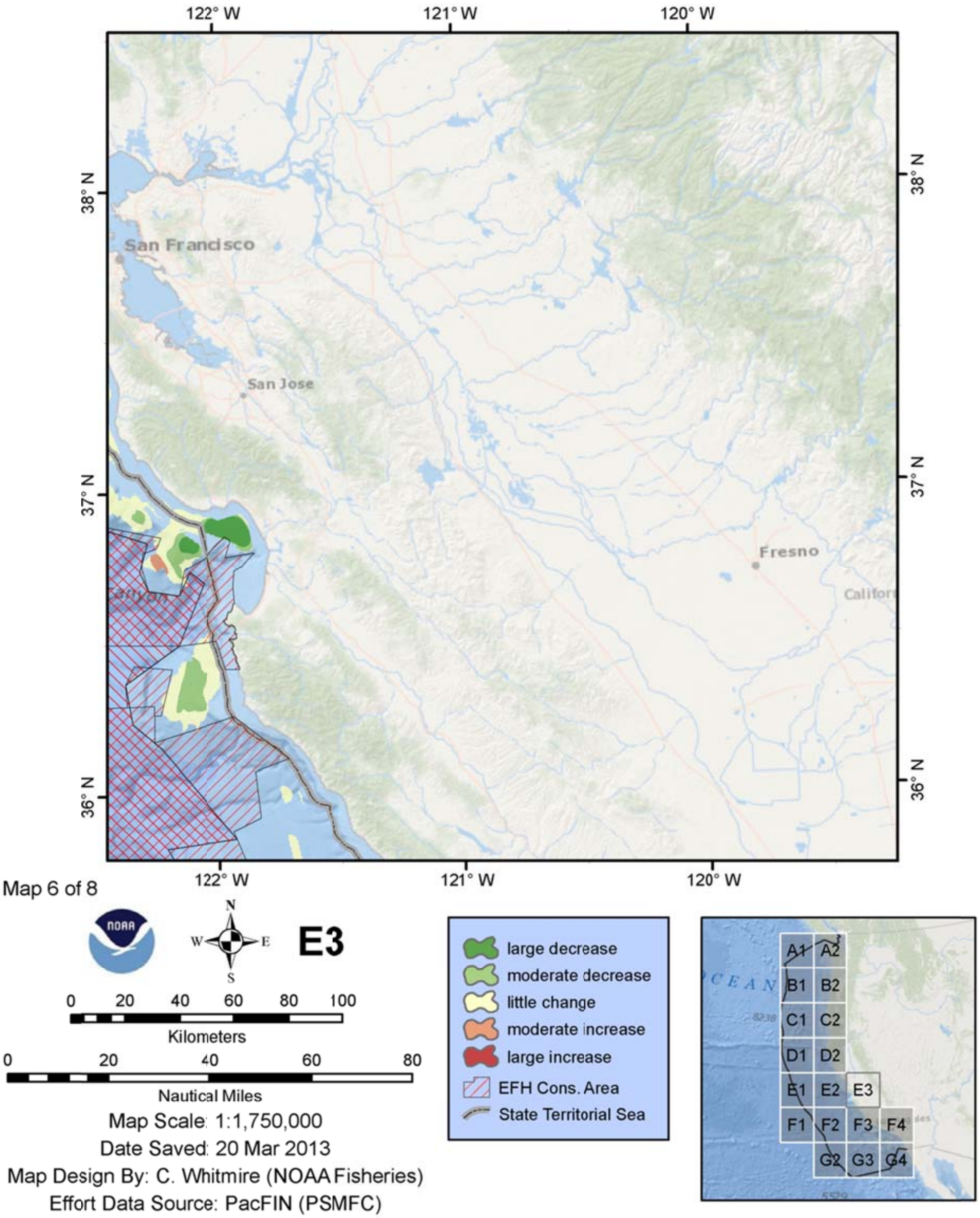
Bottom Trawl Effort (Temporal Change)



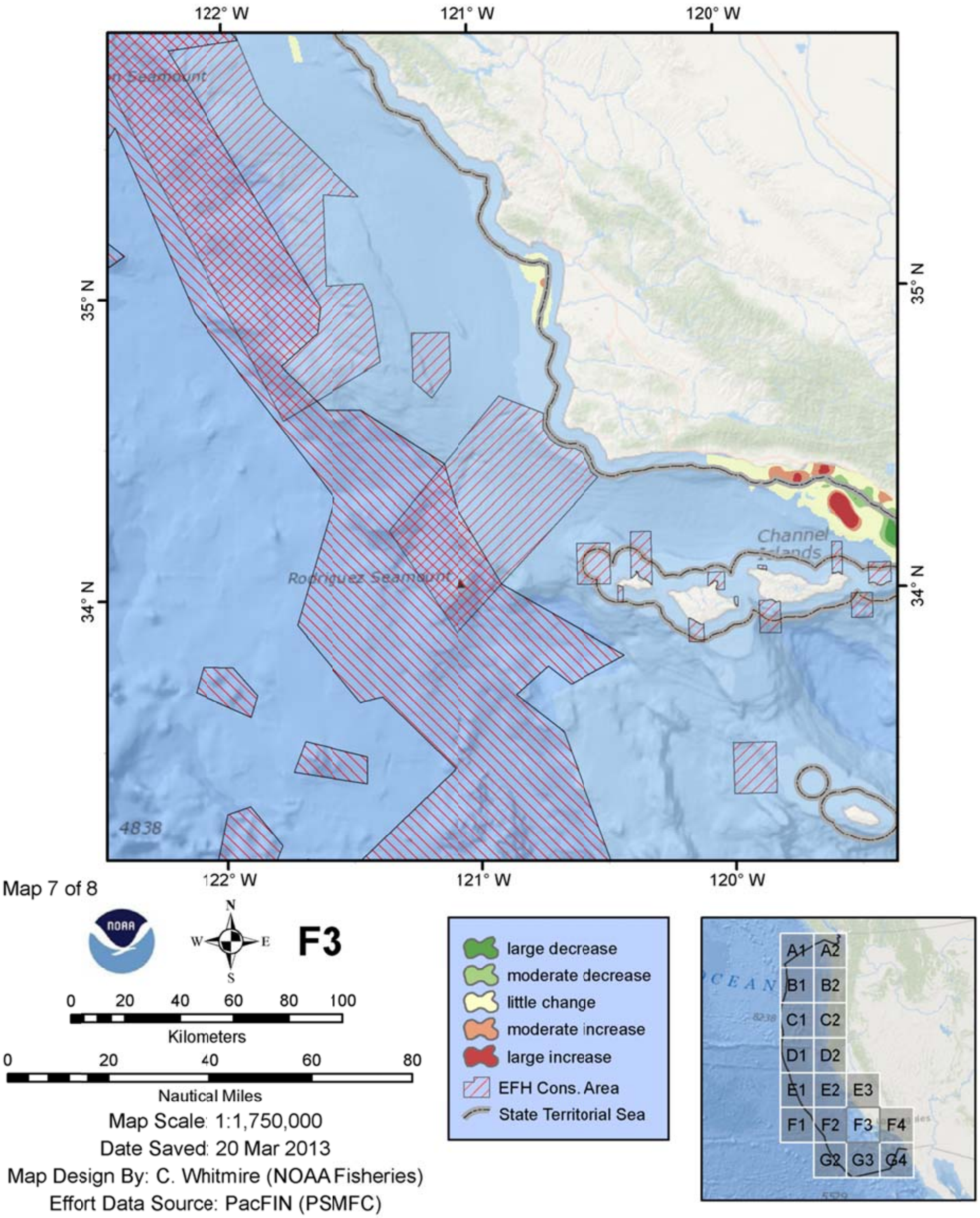
Bottom Trawl Effort (Temporal Change)



Bottom Trawl Effort (Temporal Change)



Bottom Trawl Effort (Temporal Change)



Bottom Trawl Effort (Temporal Change)

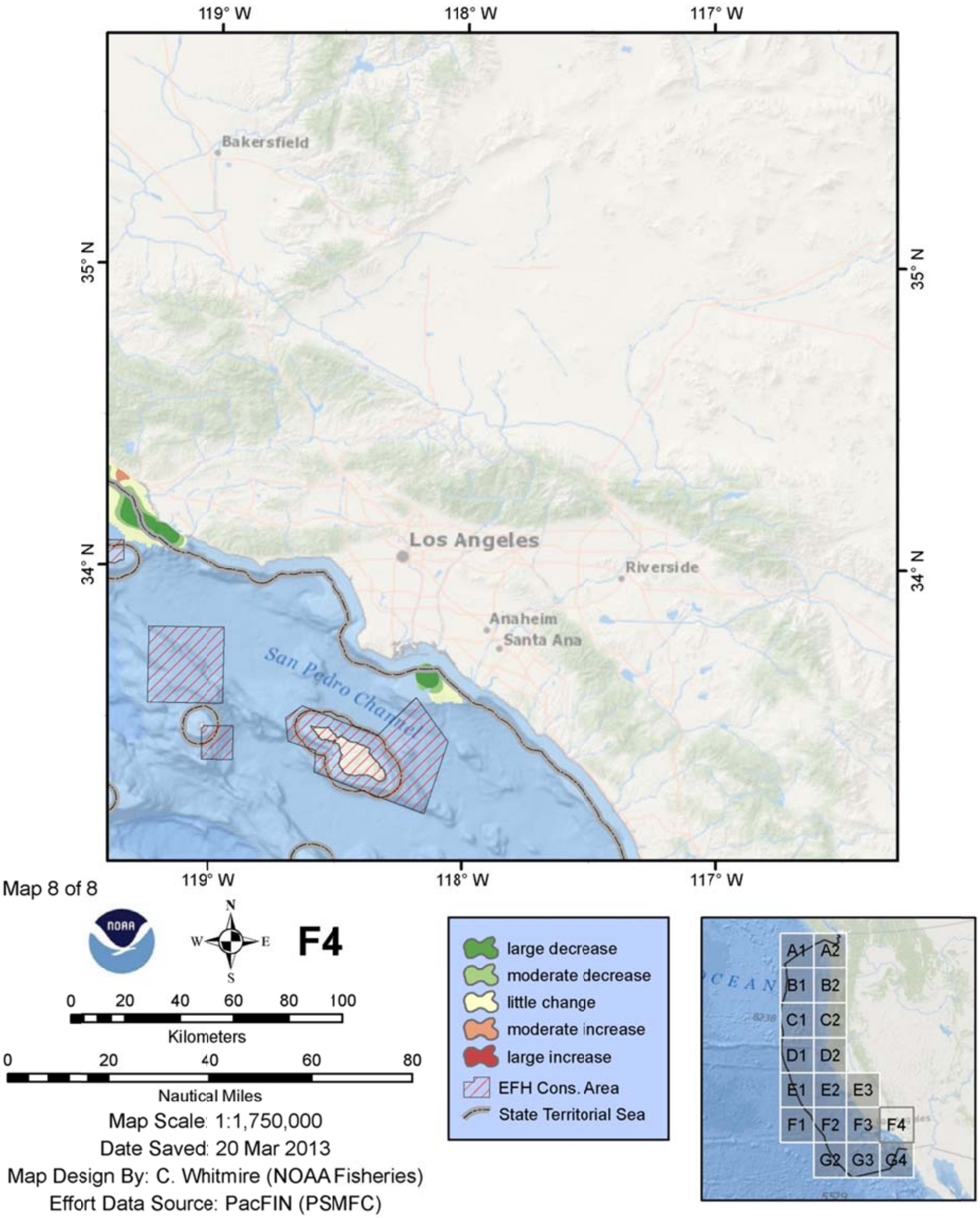
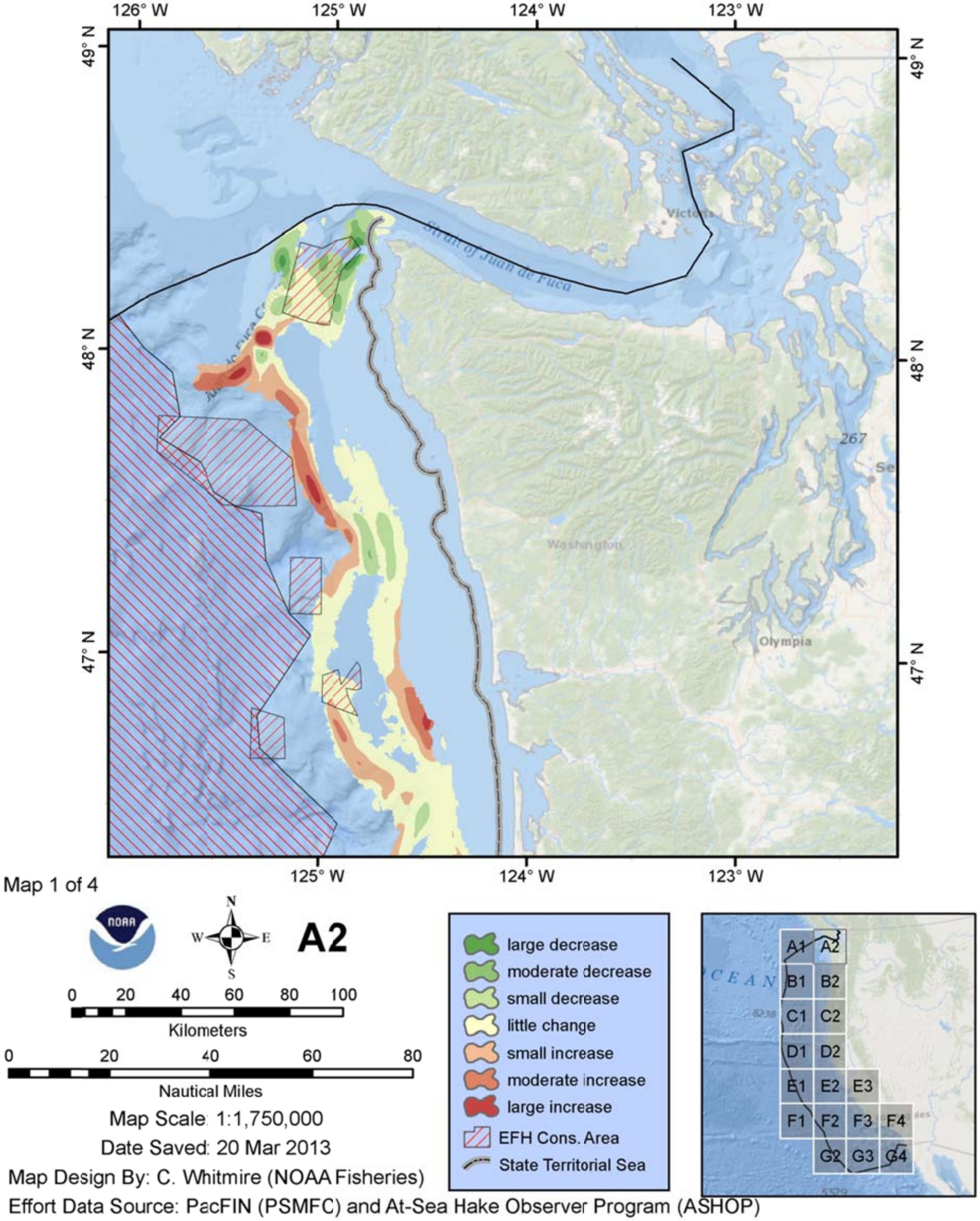
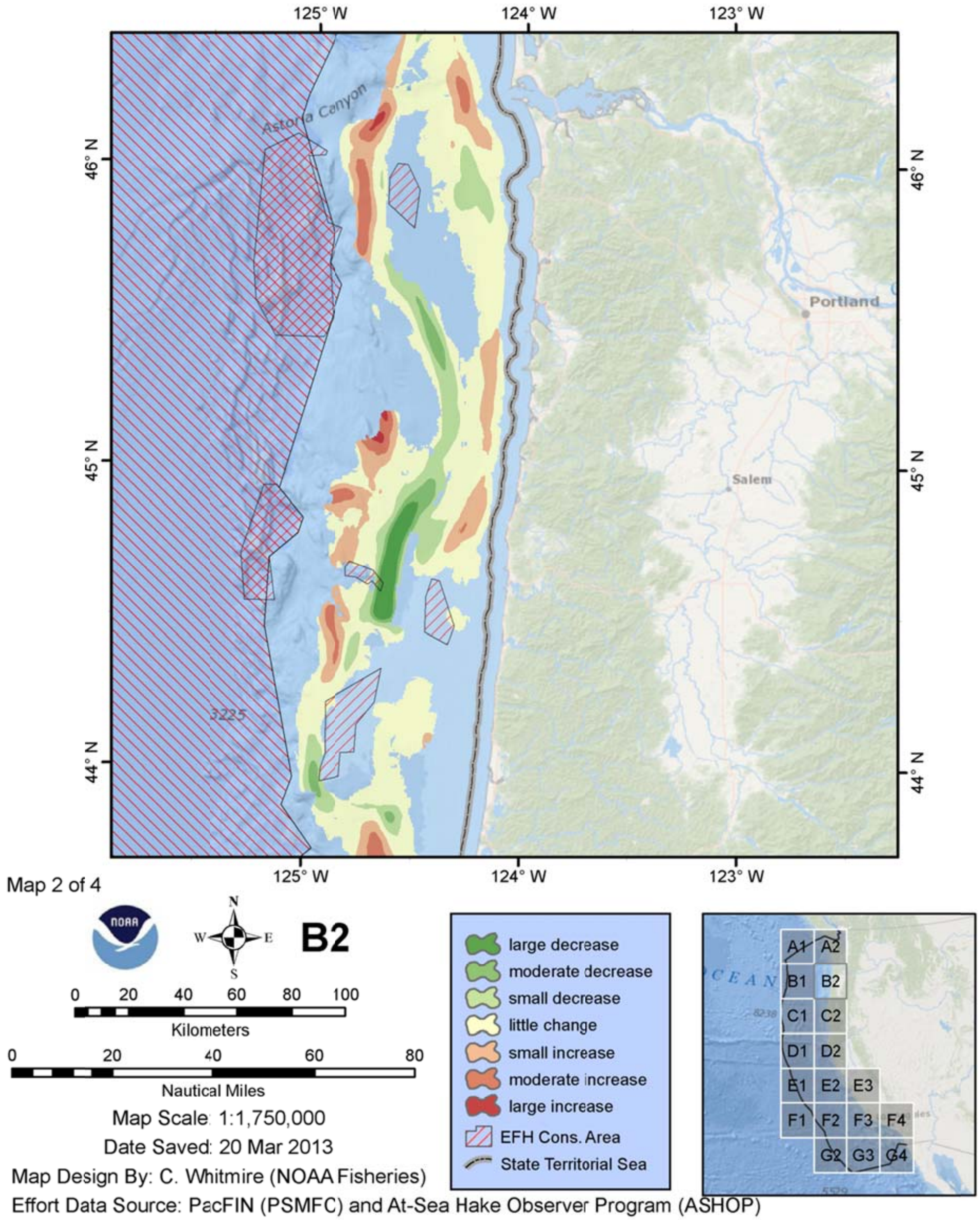


Figure A3a.5. Map views (following pages; plates A2-D2) showing change in midwater trawl effort between two time periods: “before” (i.e., 1 Jan 2002 – 11 Jun 2006) and “after” (i.e., 12 Jun 2006 – 31 Dec 2010) implementation of Amendment 19 regulatory measures.

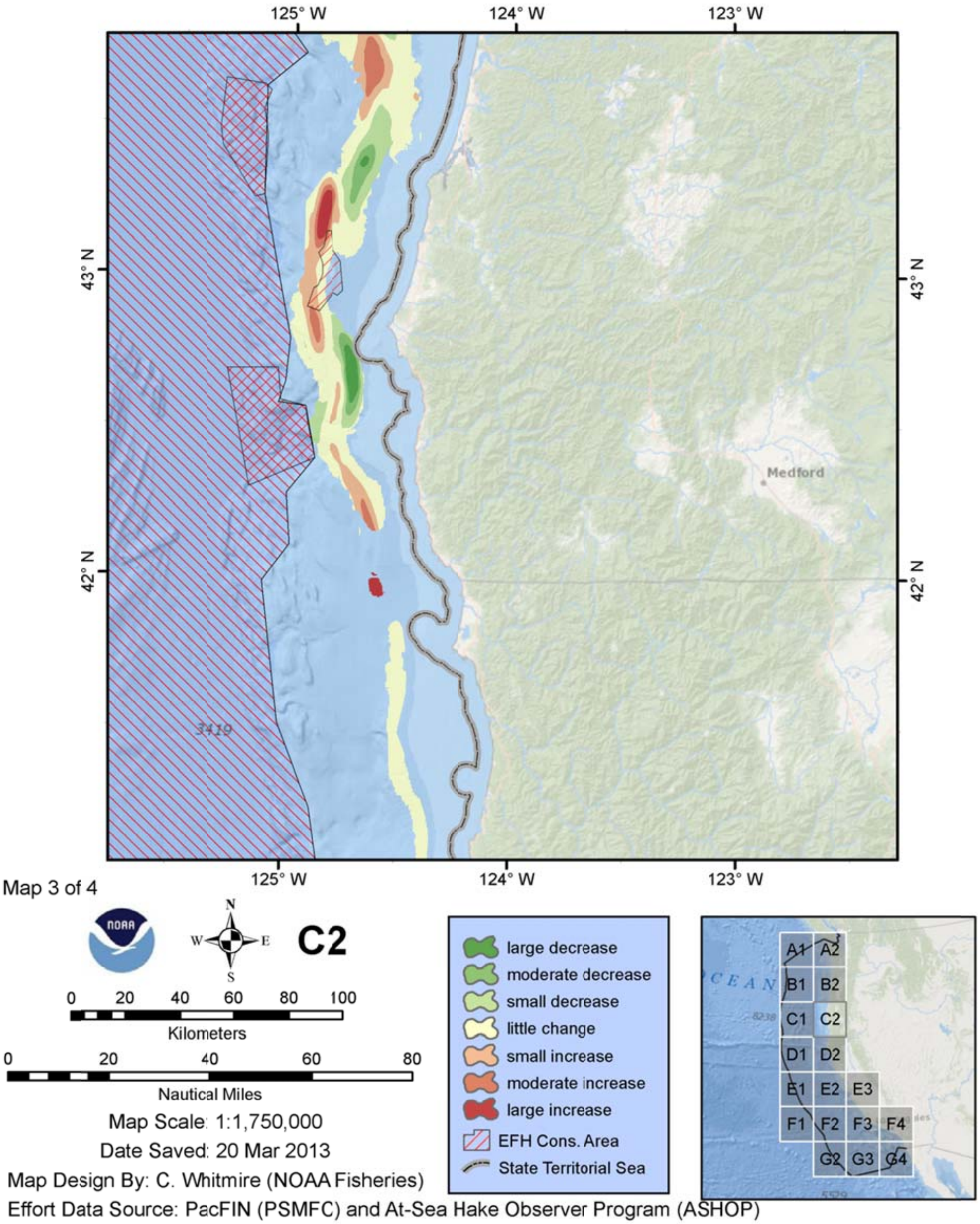
Midwater Trawl Effort (Temporal Change)



Midwater Trawl Effort (Temporal Change)



Midwater Trawl Effort (Temporal Change)



Midwater Trawl Effort (Temporal Change)

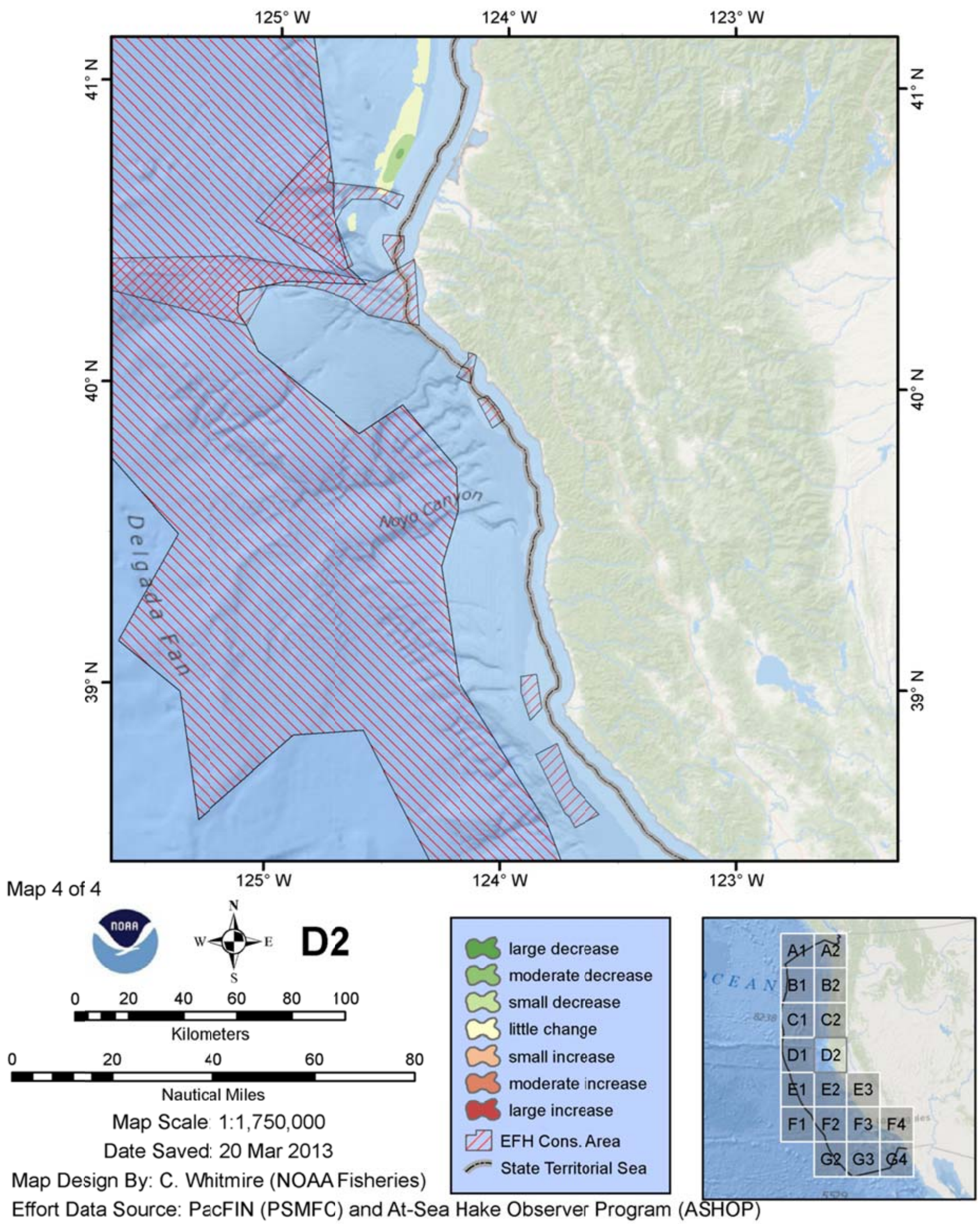
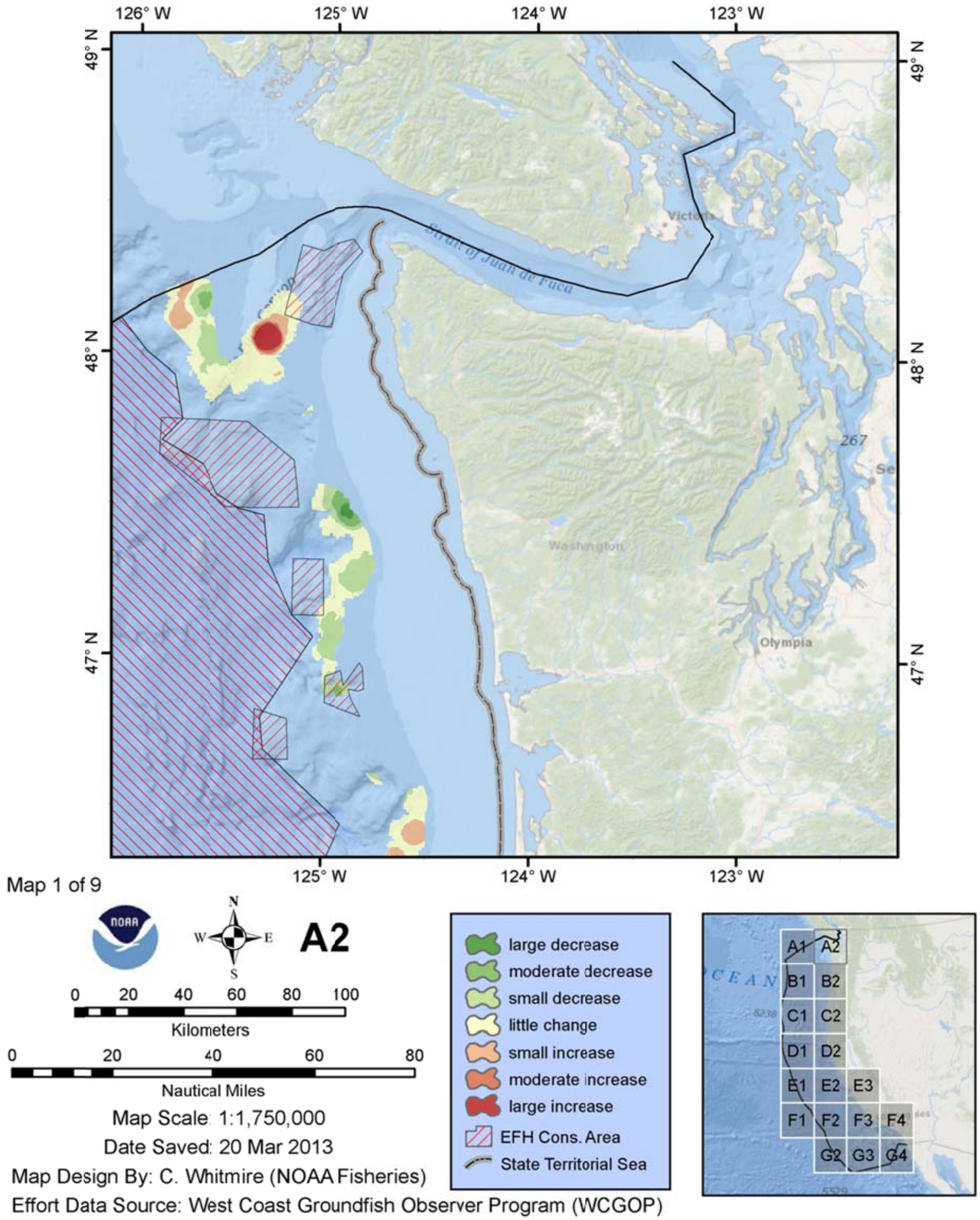
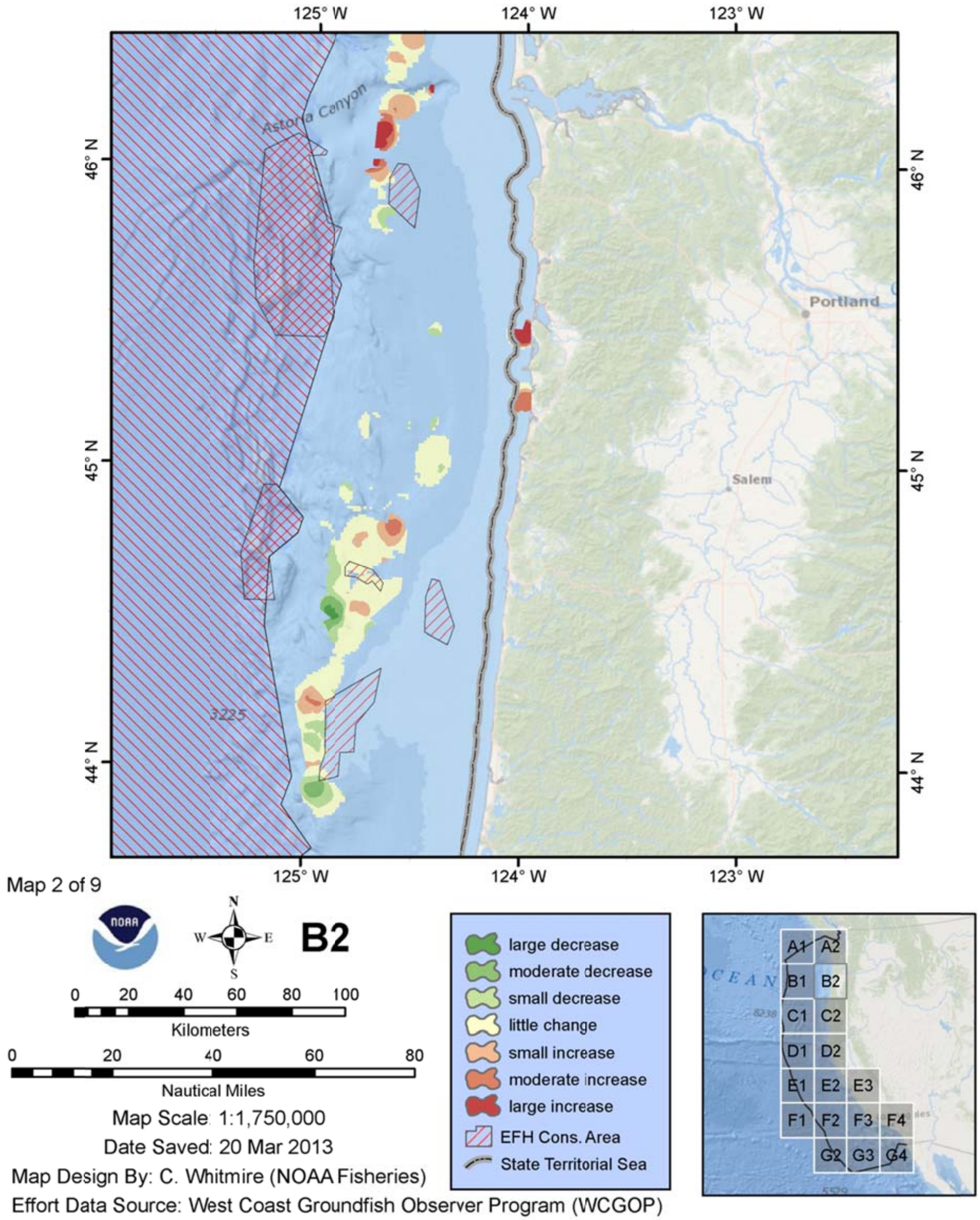


Figure A3a.6. Map views (following pages; plates A2-G4) showing change in observed fixed gear effort between two time periods: “before” (i.e., 1 Jan 2002 – 11 Jun 2006) and “after” (i.e., 12 Jun 2006 – 31 Dec 2010) implementation of Amendment 19 regulatory measures.

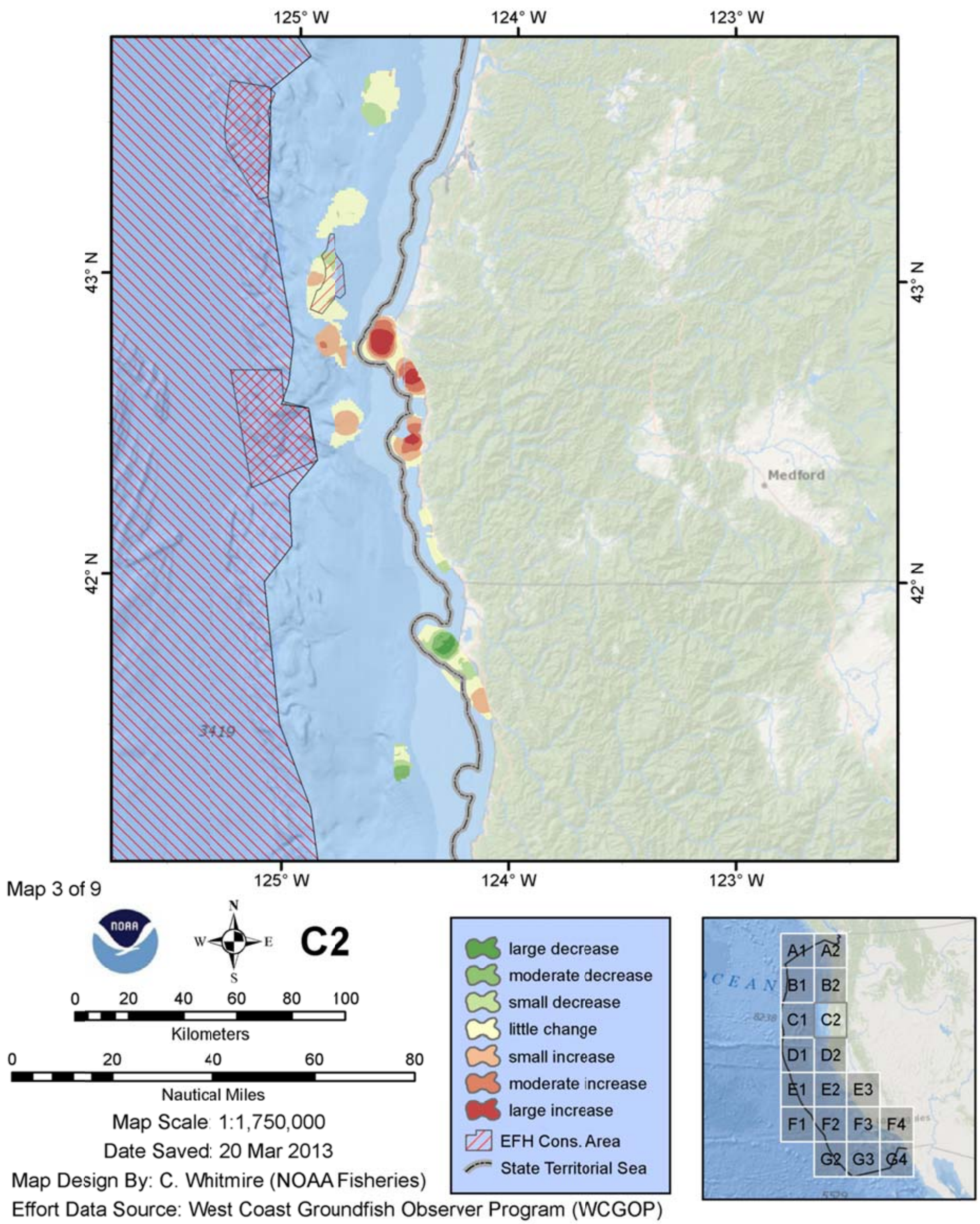
Observed Fixed Gear Effort (Temporal Change)



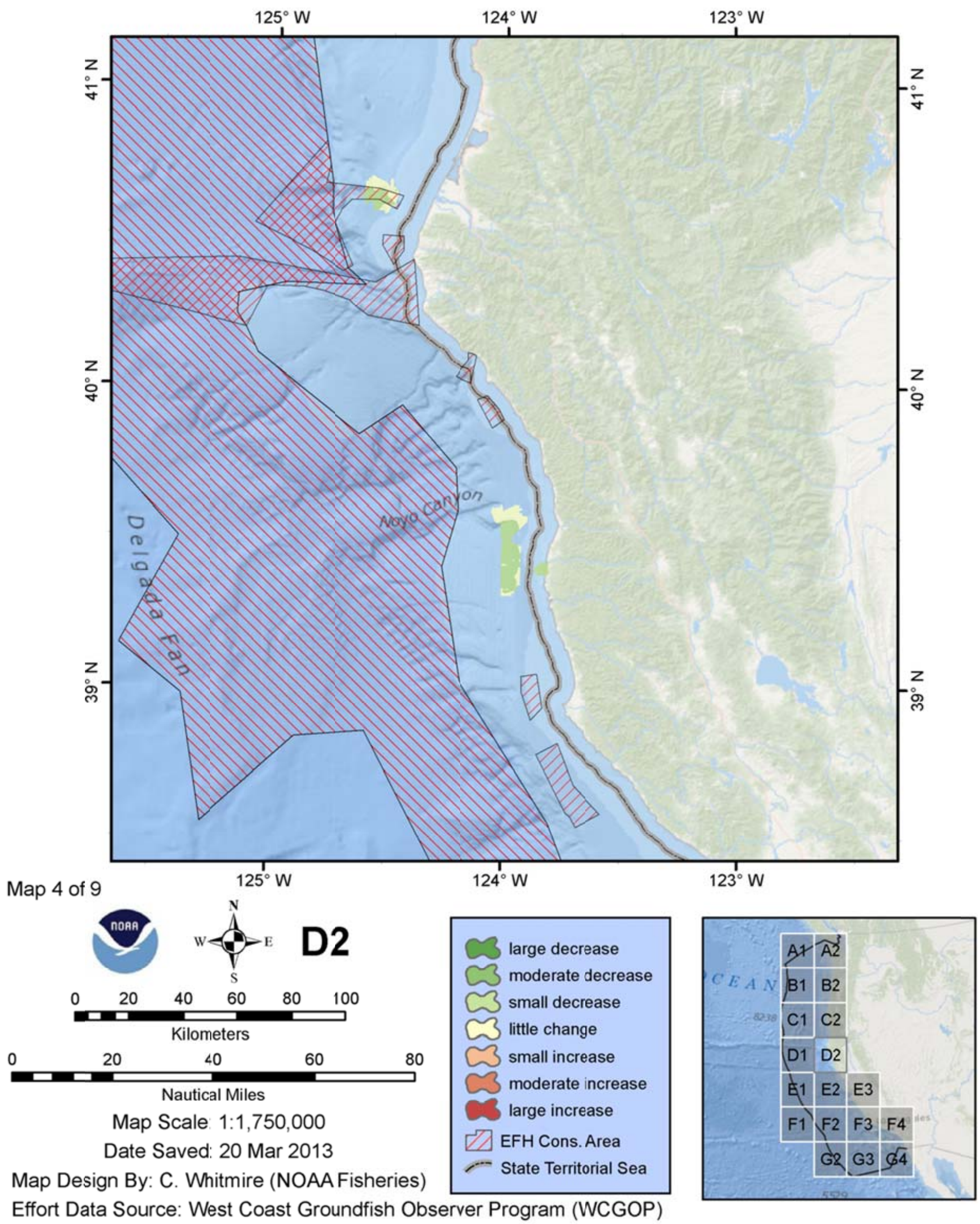
Observed Fixed Gear Effort (Temporal Change)



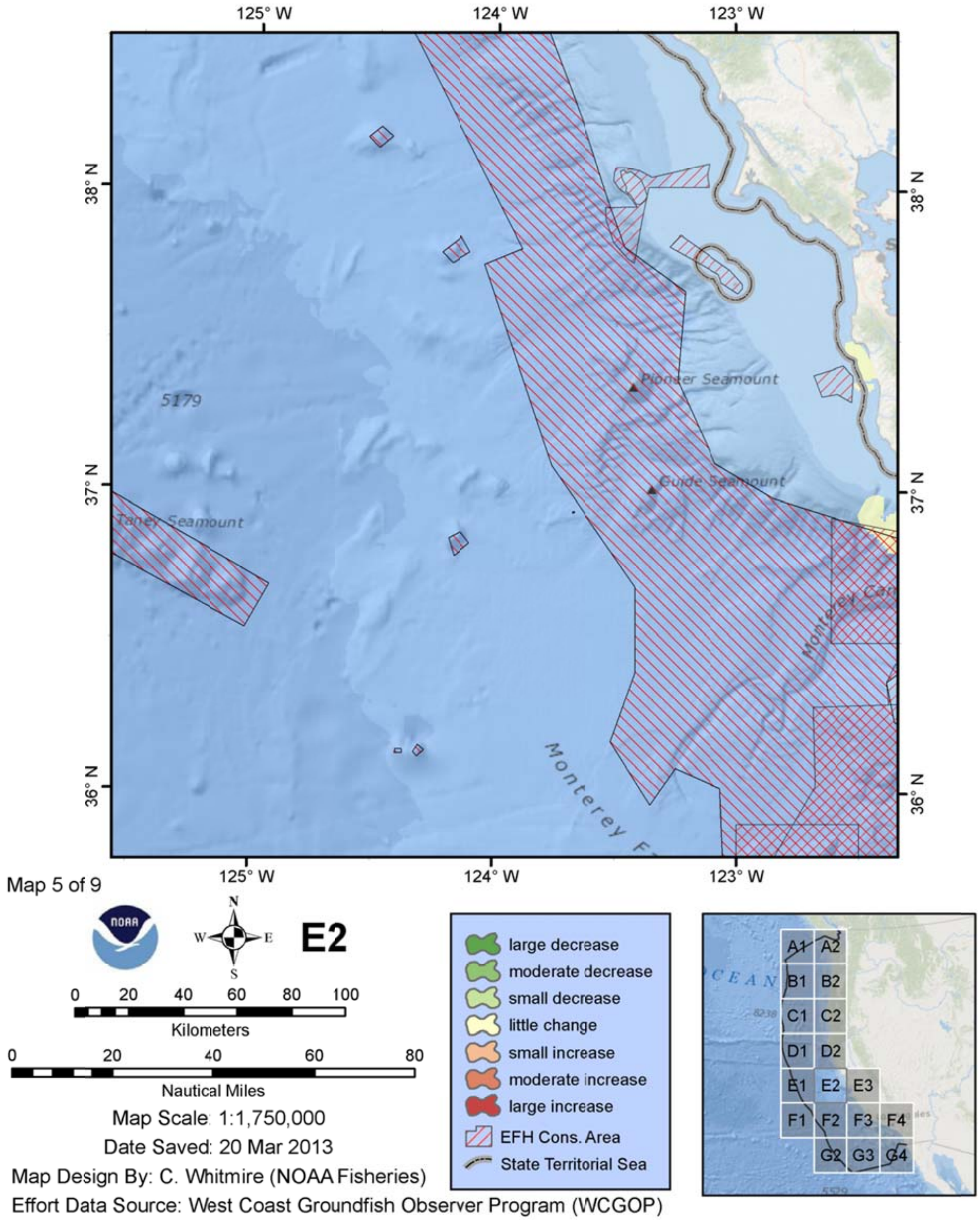
Observed Fixed Gear Effort (Temporal Change)



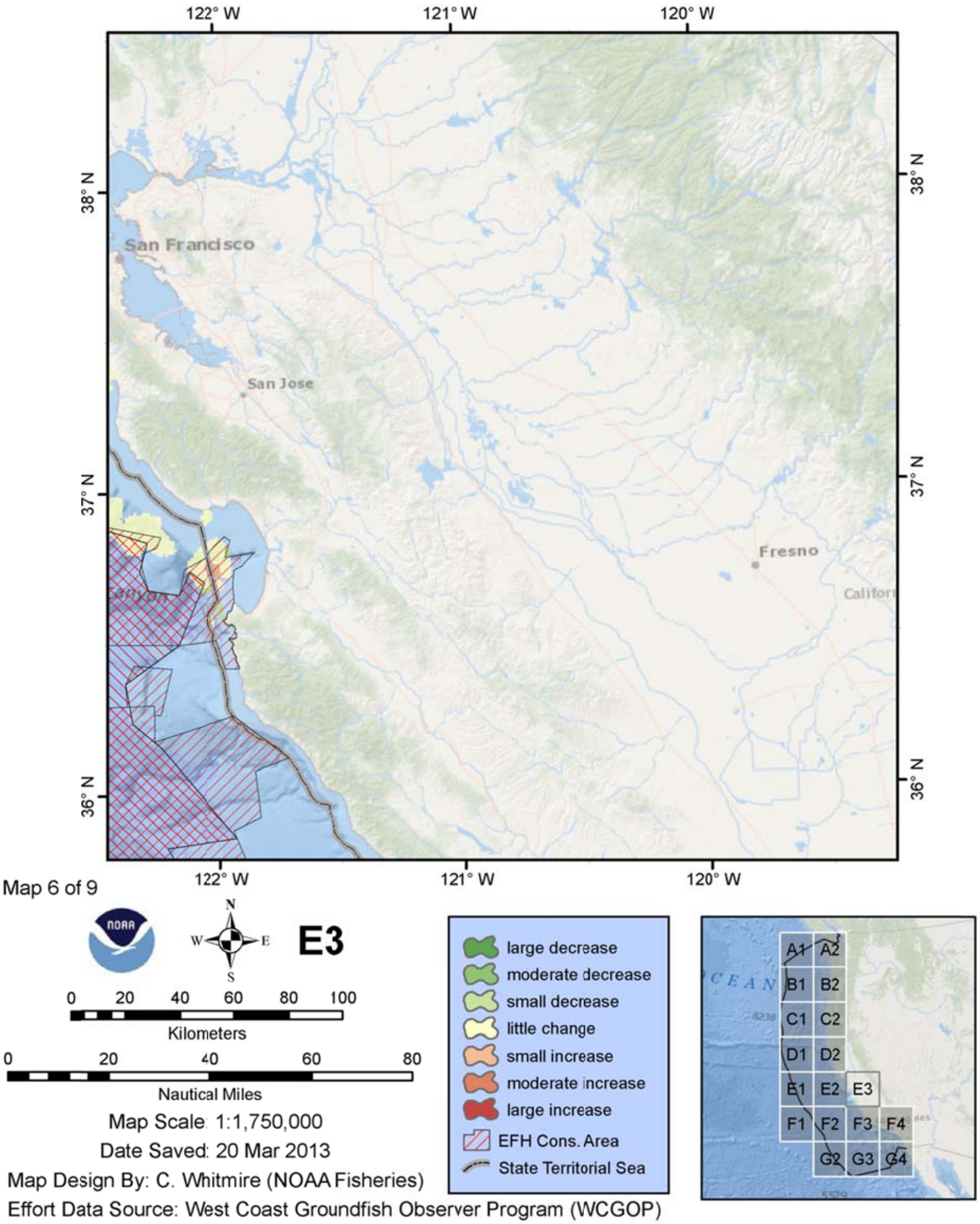
Observed Fixed Gear Effort (Temporal Change)



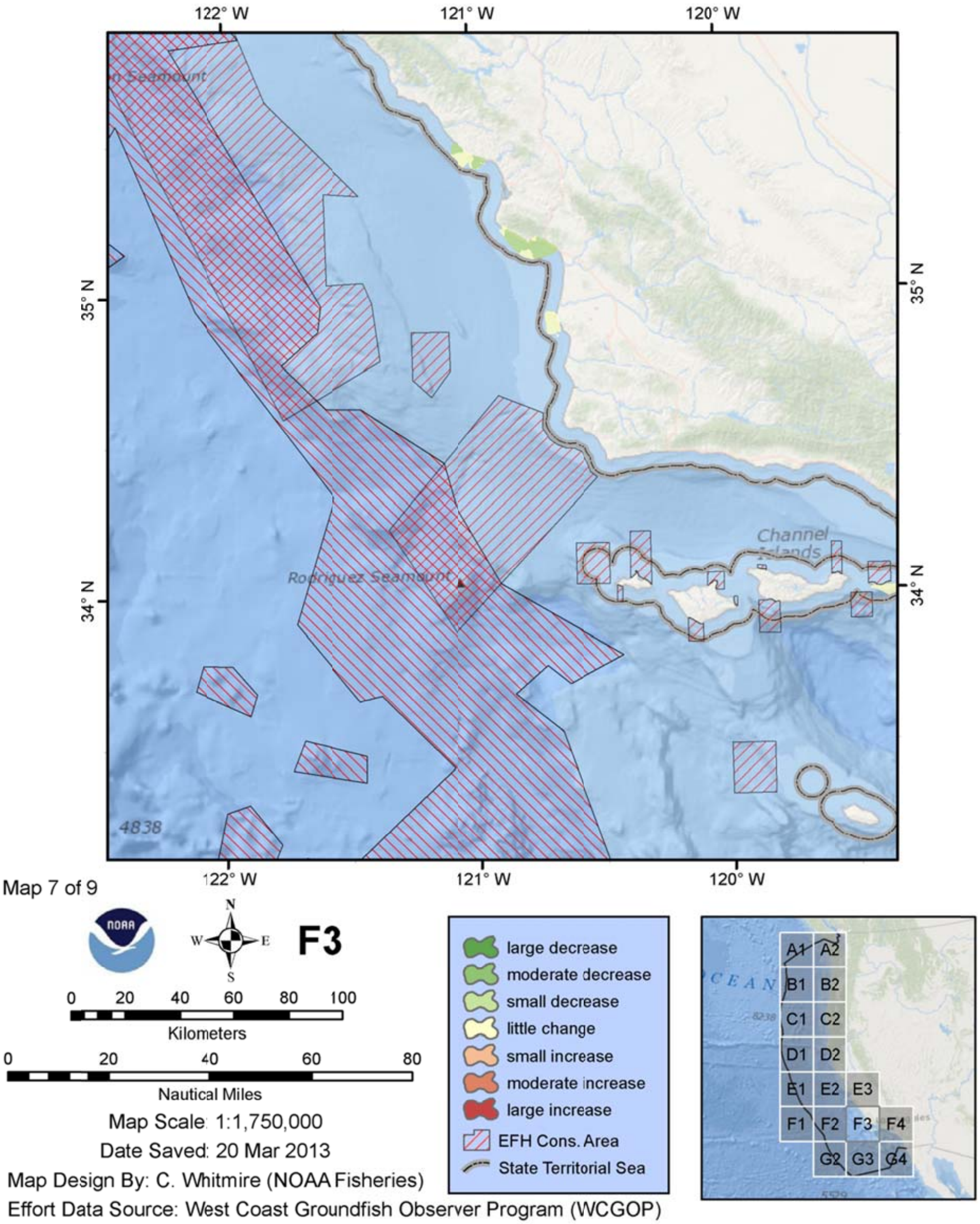
Observed Fixed Gear Effort (Temporal Change)



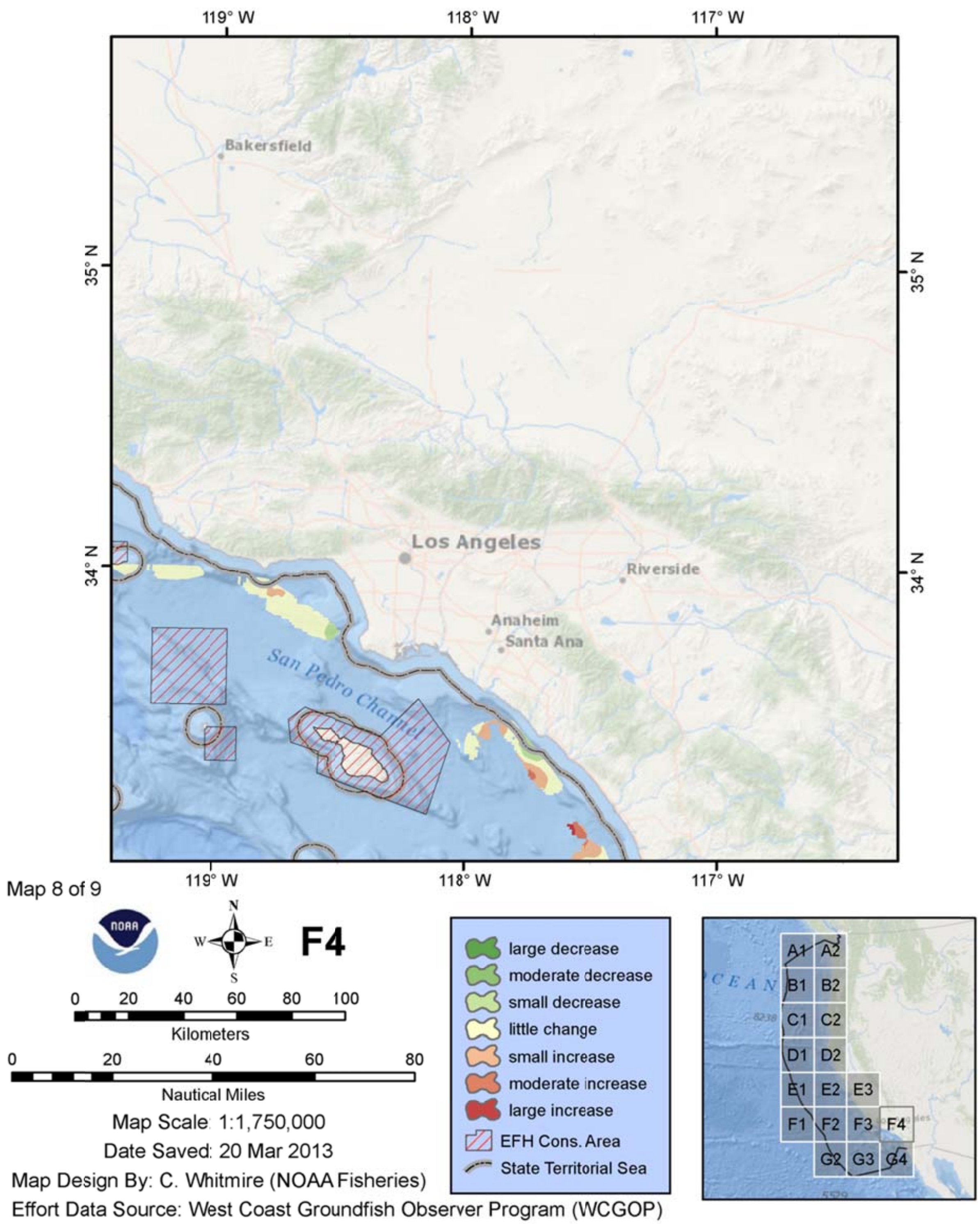
Observed Fixed Gear Effort (Temporal Change)

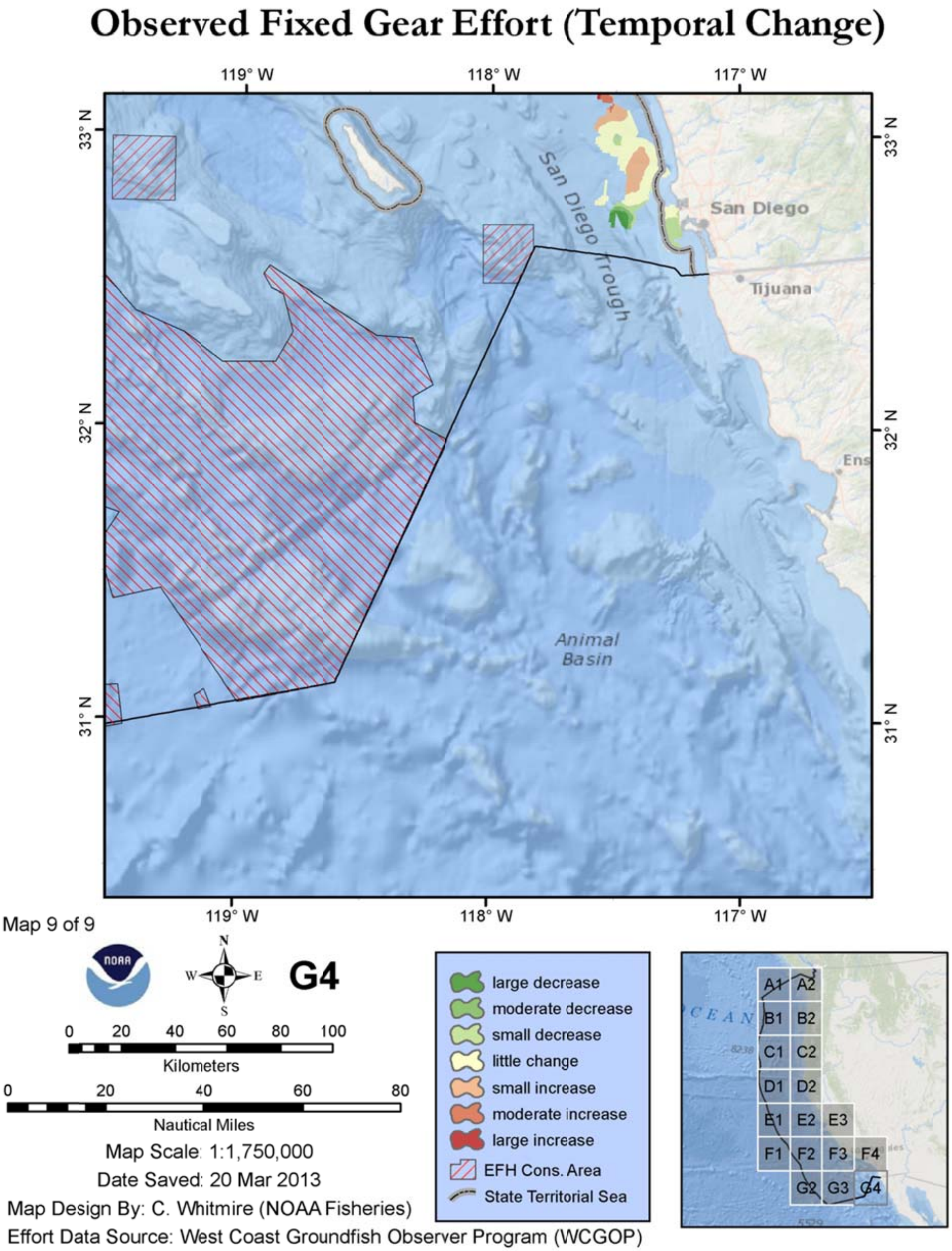


Observed Fixed Gear Effort (Temporal Change)



Observed Fixed Gear Effort (Temporal Change)




Observed Fixed Gear Effort (Temporal Change)
119° W
118° W
117° W
33° N
32° N
31° N
San Diego Trough
San Diego
Tijuana
Ens
Animal Basin
Map 9 of 9
NOAA
G4
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map Scale: 1:1,750,000
Date Saved: 20 Mar 2013
Map Design By: C. Whitmire (NOAA Fisheries)
Effort Data Source: West Coast Groundfish Observer Program (WCGOP)
large decrease
moderate decrease
small decrease
little change
small increase
moderate increase
large increase
EFH Cons. Area
State Territorial Sea
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

3.2 NON-FISHERIES PRESSURES

Kelly S. Andrews, Conservation Biology Division, Northwest Fisheries Science Center

3.2.1 Introduction

As human population size and demand for marine resources and waterways increases along the coast, numerous human activities in the ocean (e.g., fishing and shipping activity) and on land (e.g., pollutants from industrial activities and runoff from agricultural activities) need to be recognized and incorporated into management of marine resources. There are numerous non-fisheries related pressures acting upon groundfish essential fish habitat (EFH) along the West Coast of the United States (PFMC 2005). This document is not meant to be an exhaustive description of all these pressures, but a synthesis of how non-fisheries pressures can be analyzed in order to be incorporated into the management framework for West Coast groundfish EFH.

First, we take advantage of 16 spatially-explicit data layers available from Halpern et al. (2009) to quantify the intensity of non-fisheries pressures among various regions, depth strata, habitat substrate types, and spatial management boundaries related to West Coast groundfish EFH. The pressure data layers were produced from data collected prior to 2007, but represent the most standardized and rigorous analysis of the relative spatial intensity of non-fisheries pressures across the West Coast of the United States. These data layers are currently being updated and will provide estimates for future analyses of non-fisheries pressures on West Coast groundfish EFH.

From the 16 non-fisheries related pressures, we identified seven (Table A3b.1) that were most relevant to West Coast groundfish EFH and which had enough data to be useful for a coastwide analysis. We report on these pressures along with two climate change pressures individually below. In order to summarize the distribution of non-fisheries pressures, we combined all 16 non-fisheries pressures into a “combined” pressures data layer and report on the findings below. Each pressure data layer was normalized to values between 0 and 1 so they could be compared and combined into a cumulative impact layer for the Halpern et al. (2009) project; thus, the data layers were easily combined for our purposes.

3.2.2 Data and Methods

3.2.2.1 Non-fisheries pressures data

The data and models used to create the non-fisheries pressure data layers are described in detail in the supporting materials found in Halpern et al. (2008, 2009). Briefly, the raw data values produced for each ~1km^2 (0.00913 decimal degrees) cell throughout the U.S. West Coast economic exclusive zone (EEZ) were log transformed and normalized to the maximum value for each pressure layer independently to allow for direct comparison and incorporation into cumulative impact effects models for the Halpern et al. (2009) project. Values for each pressure range from 0 to 1.

Table A3b.1. Non-fisheries pressures data layers from Halpern et al. (2009).

NON-FISHERIES PRESSURES DATA LAYERS	
Pressures reported individually	Brief description of data used to create data layer
Atmospheric pollution	Deposition of sulfates derived from the National Atmospheric Deposition Program.
Inorganic pollution	Point source pollution from factories and mines and non-point source pollution that scales with the amount of impervious surface area.
Organic pollution	Input of pesticides.
Ocean-based pollution	Combination of "Commercial shipping activity" and "Invasive species" below.
Nutrient input	Nitrogen input from farming and atmospheric deposition.
Sediment decrease	Sediment input from watersheds with dams.
Sediment increase	Sediment input from watersheds without dams.
Combined pressures	Sum of all 16 pressures.
Additional pressures for calculating "Combined Pressures"	
Coastal trash	Amount of trash collected from beach clean-up efforts in CA.
Recreational beach use	Beach attendance.
Power plants	Locations of coastal power plants.
Light pollution	Stable lights at night database (National Geophysical Data Center).
Coastal engineering	Location of hardened shorelines.
Commercial shipping activity	Vessel track lines from the World Meteorological Organization Voluntary Observing Ships Scheme and ferries.
Oil rig platforms	Locations of offshore oil rigs.
Aquaculture – fish net-pens	Locations of fish net-pens.
Species invasions	Based on annual tonnage of goods passing through each port.

3.2.2.2 Data preparation

Pressure data layers from Halpern et al. (2009) were used to calculate all pressure metrics related to biogeographic regions, depth strata, habitat substrate, specific spatial management boundaries, biogenic habitat suitability, and species-habitat relationships found in *"Section 4.4: Non-fisheries pressures"* of the main body of this report. Pressure data layers were downloaded from the National Center for Ecological Analysis and Synthesis website (http://www.nceas.ucsb.edu/globalmarine/ca_current_data) and imported into ESRI®ArcMap 10.0, ArcGIS Desktop 10 Service Pack 4. All pressure data layers were clipped to the U.S.'s economic exclusive zone and projected using a customized "WGS 1984 Transverse Mercator" coordinate system. We report on seven of the most relevant pressure data layers individually and used all 16 pressure data layers to calculate a "combined pressures" data layer. Two other climate change pressure data layers were used as examples of ways to incorporate climate change into the EFH management framework (Table A3b.2).

Table A3b.2. Identification of all GIS data layers used in calculations related to non-fisheries pressures. EFH CA: essential fish habitat conservation areas; HAPC: habitat areas of particular concern.

ALL DATA LAYERS USED IN NON-FISHERIES ANALYSES					
Pressures reported individually	*Additional pressures for calculating "Combined Pressures"*	*Climate change pressures*	*Habitat*	*Spatial management boundaries*	*Species distributions*
*Atmospheric pollution	Coastal trash	Ocean acidification	*Sub-regions	*EFH CA	Darkblotched rockfish
*Inorganic pollution	Recreational beach use	Sea-surface temperature anomalies	*Depth strata	*HAPC	Greenstriped rockfish
*Organic pollution	Power plants		*Substrate type	*Commercial fishing	Yelloweye rockfish
*Ocean-based pollution	Light pollution		Biogenic habitat occurrence	*Bottom-trawl fishing	Longspine thornyhead
*Nutrient input	Coastal engineering		Coral habitat suitability probabilities	*Fixed-gear fishing	Petrale sole
*Sediment decrease	Commercial shipping activity			*Mid-water trawling	Sablefish
*Sediment increase	Oil rig platforms			*Recreational fishing	
*Combined pressures	Aquaculture – fish net-pens				
	Species invasions				

*Data layers that were combined to calculate mean pressure values across habitat and spatial management boundaries.

We used the same sub-regions, depth strata, habitat substrate type, and spatial management boundary data layers as described in the methods for habitat in *"Section 2: Habitat Distribution*" in the main body of this report. For substrate type, "undefined" substrate was defined as any habitat in the U.S. economic exclusive zone not characterized in *"Section 2: Habitat Distribution"* of the main report; this primarily included lower slope habitat or nearshore bays and estuaries (e.g., Puget Sound proper of the Salish Sea sub-region) that have not been surveyed or nearshore areas that weren't included in *"Section 2: Habitat Distribution"* (Columbia River and San Francisco Bay estuaries). In addition, we used the "habitat areas of particular concern" (HAPC) data layer found at: http://efh-catalog.coas.oregonstate.edu/platesES/ (Table A3b.2). For

"Commercial fishing", "Bottom-trawl fishing", "Fixed-gear fishing", "Mid-water trawling", and "Recreational fishing", we combined fishing restrictions from EFH conservation areas, rockfish conservation areas, and state territorial sea restrictions found in NOAA's Marine Protected Area Inventory (http://www.mpa.gov/dataanalysis/mpainventory/). We also used two biogenic habitat maps to describe the relative exposure intensity to ocean acidification. The first was the biogenic habitat occurrence data layer that was developed in *"Section 2: Habitat Distribution*" to characterize the spatial distribution of living habitats (i.e. corals and sponges). The second biogenic habitat data layer was output for the California Current ecosystem based on predictive habitat modeling for deep sea corals developed by Davies & Guinotte (2011) & Guinotte & Davies (2012). Using several habitat variables, the model predicts how suitable the habitat in each cell is for deep sea corals. All data layers were converted to rasters and projected to the same customized "WGS 1984 Transverse Mercator" coordinate system as the pressure data layers.

We also converted each of the six species-habitat relationship maps based on the presence/absence models developed in *"Section 3: Species-habitat associations"* in the main body of this report to rasters using the combined mean probability values across all years. These data layers were used to calculate exposure intensity values for each species to sea-surface temperature anomaly data.

For each map in *"Section 4.4: Non-fisheries pressures"* and this appendix, we classified the data using the "quantile" method with 5 categories within ArcMap; thus, each color symbolizes 20% of the data.

3.2.2.3 Data analysis

Combined pressures

Importantly, individual pressures do not act upon groundfish EFH individually, but collectively. Pressures from terrestrial-based pollution, shipping, offshore energy development, fisheries and coastal development exert cumulative effects on the ecosystem and should be managed in a holistic way (Vinebrooke et al. 2004, Crain et al. 2008, Halpern et al. 2008, Curtin and Prellezo 2010, Stelzenmüller et al. 2010). However, quantifying the cumulative effects of these pressures is a difficult task. Previous studies developing cumulative impact metrics have used qualitative risk metrics (Stelzenmüller et al. 2010) or expert-based scoring systems (Halpern et al. 2008, 2009, Teck et al. 2010) that weight the relative importance of each pressure prior to summing scores across pressures. However, qualitative risk and expert-based scoring systems have been heavily criticized for two reasons. First, the weighting of pressures qualitatively or by expert surveys may be heavily influenced by a range of heuristic and cognitive biases that may lead to arbitrary or misleading results (Hubbard 2009). Second, our understanding of whether the effects of multiple pressures are additive, synergistic, or antagonistic is relatively poor (Darling and Côté 2008, Hoegh-Guldberg and Bruno 2010). Several studies have suggested that multiple pressures interact on various ecosystem components in non-additive ways, either causing effects greater than (synergistic) or less than (antagonistic) that explained by the sum of individual pressures (Sala and Knowlton 2006, Darling and Côté 2008, Griffith et al. 2012, Sunda and Cai 2012). Thus, linear combinations of weighted pressures will not account for these interactions. Because of these unknowns and time constraints, we did not try to calculate cumulative effects values of non-fisheries pressures on groundfish EFH; instead, we used a simplified approach which simply summed the pressure intensity values of all 16 non-fisheries pressures (Table A3b.1) for each 1 km^2 cell within the U.S. EEZ to calculate a "combined pressures" data layer. The values for each individual pressure layer range between 0 and 1, so the maximum value for this layer was 16. This data layer simply shows the additive sum of all overlapping pressures within each cell; it is not intended to describe the cumulative impacts of all pressures present in each cell.

3.2.2.4 Calculation of mean pressure intensity values

In order to calculate mean values for each pressure among various habitat and spatial management boundaries, we combined 18 different data layers (asterisks in Table A3b.2) using the "Combine" tool in ArcMap. Prior to combining, all pressure data layers were multiplied by 1000 because the "Combine" tool only works for integer data and would truncate the decimal values. Values were returned to the original scale during subsequent processing. Also, any missing data values in any data layer were given the value 10000 so that no cells were discarded during the combining process. After combining, these cells were given values of -99999 to represent 'no data'. The value attribute table for this combined raster file was then exported as a text file. We then used the "aggregate" function within R, ver. 2.15.1 (R Development Team 2012) to calculate the mean intensity value for each of the eight non-fisheries pressures (7 individual pressures and 1 combine pressures index) within every combination of depth strata, habitat substrate type and spatial management boundary categories. The results are presented as tables and figures for each sub-region and pressure below.

3.2.3 Summary of non-fisheries pressures

We begin by presenting a summary of the distribution of non-fisheries pressures across the U.S. West Coast using the "combined pressures" data layer and then describe the distribution of each individual pressure separately.

The distribution of combined pressures showed the distinct influence of land-based pollution pressures in nearshore habitats and the exposure of offshore habitats to ocean-based pollution and commercial shipping activity (Fig. A3b.1). Overall, mean intensity values were highest in the Salish Sea biogeographic sub-region and in the shelf depth strata (Fig. A3b.2a). The Salish Sea was most exposed because the vast majority of the region is exposed to highly populated areas and is completely locked within the shelf habitat, which is the most exposed depth stratum. The northern sub-region was the next most-greatly exposed region, but this varied among depth strata (Table A3b.3). For example, pressure intensity values were highest in lower slope habitat

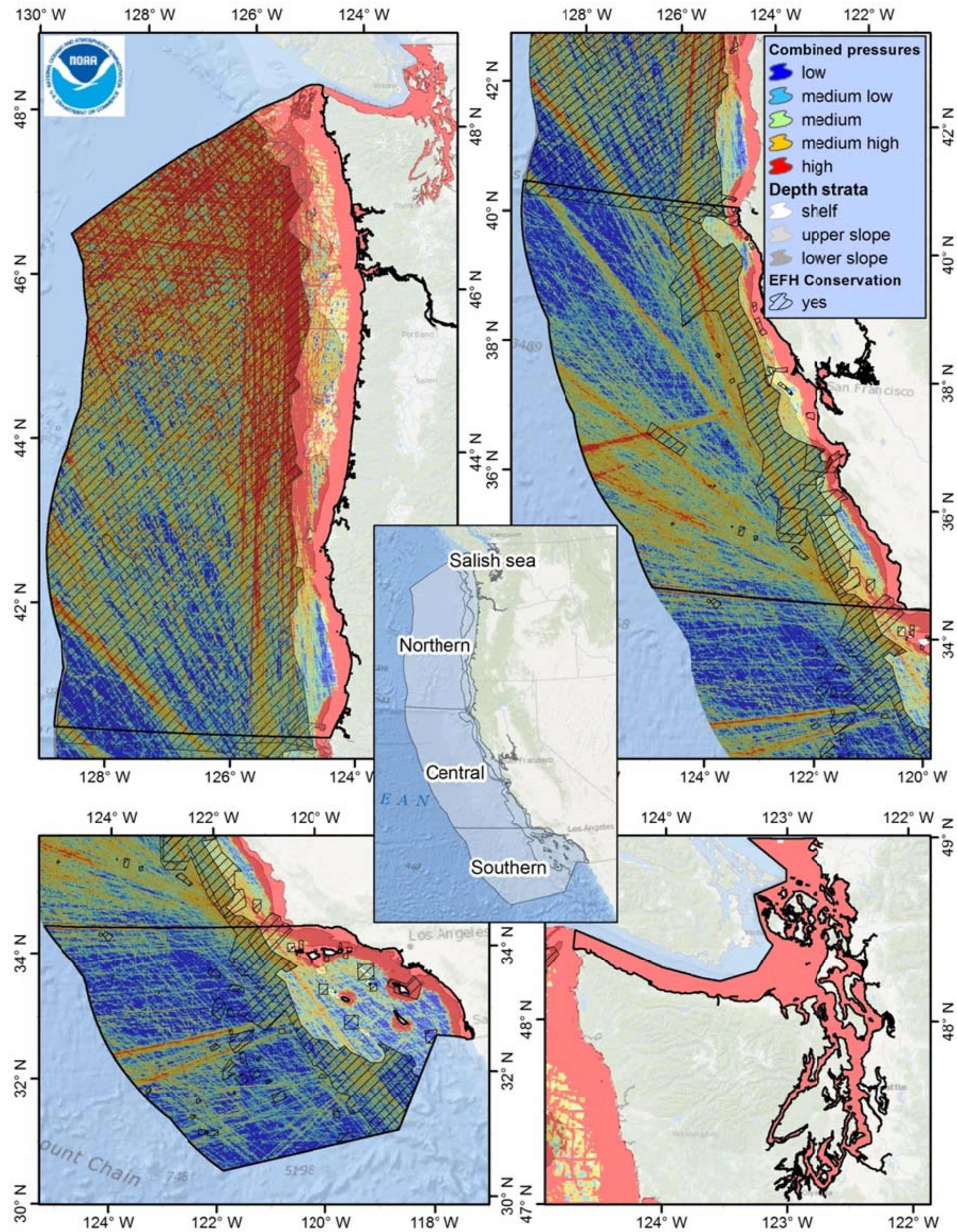


Figure A3b.1. Distribution of combined pressures intensity values among biogeographic sub-regions, depth strata and essential fish habitat (EFH) conservation areas. Combined pressures data is the sum of 16 non-fisheries pressures identified in Table A3b.1. Data for each pressure comes from Halpern et al. 2009.

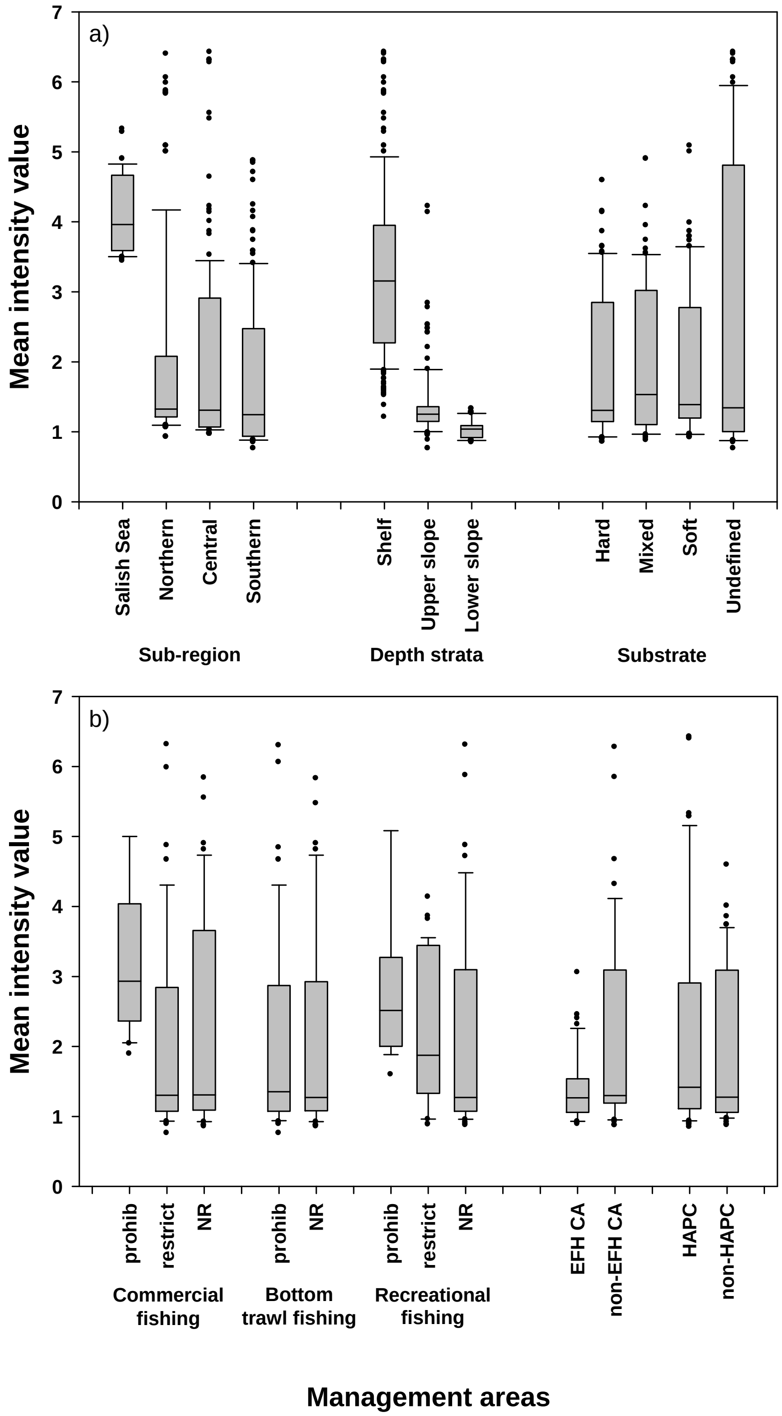


Figure A3b.2. Mean intensity values of combined pressures across a) sub-regions, depth strata, substrate, and b) management areas. The shaded box indicates the 25th to 75th percentile, the line within the box marks the median, the whiskers indicate the 10th and 90th percentiles, and the dots indicate all outliers. prohib: type of fishing is prohibited; restrict: type of fishing is restricted; NR: type of fishing has no restrictions; EFH CA: essential fish habitat conservation areas for West Coast groundfish; HAPC: habitat areas of particular concern. Fishing restrictions include areas within EFH CA, rockfish conservation areas (RCAs), and state territorial sea restrictions.

Table A3b.3. Mean intensity values for combined non-fisheries pressures by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from the sums of 16 pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

COMBINED PRESSURES						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	2.20	2.71	2.92	4.31	2.63
	hard	1.76	3.00	2.57	3.57	2.30
	mixed	1.98	3.04	2.41	3.55	2.31
	soft	2.18	2.45	2.93	3.64	2.40
	undefined	5.85	6.27	4.71	4.67	5.03
Upper Slope[2]	All	1.22	1.22	1.28	NA	1.25
	hard	1.28	1.15	1.17	NA	1.18
	mixed	1.34	1.37	0.98	NA	1.29
	soft	1.21	1.23	1.29	NA	1.25
	undefined	NA	1.05	1.00	NA	1.03
Lower Slope[3]	All	1.08	0.98	0.88	NA	1.00
	hard	1.26	1.05	0.90	NA	1.03
	mixed	1.10	1.09	0.91	NA	0.99
	soft	1.26	1.06	0.95	NA	1.10
	undefined	1.06	0.97	0.87	NA	0.98
Grand mean	All	1.22	1.10	1.04	4.31	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

in the north, but pressures were higher in the southern sub-region in shelf and upper slope habitat. High values in the lower slope of the northern sub-region were most likely the result of high atmospheric pollution values (see *'Atmospheric pollution'* below), whereas multiple land-based pressures (see individual pressures below) were responsible for high values in the shelf and upper-slope in the southern sub-region. Within each depth stratum, pressure intensity values varied across habitat types, but showed no clear trend.

We used EFH conservation areas (EFH CA), rockfish conservation areas, and state territorial sea restrictions to define management areas that were prohibited, restricted, or had no restrictions on fishing. Identifying differences in pressure intensity values among management boundaries were more difficult to determine, but pressure intensity values seemed to be higher in areas where commercial and recreational fishing was prohibited (Fig. A3b.2b). This was likely because many prohibited areas were located nearshore or inside bays where pressure intensity values were relatively high because of numerous land-based pressures. We also found there was relatively little variation in non-fisheries pressures in EFH CA compared to nearly all other habitat or management regions (Fig. A3b.2). This was likely because EFH CA are located offshore and are not exposed to most land-based pressures along the coast (Fig. A3b.1). It should be noted that mean intensity values were simply calculated using all cell values (units were ~1km^2 cells across the entire U.S. EEZ) within the habitat or management boundaries; this analysis does not take spatial autocorrelation into account. Future work will account for spatial autocorrelation and make explicit statistical comparisons among habitats and management boundaries.

We also calculated what proportion of various management areas were exposed to the highest pressure intensity values (i.e. the "high" values in Fig. A3b.1 represent the top 20% of all pressure intensity values coastwide). EFH CA and non-EFH CA were equally exposed to the highest combined non-fisheries pressures, but this pattern varied among individual pressures (Fig. A3b.3). Habitat areas of particular concern (HAPC) were most exposed to the highest non-fisheries pressures with nearly 40% of all area within HAPC boundaries exposed to the highest combined pressures intensity values (Fig. A3b.3). This was most distinct across land-based pressures as most HAPCs are located in nearshore habitats. However, differences observed coastwide among management areas varied among sub-regions (Table A3b.4). For example, in the northern sub-region, the proportion of EFH CA exposed to the highest combined pressures (23%) was less than the proportion of areas with no commercial fishing restrictions exposed to high pressures (58%), whereas in the central and southern sub-regions we found that EFH CA and areas with no commercial fishing restrictions were equally exposed.

Overall, we found four main findings from non-fisheries pressures that may potentially affect management of West Coast groundfish EFH. First, non-fisheries pressures were greatest in the Salish Sea, but this is because the entire region is in shelf habitat and is highly exposed to numerous land-derived pressures. Second, among other sub-regions, pressure intensity values varied across depth strata. Lower slope habitat was exposed to higher pressure intensity values in the northern sub-region (offshore pressures), while shelf and upper-slope habitat was exposed to higher pressure intensity values in the southern sub-region (nearshore pressures). Third, we found little variation in mean intensity values for non-fisheries pressures across EFH conservation areas compared to other spatial management regions. This was likely because EFH conservation areas were located offshore and relatively unexposed to land-based pressures. Fourth, we found that HAPCs were proportionately more exposed to high non-fisheries pressures than other spatial management areas, and this is generally true across other individual pressures.

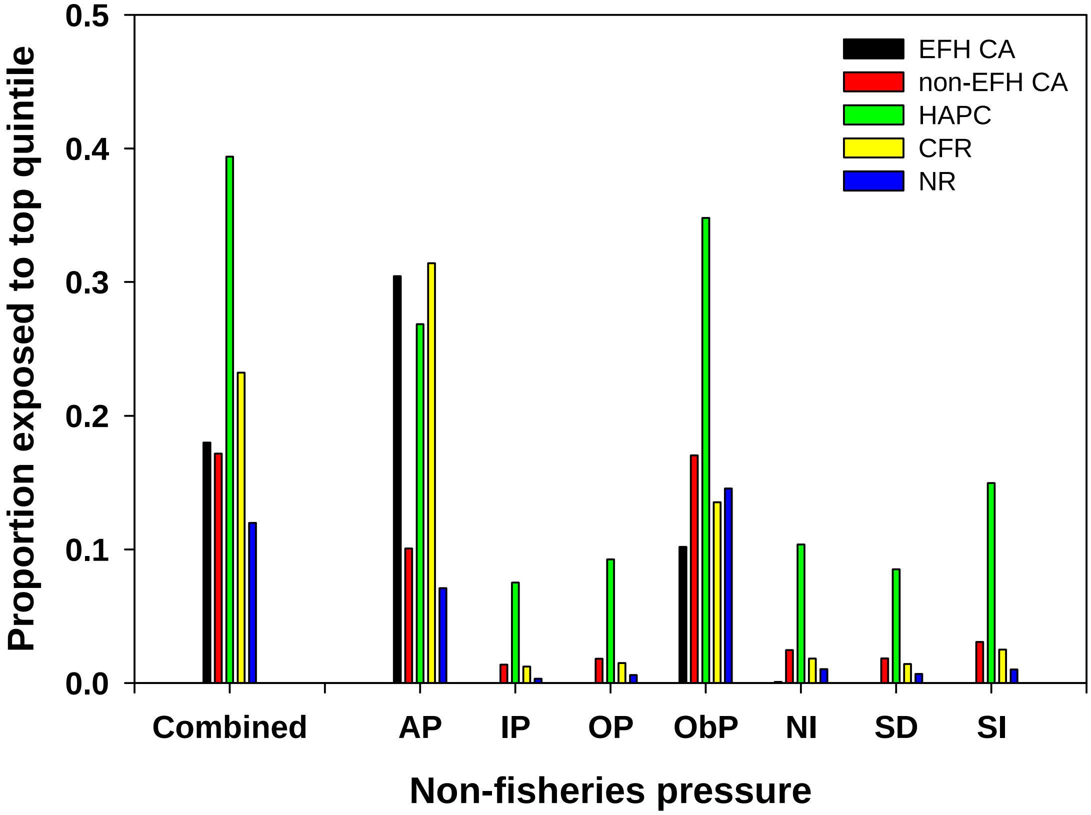


Figure A3b.3. Proportion of coastwide habitat in each management area exposed to the highest intensity values (top 20% - "high" values in Fig. 3b.1) for each pressure. EFH CA: essential fish habitat conservation areas; HAPC: habitat areas of particular concern; CFR: all commercial fishing restricted areas, including EFH CA, Rockfish Conservation Areas and state territorial sea restrictions; NR: areas with no commercial fishing restrictions.

Table A3b.4. Proportion of habitat within management boundaries exposed to the highest (top 20% - "high" values in Fig. 3b.1) intensity values for each pressure within each biogeographic sub-region and across the entire U.S. West Coast. EFH CA: essential fish habitat conservation areas; CFR: all commercial fishing restricted areas, including EFH CA, Rockfish Conservation Areas and state territorial sea restrictions; NR: no commercial fishing restrictions; NA: no habitat in this category.

	BIOGEOGRAPHIC SUB-REGIONS														
	Northern			*Central*			*Southern*			*Salish Sea*			*Coastwide*		
Pressures	*EFH CA*	*CFR*	*NR*	*EFH CA*	*CFR*	*NR*	*EFH CA*	*CFR*	*NR*	*EFH CA*	*CFR*	*NR*	*EFH CA*	*CFR*	*NR*
Atmospheric pollution	0.44	0.46	0.64	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.98	N/A	0.30	0.31	0.07
Inorganic pollution	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.02	0.00	N/A	0.23	N/A	0.00	0.01	0.00
Organic pollution	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.02	0.00	N/A	0.29	N/A	0.00	0.01	0.01
Ocean-based pollution	0.03	0.05	0.27	0.36	0.38	0.19	0.09	0.11	0.05	N/A	0.96	N/A	0.10	0.14	0.15
Nutrient input	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.03	0.01	N/A	0.32	N/A	0.00	0.02	0.01
Sediment decrease	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.02	0.01	N/A	0.27	N/A	0.00	0.01	0.01
Sediment increase	0.00	0.01	0.06	0.00	0.05	0.01	0.00	0.02	0.00	N/A	0.51	N/A	0.00	0.02	0.01
Combined pressures	0.23	0.26	0.58	0.06	0.14	0.06	0.06	0.14	0.06	N/A	0.98	N/A	0.18	0.23	0.12

3.2.4 Individual pressures

3.2.4.1 Atmospheric pollution

The impact of pollutants deposited from the atmosphere on groundfish populations and their respective habitats is largely unstudied; however, many nutrient, chemical and heavy-metal pollutants are introduced to marine ecosystems from sources that are geographically far away via this process (Ramanathan and Feng 2009). Substances such as sulfur dioxide, nitrogen oxide, carbon monoxide, lead, volatile organic compounds, particulate matter, and other pollutants are returned to the earth through either wet or dry atmospheric deposition (Johnson et al. 2008). Atmospheric nitrogen input is rapidly approaching global oceanic estimates for N_2 fixation and is predicted to increase further due to emissions from combustion of fossil fuels and production and use of fertilizers (Paerl et al. 2002, Duce et al. 2008). Atmospheric deposition is one of the most rapidly increasing means of nutrient loading to both freshwater systems and the coastal zone, as well as one of the most important anthropogenic sources of mercury pollution in aquatic systems (Johnson et al. 2008). Industrial activities have increased atmospheric mercury levels, with modern deposition flux estimated to be 3-24 times higher than preindustrial flux (Swain et al. 1992, Hermanson 1998, Bindler 2003). In the southwestern U.S., atmospheric deposition rates have been calculated at the upper end of this range, 24 times higher than pre-industrial deposition rates (Heyvaert et al. 2000). We assume these pollutants represent similar pressures on groundfish habitat as pollutants introduced through other mechanisms (e.g., urban runoff and dumping).

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, data from 19 stations along the U.S. west coast in the National Atmospheric Deposition Program were spatially kriged over the landscape and waters of the California Current.

Atmospheric pollution was widely distributed across the U.S. West Coast with the highest intensity values in the Salish Sea and northern biogeographic sub-regions (Figs. A3b.4-5; Table A3b.5). Habitat within the central biogeographic region was exposed to the lowest values of atmospheric pollution. Atmospheric pollution was nominally greatest in shelf habitat, whereas there was no consistent pattern among substrate types (Fig. A3b.5, Table A3b.5) or management boundaries (Fig. A3b.6, Table A3b.6). These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.7-10, Tables A3b.7-10).

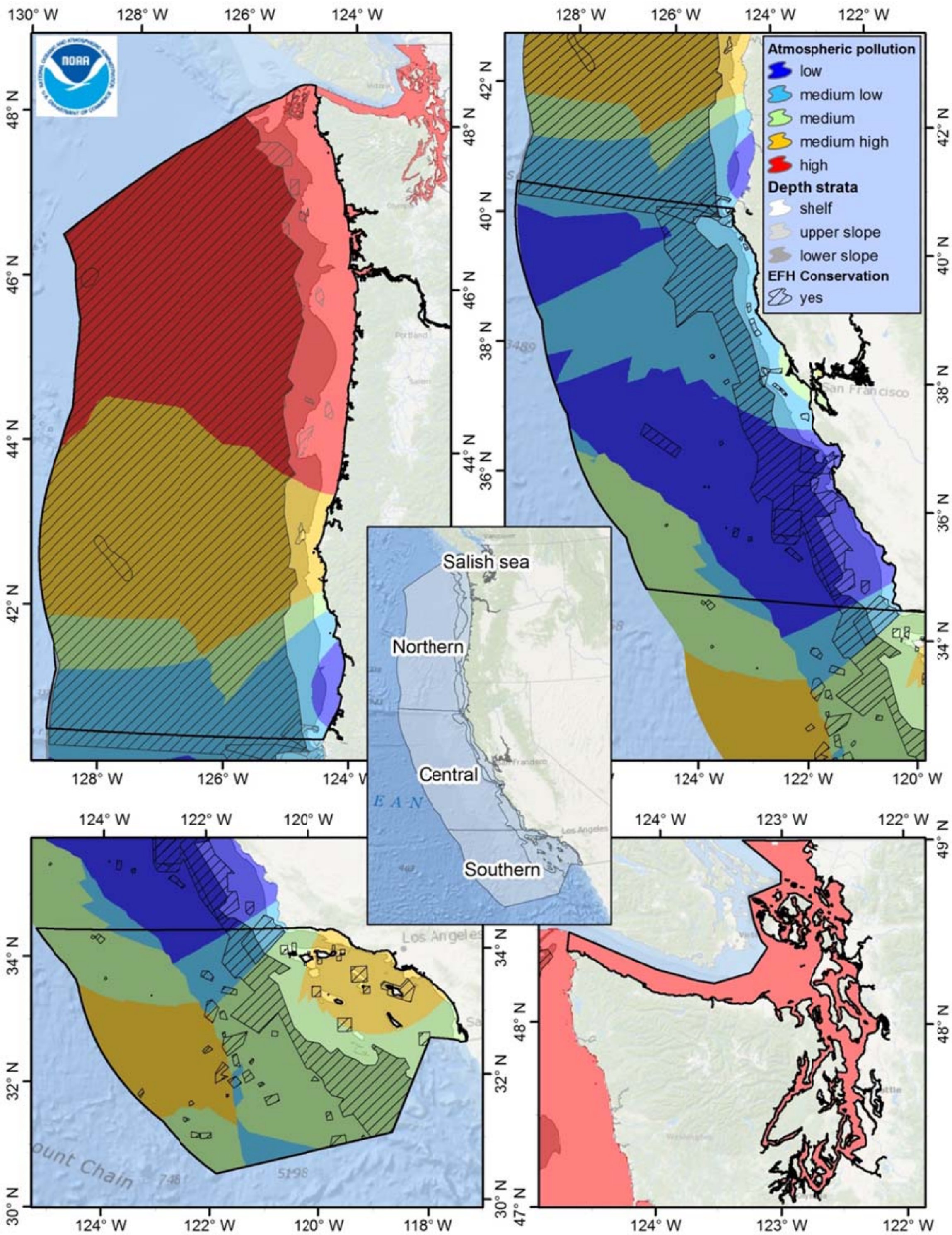


Figure A3b.4. Distribution of atmospheric pollution intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Atmospheric pollution data is from Halpern et al. 2009.

Table A3b.5. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

ATMOSPHERIC POLLUTION						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.76	0.40	0.51	0.89	0.65
	hard	0.77	0.38	0.51	0.95	0.63
	mixed	0.82	0.38	0.51	0.95	0.72
	soft	0.76	0.40	0.52	0.95	0.64
	undefined	0.68	0.46	0.40	0.86	0.78
Upper Slope[2]	All	0.71	0.35	0.51	NA	0.53
	hard	0.72	0.33	0.50	NA	0.46
	mixed	0.82	0.40	0.51	NA	0.75
	soft	0.70	0.36	0.51	NA	0.53
	undefined	NA	0.36	0.48	NA	0.40
Lower Slope[3]	All	0.67	0.38	0.47	NA	0.51
	hard	0.70	0.37	0.47	NA	0.52
	mixed	0.42	0.31	0.47	NA	0.42
	soft	0.75	0.36	0.46	NA	0.52
	undefined	0.66	0.39	0.48	NA	0.51
Grand mean	All	0.69	0.38	0.48	0.89	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

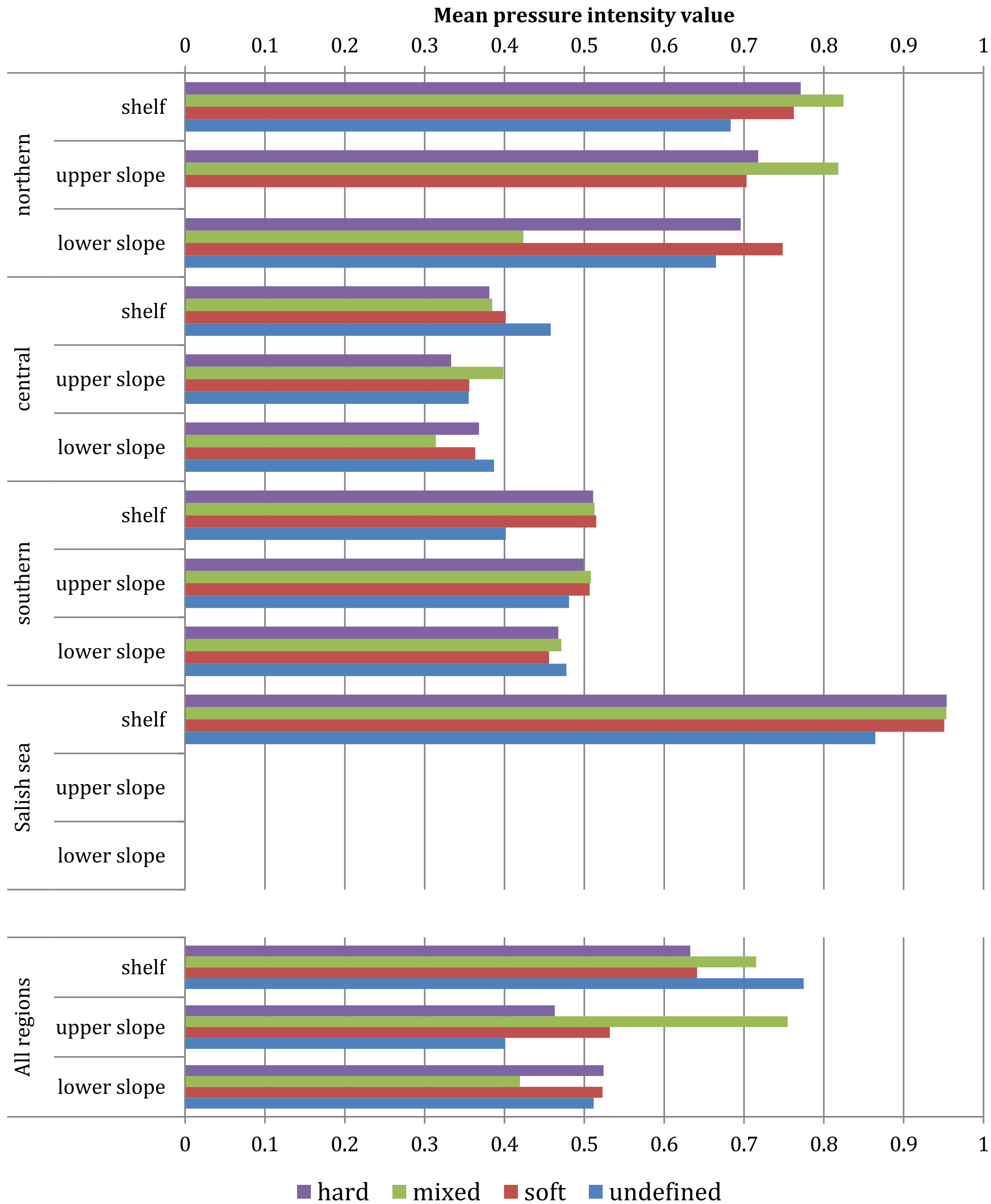


Figure A3b.5. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.6. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ATMOSPHERIC POLLUTION												
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawling*		*Recreational fishing*			*Coastwide*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.55	0.69	0.45	0.69	0.63	0.63	0.67	0.45	0.84	0.62	0.65
	hard	0.60	0.65	0.42	0.60	0.70	0.58	0.71	0.42	0.75	0.62	0.63
	mixed	0.74	0.70	0.42	0.74	0.69	0.66	0.78	0.41	0.88	0.61	0.72
	soft	0.51	0.68	0.46	0.67	0.63	0.58	0.67	0.45	0.84	0.60	0.64
	undefined	0.35	0.73	0.47	0.79	0.64	0.79	0.64	0.40	0.86	0.77	0.78
Upper Slope[2]	All	0.49	0.49	0.50	0.52	0.53	0.51	0.54	0.50	0.56	0.53	0.53
	hard	0.37	0.44	0.55	0.42	0.50	0.39	0.50	0.55	0.51	0.46	0.46
	mixed	0.74	0.74	0.28	0.76	0.75	0.76	0.75	NA	0.78	0.74	0.75
	soft	0.50	0.53	0.51	0.53	0.53	0.52	0.54	0.50	0.55	0.53	0.53
	undefined	0.35	0.38	NA	0.35	0.46	0.35	0.46	NA	NA	0.40	0.40
Lower Slope[3]	All	0.60	0.50	NA	0.60	0.42	0.60	0.42	NA	0.48	0.51	0.51
	hard	0.52	0.50	NA	0.52	0.58	0.52	0.58	NA	0.48	0.52	0.52
	mixed	0.42	0.41	NA	0.42	NA	0.42	NA	NA	NA	0.42	0.42
	soft	0.53	0.48	NA	0.53	0.43	0.53	0.43	NA	0.49	0.52	0.52
	undefined	0.62	0.51	NA	0.62	0.42	0.62	0.42	NA	NA	0.51	0.51
Grand mean	All	0.59	0.56	0.46	0.60	0.46	0.60	0.47	0.46	0.68	0.52	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

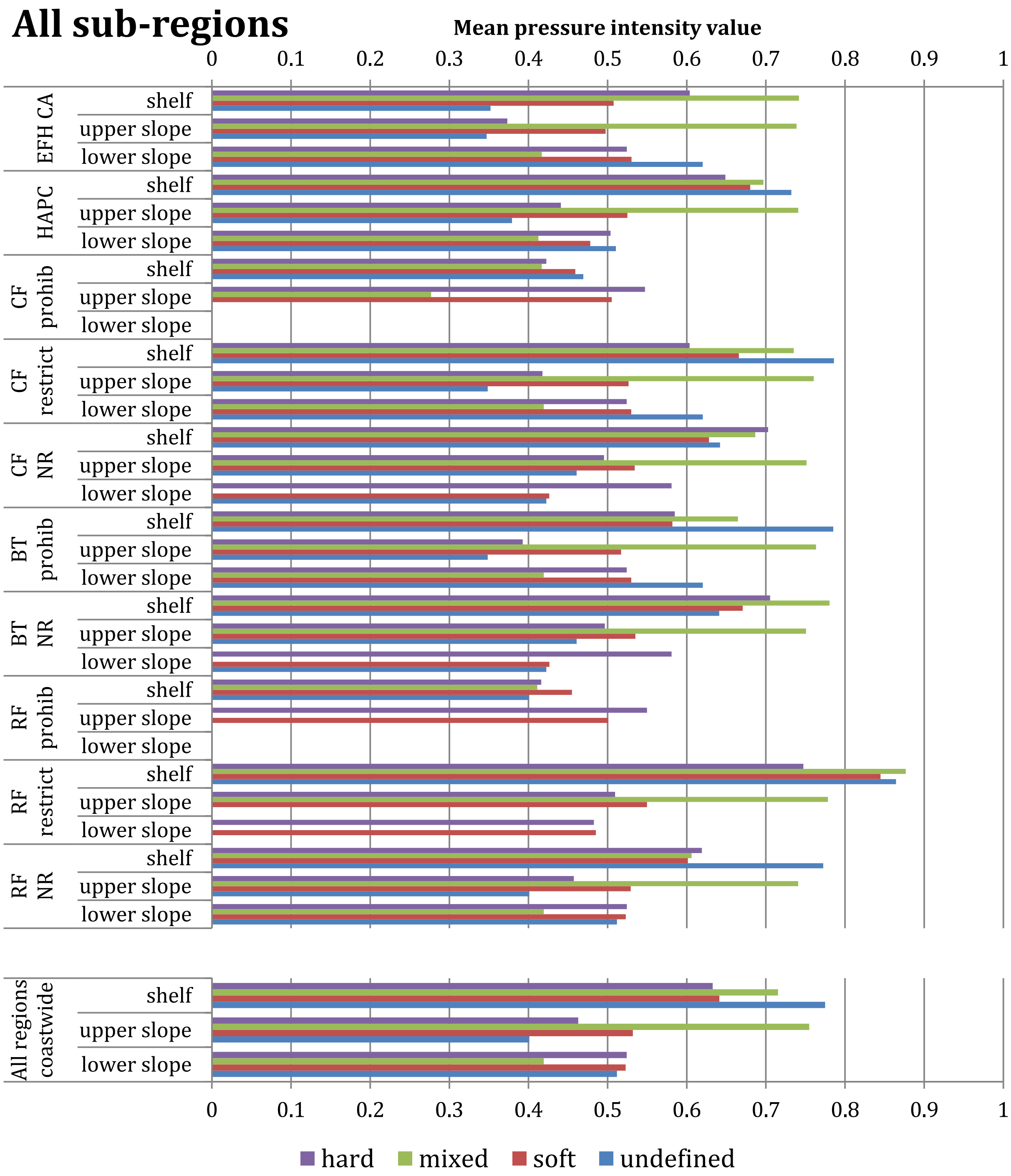


Figure A3b.6. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.7. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ATMOSPHERIC POLLUTION	**NORTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.82	0.83	0.90	0.83	0.73	0.75	0.77	0.90	0.93	0.72	0.65
	hard	0.77	0.79	NA	0.80	0.75	0.78	0.76	NA	0.92	0.75	0.63
	mixed	0.87	0.79	NA	0.89	0.71	0.85	0.81	NA	0.94	0.71	0.72
	soft	0.84	0.86	0.90	0.83	0.73	0.74	0.77	0.90	0.93	0.72	0.64
	undefined	NA	0.76	NA	0.75	0.67	0.74	0.67	NA	0.97	0.68	0.78
Upper Slope[2]	All	0.86	0.76	NA	0.82	0.68	0.80	0.69	NA	0.95	0.70	0.53
	hard	0.69	0.72	NA	0.72	0.72	0.71	0.72	NA	0.95	0.71	0.46
	mixed	0.91	0.87	NA	0.92	0.77	0.91	0.78	NA	0.95	0.77	0.75
	soft	0.86	0.75	NA	0.82	0.68	0.80	0.69	NA	0.95	0.69	0.53
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.40
Lower Slope[3]	All	0.67	0.68	NA	0.67	0.72	0.67	0.72	NA	NA	0.67	0.51
	hard	0.70	0.69	NA	0.70	0.61	0.70	0.61	NA	NA	0.70	0.52
	mixed	0.42	0.42	NA	0.42	NA	0.42	NA	NA	NA	0.42	0.42
	soft	0.75	0.71	NA	0.75	0.77	0.75	0.77	NA	NA	0.75	0.52
	undefined	0.66	0.65	NA	0.66	0.58	0.66	0.58	NA	NA	0.66	0.51
Grand mean	All	0.68	0.75	0.90	0.68	0.70	0.68	0.73	0.90	0.93	0.68	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

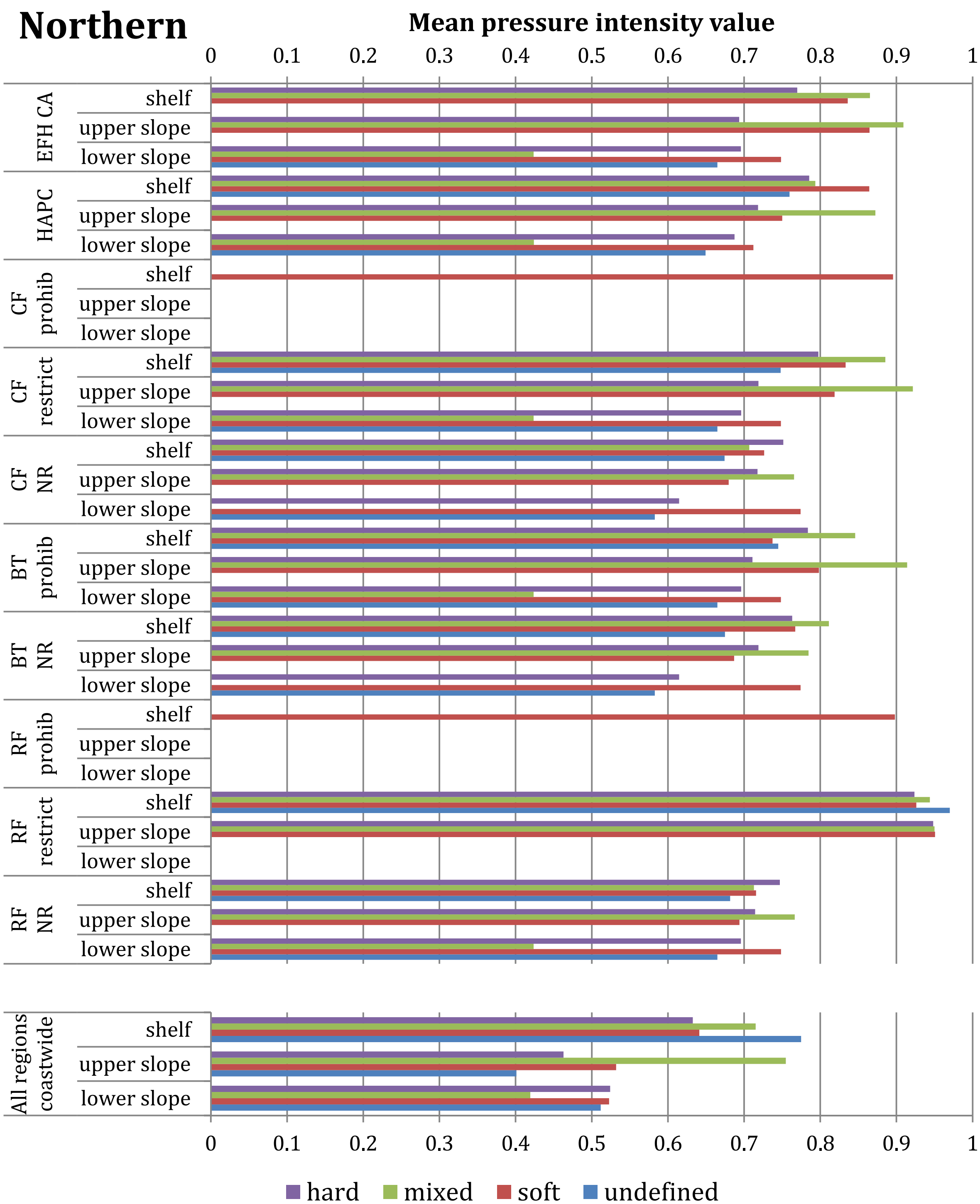


Figure A3b.7. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.8. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ATMOSPHERIC POLLUTION	CENTRAL BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	Substrate			Prohib	Restr	NR	Prohib	NR	Prohib	Restr	NR	
Shelf[1]	All	0.39	0.42	0.39	0.40	0.41	0.40	0.41	0.39	0.37	0.40	0.65
	hard	0.38	0.38	0.37	0.39	0.36	0.38	0.36	0.36	0.37	0.38	0.63
	mixed	0.39	0.40	0.35	0.39	0.36	0.39	0.37	0.35	0.37	0.39	0.72
	soft	0.39	0.39	0.40	0.39	0.41	0.39	0.41	0.40	0.38	0.40	0.64
	undefined	0.36	0.47	0.42	0.46	0.32	0.46	0.31	0.34	0.29	0.46	0.78
Upper Slope[2]	All	0.33	0.34	0.26	0.33	0.36	0.33	0.36	0.26	0.28	0.35	0.53
	hard	0.32	0.33	NA	0.32	0.35	0.32	0.35	NA	0.31	0.33	0.46
	mixed	0.31	0.32	0.28	0.39	0.41	0.39	0.41	NA	NA	0.40	0.75
	soft	0.33	0.35	0.26	0.33	0.36	0.33	0.36	0.26	0.28	0.36	0.53
	undefined	0.35	0.38	NA	0.35	0.40	0.35	0.40	NA	NA	0.36	0.40
Lower Slope[3]	All	0.37	0.36	NA	0.37	0.39	0.37	0.39	NA	NA	0.38	0.51
	hard	0.37	0.37	NA	0.37	NA	0.37	NA	NA	NA	0.37	0.52
	mixed	0.31	0.32	NA	0.31	NA	0.31	NA	NA	NA	0.31	0.42
	soft	0.36	0.34	NA	0.36	0.36	0.36	0.36	NA	NA	0.36	0.52
	undefined	0.38	0.38	NA	0.38	0.39	0.38	0.39	NA	NA	0.39	0.51
Grand mean	All	0.37	0.37	0.39	0.37	0.39	0.37	0.39	0.38	0.37	0.38	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

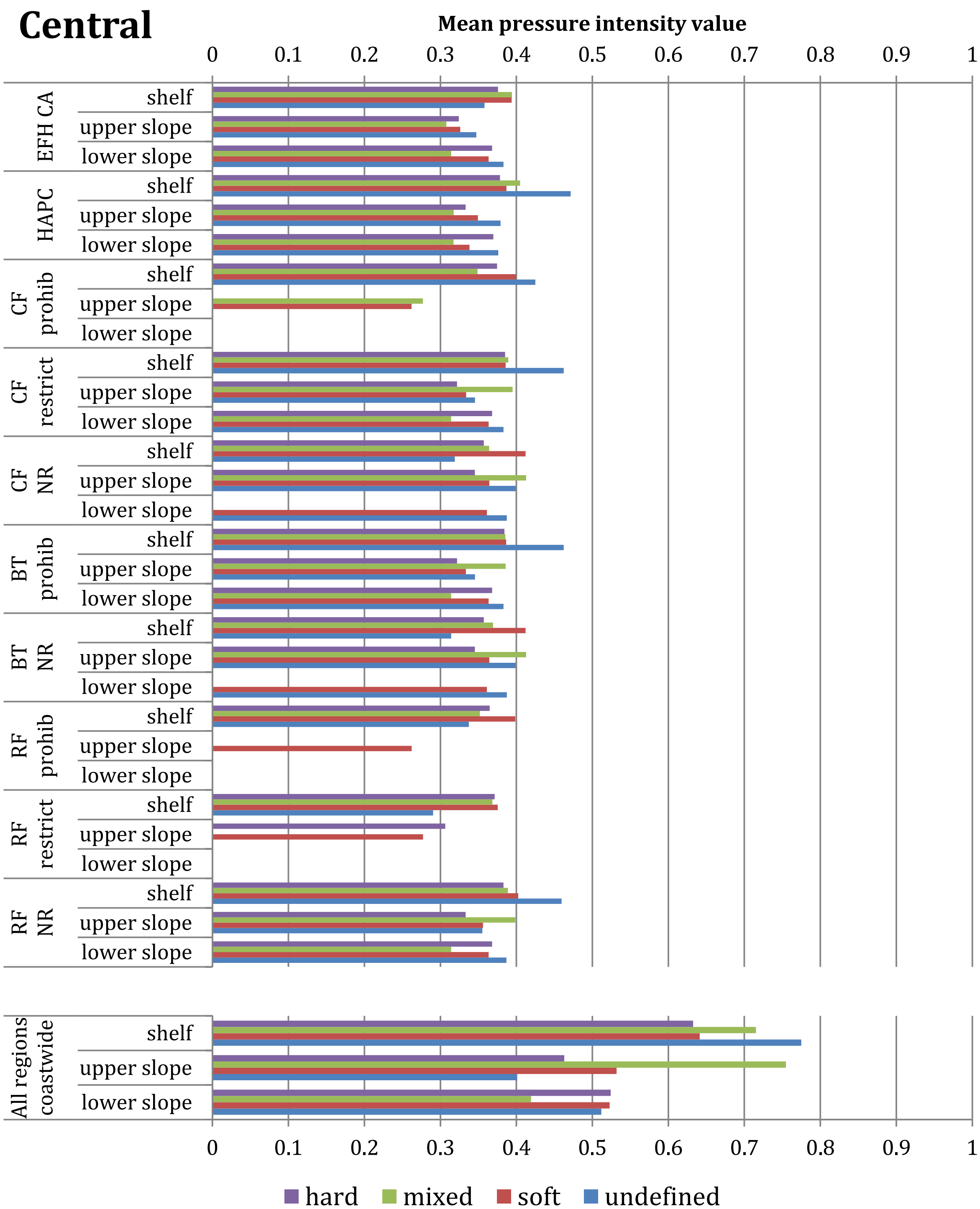


Figure A3b.8. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.9. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ATMOSPHERIC POLLUTION	**SOUTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.52	0.51	0.49	0.51	0.52	0.51	0.52	0.49	0.52	0.51	0.65
	hard	0.51	0.52	0.49	0.51	0.55	0.50	0.53	0.49	0.51	0.51	0.63
	mixed	0.53	0.52	0.51	0.52	0.48	0.52	0.50	0.51	0.52	0.51	0.72
	soft	0.52	0.52	0.49	0.52	0.52	0.51	0.52	0.49	0.52	0.52	0.64
	undefined	0.35	0.34	0.40	0.41	0.31	0.41	0.31	0.53	0.49	0.39	0.78
Upper Slope[2]	All	0.49	0.51	0.54	0.51	0.50	0.50	0.51	0.54	0.51	0.50	0.53
	hard	0.52	0.50	0.55	0.51	0.49	0.52	0.50	0.55	0.50	0.50	0.46
	mixed	0.51	0.51	NA	0.51	0.51	0.51	0.51	NA	0.51	0.52	0.75
	soft	0.49	0.52	0.54	0.51	0.50	0.50	0.51	0.54	0.51	0.50	0.53
	undefined	NA	NA	NA	0.47	0.48	0.47	0.48	NA	NA	0.48	0.40
Lower Slope[3]	All	0.46	0.47	NA	0.46	0.48	0.46	0.48	NA	0.48	0.47	0.51
	hard	0.47	0.47	NA	0.47	0.47	0.47	0.47	NA	0.48	0.47	0.52
	mixed	0.47	0.47	NA	0.47	NA	0.47	NA	NA	NA	0.47	0.42
	soft	0.46	0.47	NA	0.46	0.43	0.46	0.43	NA	0.49	0.46	0.52
	undefined	0.47	0.48	NA	0.47	0.48	0.47	0.48	NA	NA	0.48	0.51
Grand mean	All	0.47	0.49	0.50	0.48	0.48	0.47	0.48	0.50	0.51	0.48	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

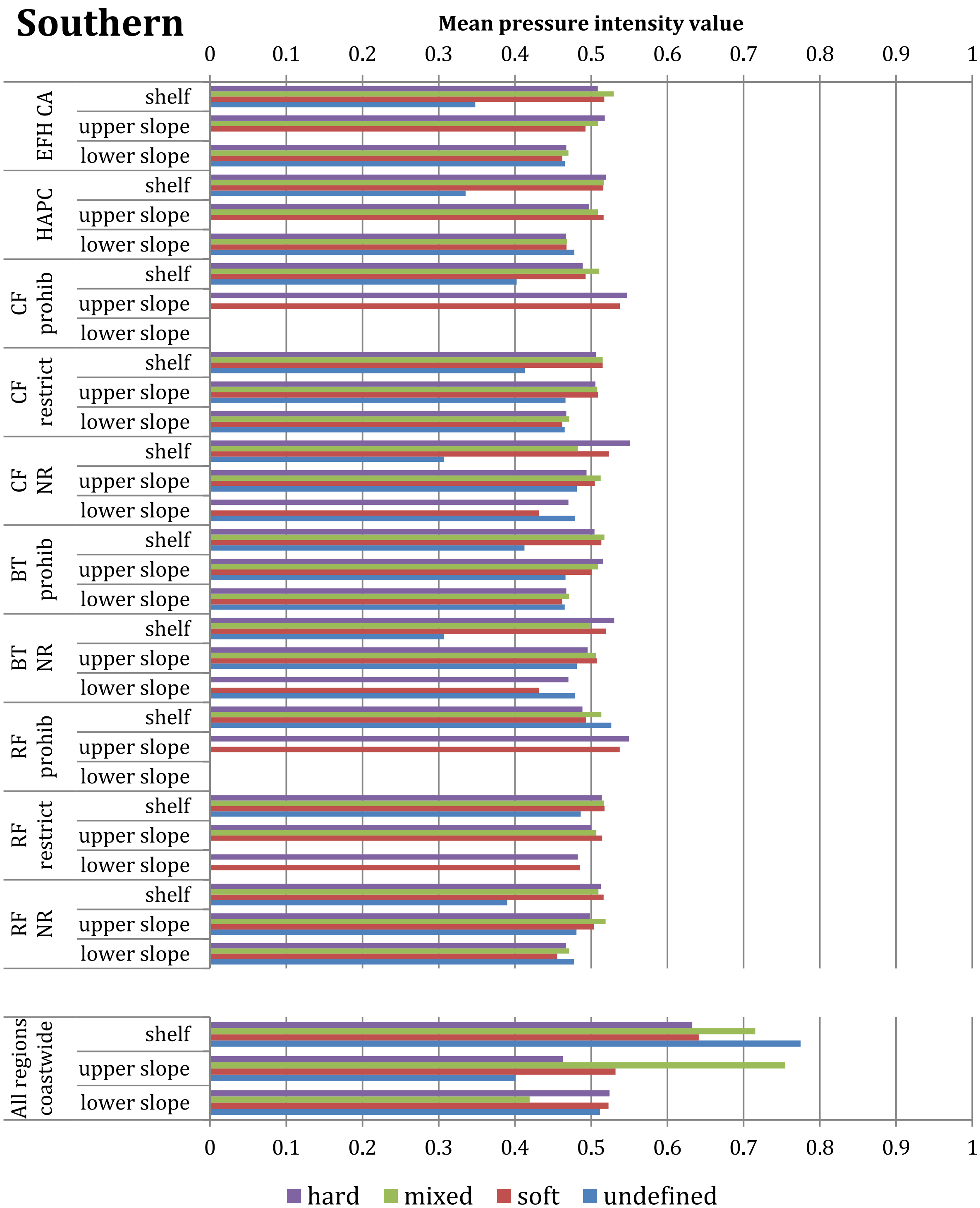


Figure A3b.9. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.10. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ATMOSPHERIC POLLUTION	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.84	0.67	0.89	NA	0.89	NA	NA	0.91	0.89	0.65
	hard	NA	0.99	NA	0.95	NA	0.95	NA	NA	0.92	0.99	0.63
	mixed	NA	0.97	NA	0.95	NA	0.95	NA	NA	0.95	0.97	0.72
	soft	NA	0.91	NA	0.95	NA	0.95	NA	NA	0.91	0.98	0.64
	undefined	NA	0.84	0.67	0.87	NA	0.86	NA	NA	0.91	0.86	0.78
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.53
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.46
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.75
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.53
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.40
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.51
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.52
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.42
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.52
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.51
Grand mean	All	NA	0.84	0.67	0.89	NA	0.89	NA	NA	0.91	0.89	0.53

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

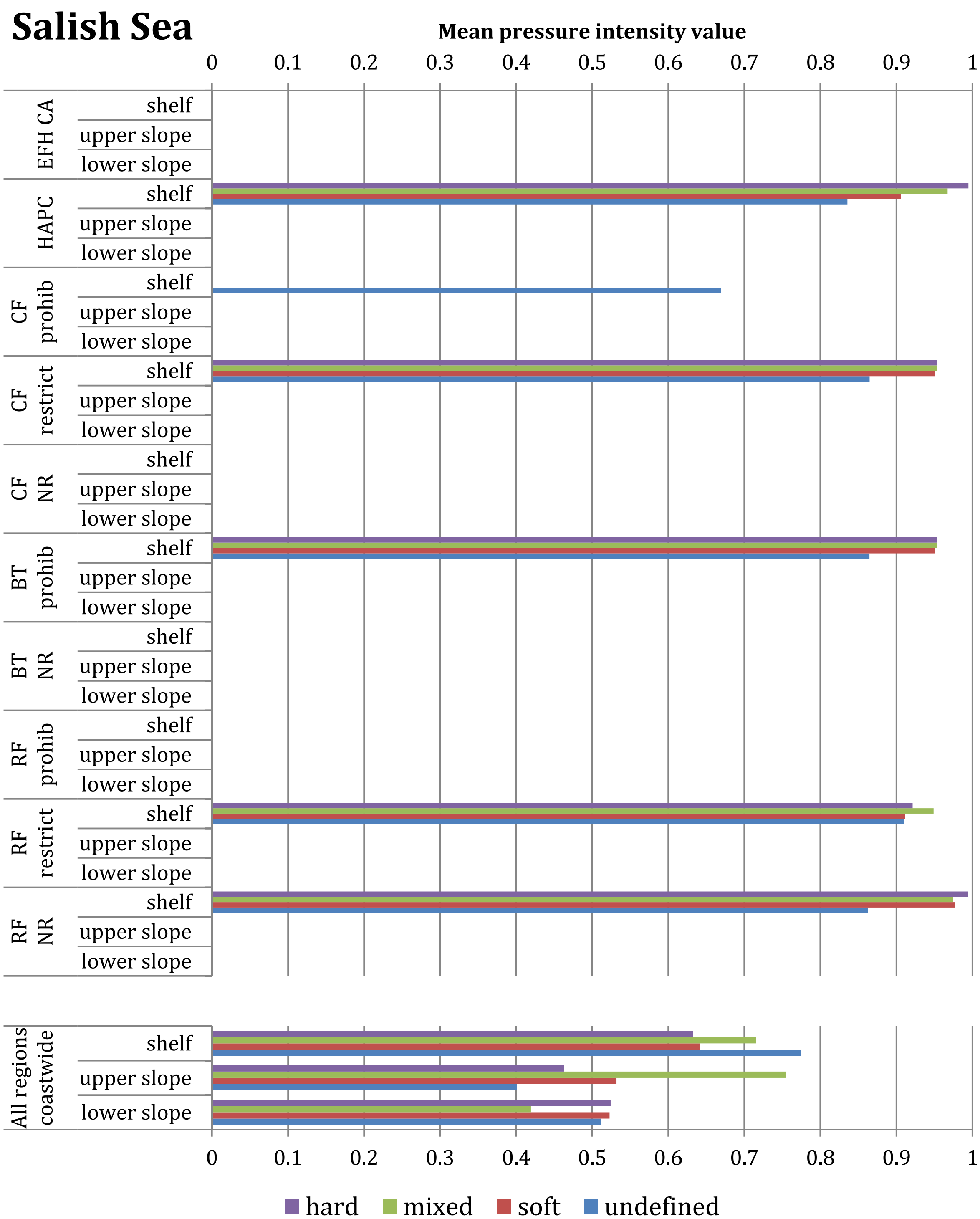


Figure A3b.10. Atmospheric pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.2 Inorganic pollution

Tens of thousands of chemicals are used by industries and businesses in the United States for the production of goods which our society depends. Many of the chemicals used in the manufacturing and production of these goods are toxic at some level to humans and other organisms and some are inevitably released into the environment. The production, use and release of various toxic chemicals have changed over time depending on economic indices, management methods (recycling and treatment of chemicals), and environmental regulations (USEPA 2010). The pathway of these chemicals to estuarine and marine environments can be direct (e.g., wastewater discharge into coastal waters or rivers) or diffuse (e.g., atmospheric deposition or urban runoff). Over the past 40 years, direct discharges have been greatly reduced; however, the input of pollutants to the marine environment from more diffuse pathways such as runoff from land-based activities is still a major concern (Boesch et al. 2001).

While all pollutants can become toxic at high enough levels, there are a number of compounds that are toxic even at relatively low levels (Johnson et al. 2008). The US Environmental Protection Agency (USEPA) has identified and designated more than 126 analytes as “priority pollutants.” According to the USEPA, “priority pollutants” of particular concern for aquatic systems include: (1) dichlorodiphenyl trichloroethane (DDT) and its metabolites; (2) chlorinated pesticides other than DDT (e.g., chlordane and dieldrin); (3) polychlorinated biphenyl (PCB) congeners; (4) metals (e.g., cadmium, copper, chromium, lead, mercury); (5) polycyclic aromatic hydrocarbons (PAHs); (6) dissolved gases (e.g., chlorine and ammonium); (7) anions (e.g., cyanides, fluorides, and sulfides); and (8) acids and alkalis (Kennish 1998, USEPA 2003). While acute exposure to these substances produce adverse effects on aquatic biota and habitats, chronic exposure to low concentrations probably is a more significant issue for fish population structure and may result in multiple substances acting in “an additive, synergistic or antagonistic manner” that may render impacts relatively difficult to discern (Thurberg and Gould 2005).

Coastal and estuarine pollution can affect all life stages of fish, but fish can be particularly sensitive to toxic contaminants during the first year of life (Rosenthal and Alderdice 1976). Over time, organisms will accumulate contaminants from water, sediments or food in their tissues, which then transfers to offspring through reproduction and throughout the food web via trophic interactions. One of the most widely recognized effects of inorganic pollution was the decline of bald eagles and brown pelicans during the 1960’s and 1970’s. These birds accumulated DDT in their tissues which changed their ability to metabolize calcium, which resulted in birds producing abnormally thin eggshells which led to reproductive failure (Hickey and Anderson 1968, Blus et al. 1971). Negative impacts of pollution on commercial fish stocks have generally not been demonstrated, largely due to the fact that only drastic changes in marine ecosystems are detectable and the difficulty in distinguishing pollution-induced changes from those due to other causes (Sindermann 1994). Normally, chronic and sublethal changes take place very slowly and it is impossible to separate natural fluctuations from anthropogenic causes. Furthermore, fish populations themselves are estimated only imprecisely, so the ability to detect and partition contaminant effects is made even more difficult. However, measurements of marine biodiversity have shown that species richness and evenness are reduced in areas of anthropogenic pollution (Johnston and Roberts 2009).

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, data from point source pollution from factories and mines and non-point source pollution that scales with the amount of impervious surface area (ISA) was the basis for the layer. Pollution from point sources were summed across watersheds that drain into the California Current. The total area of ISA within a watershed was used as a proxy for non-point source pollution. Point source and ISA estimates were log-transformed, normalized, summed, and re-normalized for a single value for each watershed. These values were then distributed to streams and river mouths in the watersheds and the diffusive 'spread' of these pollutants was modeled downstream.

Inorganic pollution was generally only observed in shelf habitat (Figs. A3b.11-13; Table A3b.11-12). Habitat within the Salish Sea and the southern biogeographic regions were exposed to the highest values of inorganic pollution, while the northern sub-region was exposed to the lowest values (Figs. A3b.11-12, Table A3b.11). Inorganic pollution was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.13, Table A3b.12); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.14-17, Tables A3b.13-16).

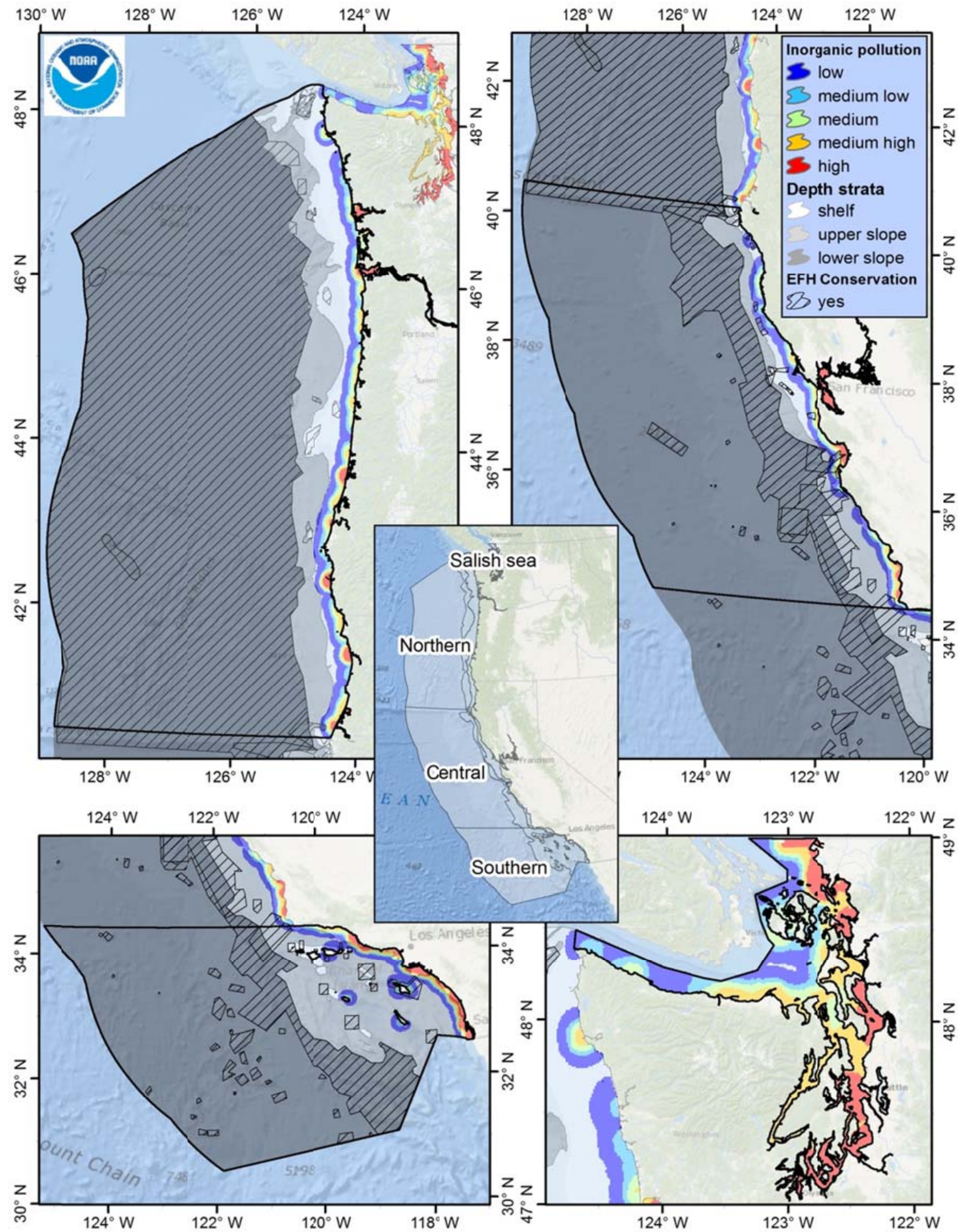


Figure A3b.11. Distribution of inorganic pollution intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Inorganic pollution data is from Halpern et al. 2009.

Table A3b.11. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

INORGANIC POLLUTION						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.04	0.08	0.12	0.16	0.07
	hard	0.03	0.08	0.10	0.06	0.05
	mixed	0.01	0.09	0.05	0.04	0.03
	soft	0.03	0.05	0.13	0.06	0.05
	undefined	0.54	0.45	0.26	0.21	0.28
Upper Slope[2]	All	0.00	0.00	0.01	NA	0.00
	hard	0.00	0.00	0.00	NA	0.00
	mixed	0.00	0.01	0.00	NA	0.00
	soft	0.00	0.00	0.01	NA	0.00
	undefined	NA	0.00	0.00	NA	0.00
Lower Slope[3]	All	0.00	0.00	0.00	NA	0.00
	hard	0.00	0.00	0.00	NA	0.00
	mixed	0.00	0.00	0.00	NA	0.00
	soft	0.00	0.00	0.00	NA	0.00
	undefined	0.00	0.00	0.00	NA	0.00
Grand mean	All	0.00	0.00	0.01	0.16	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

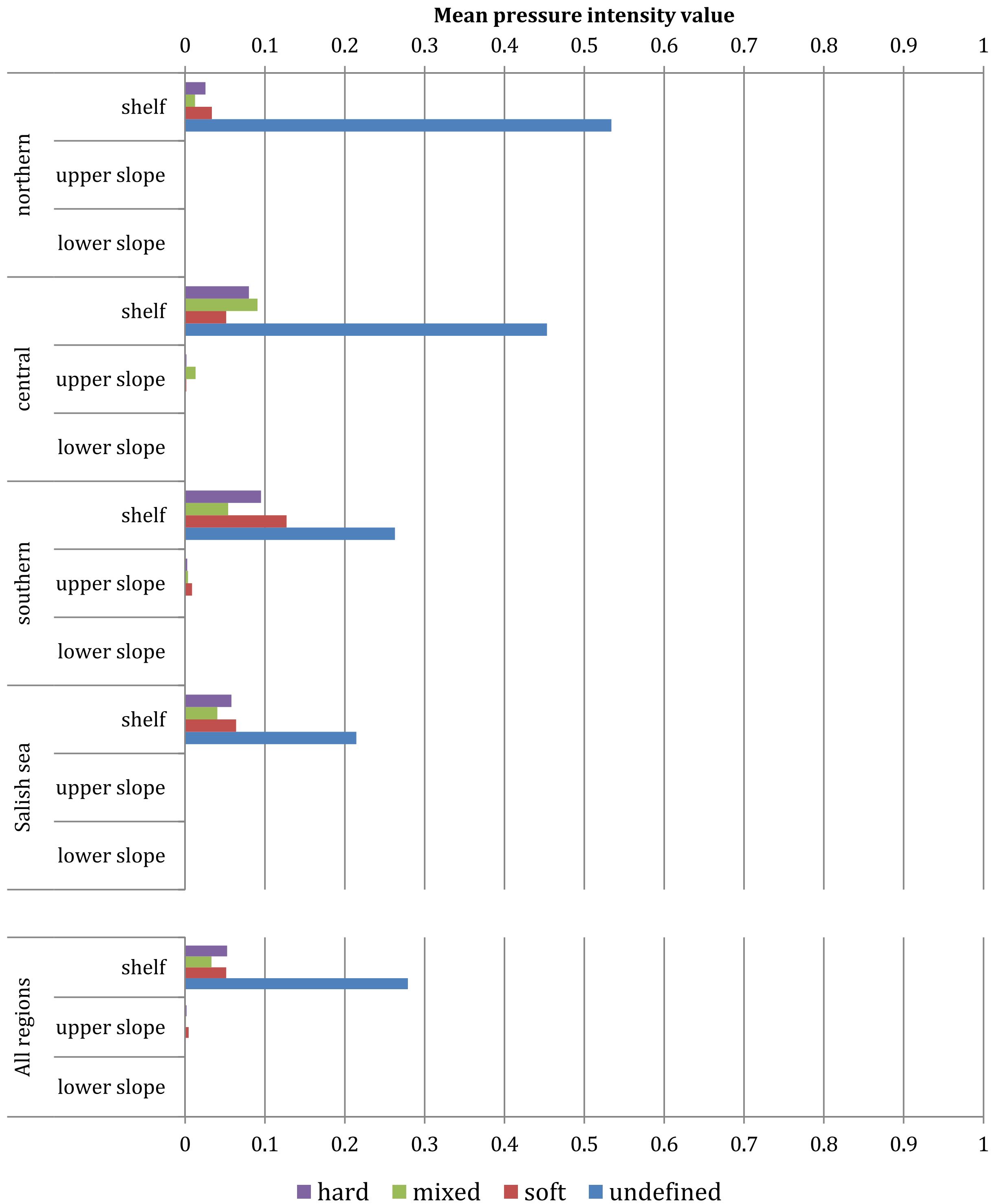


Figure A3b.12. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.12. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

INORGANIC POLLUTION												
		EFH CA	***HAPC***	***Commercial fishing***			***Bottom trawling***		***Recreational fishing***			***Coastwide***
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.01**	**0.15**	**0.08**	**0.10**	**0.04**	**0.12**	**0.04**	**0.07**	**0.02**	**0.08**	**0.07**
	hard	0.02	0.03	0.12	0.05	0.05	0.06	0.04	0.11	0.03	0.05	0.05
	mixed	0.01	0.02	0.09	0.03	0.03	0.05	0.02	0.08	0.01	0.05	0.03
	soft	0.02	0.06	0.07	0.07	0.04	0.09	0.03	0.06	0.02	0.06	0.05
	undefined	0.05	0.36	0.25	0.26	0.52	0.26	0.51	0.06	0.05	0.29	0.28
Upper Slope[2]	**All**	**0.00**	**0.00**	**0.05**	**0.00**	**0.00**	**0.01**	**0.00**	**0.04**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
	mixed	0.00	0.00	0.23	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.00	0.01	0.04	0.01	0.00	0.01	0.00	0.04	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	**All**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	**All**	**0.00**	**0.05**	**0.07**	**0.01**	**0.00**	**0.01**	**0.00**	**0.06**	**0.01**	**0.01**	**0.01**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

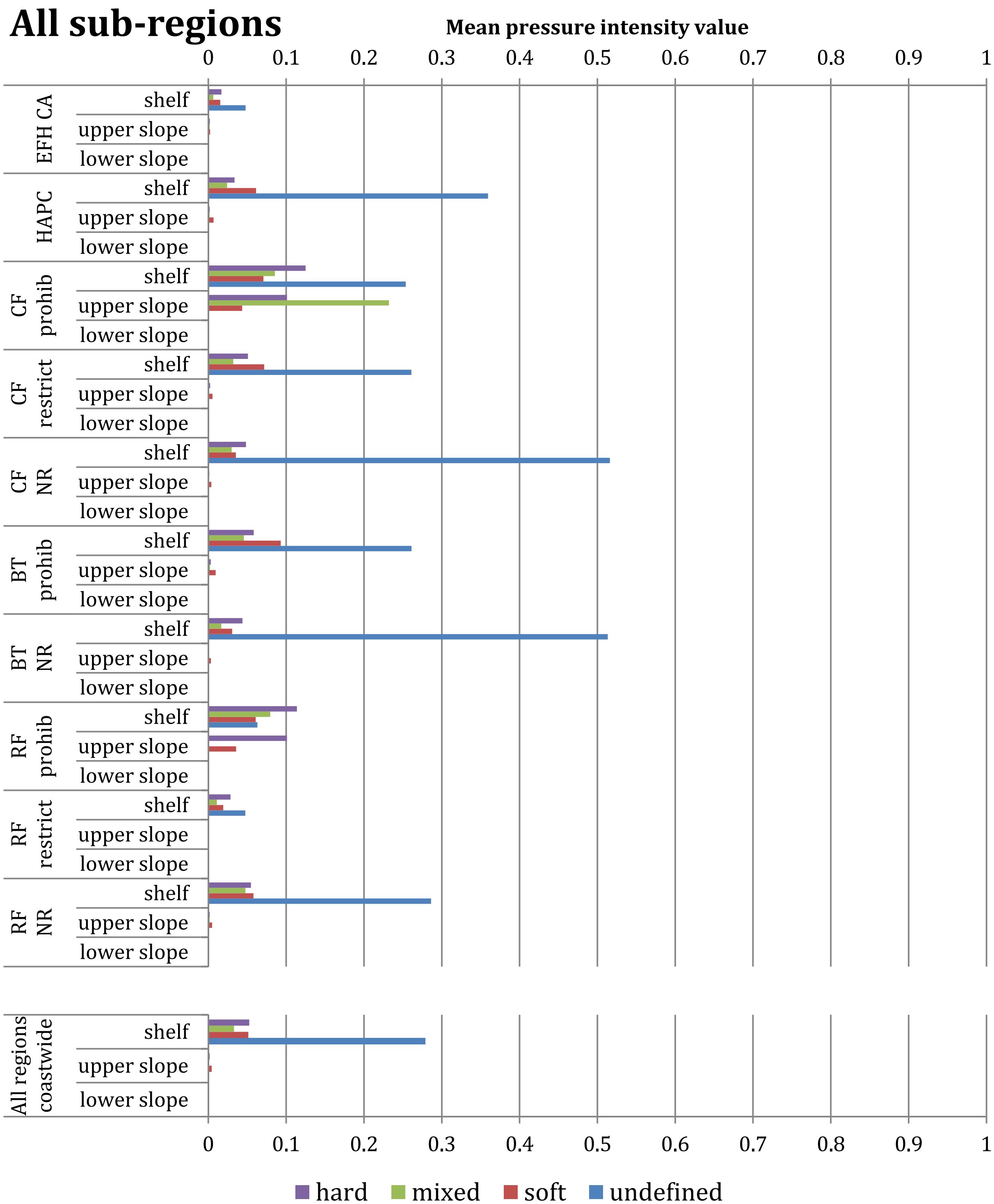


Figure A3b.13. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.13. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

INORGANIC POLLUTION	**NORTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.00	0.09	0.24	0.04	0.04	0.06	0.03	0.24	0.01	0.05	0.07
	hard	0.00	0.01	NA	0.01	0.04	0.01	0.04	NA	0.01	0.03	0.05
	mixed	0.00	0.01	NA	0.00	0.03	0.01	0.02	NA	0.00	0.02	0.03
	soft	0.00	0.08	0.24	0.04	0.03	0.07	0.03	0.24	0.01	0.04	0.05
	undefined	NA	0.60	NA	0.52	0.54	0.53	0.54	NA	0.01	0.54	0.28
Upper Slope[2]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.04	0.24	0.00	0.02	0.00	0.02	0.24	0.01	0.00	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.

[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.

[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

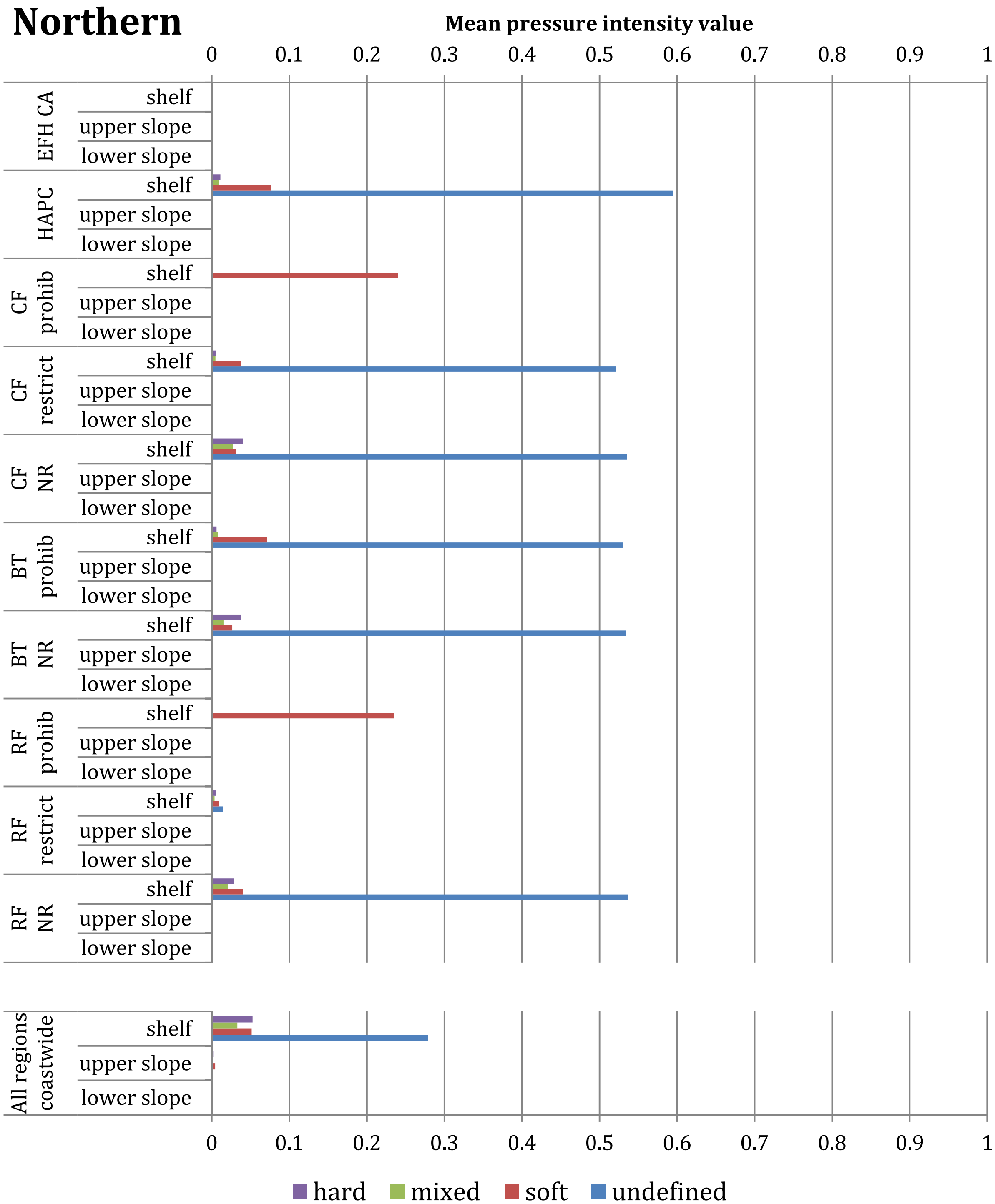


Figure A3b.14. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.14. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

INORGANIC POLLUTION	CENTRAL BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.03	0.22	0.11	0.14	0.02	0.14	0.02	0.11	0.09	0.08	0.07
	hard	0.05	0.07	0.10	0.09	0.02	0.09	0.02	0.11	0.13	0.07	0.05
	mixed	0.03	0.09	0.11	0.09	0.06	0.09	0.06	0.11	0.12	0.09	0.03
	soft	0.02	0.07	0.11	0.09	0.02	0.09	0.02	0.11	0.08	0.05	0.05
	undefined	0.08	0.47	0.30	0.46	0.37	0.46	0.36	0.01	0.20	0.46	0.28
Upper Slope[2]	All	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.12	0.00	0.00
	mixed	0.09	0.08	0.23	0.01	0.00	0.02	0.00	NA	NA	0.01	0.00
	soft	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.05	0.10	0.01	0.00	0.01	0.00	0.10	0.09	0.00	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

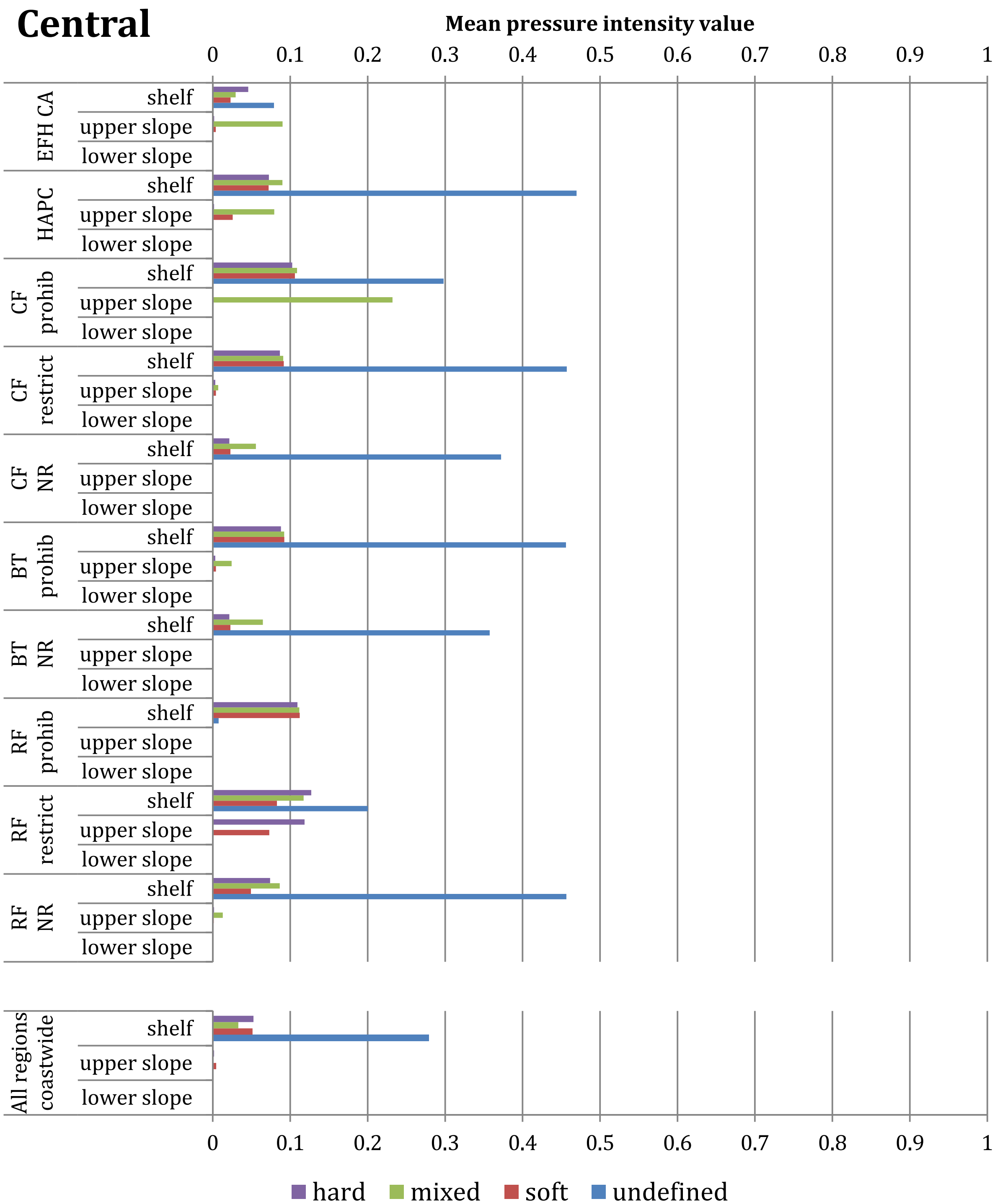


Figure A3b.15. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.15. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

INORGANIC POLLUTION	**SOUTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.01	0.03	0.06	0.12	0.17	0.12	0.13	0.03	0.02	0.16	0.07
	hard	0.00	0.06	0.16	0.07	0.20	0.09	0.11	0.12	0.01	0.13	0.05
	mixed	0.00	0.01	0.05	0.05	0.09	0.06	0.02	0.02	0.01	0.09	0.03
	soft	0.01	0.02	0.05	0.12	0.17	0.13	0.13	0.02	0.02	0.16	0.05
	undefined	0.03	0.28	0.17	0.28	0.17	0.27	0.17	0.17	0.09	0.28	0.28
Upper Slope[2]	All	0.00	0.00	0.05	0.01	0.01	0.02	0.01	0.04	0.00	0.01	0.00
	hard	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	0.03	0.00	0.01	NA	0.00	0.03	0.00
	soft	0.00	0.00	0.05	0.01	0.01	0.02	0.01	0.04	0.00	0.01	0.00
	undefined	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.01	0.05	0.01	0.00	0.02	0.00	0.04	0.00	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

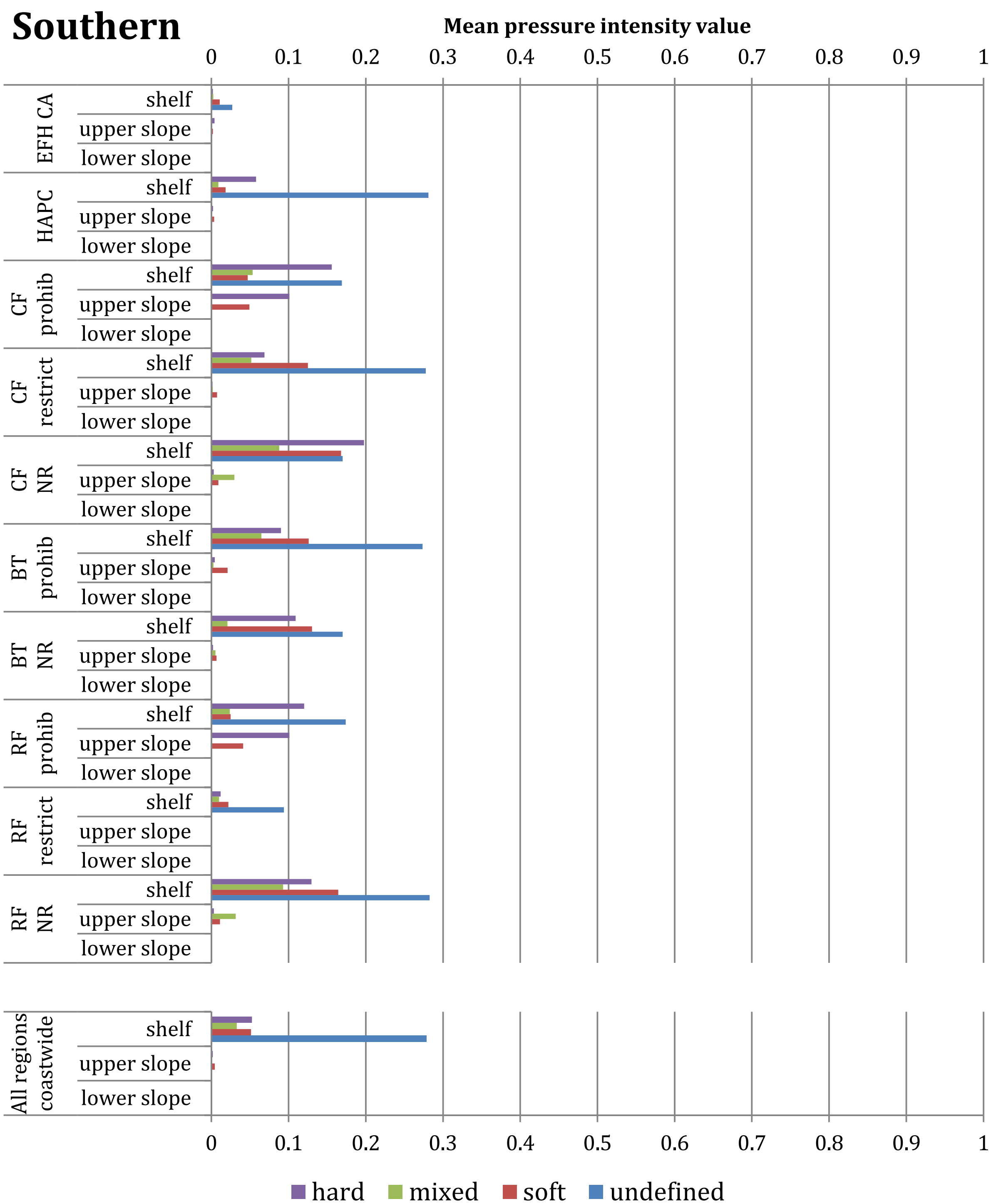


Figure A3b.16. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the “Southern” biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.16. Mean intensity values for inorganic pollution by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

INORGANIC POLLUTION	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	Substrate			Prohib	Restr	NR	Prohib	NR	Prohib	Restr	NR	
Shelf[1]	All	NA	0.28	0.21	0.16	NA	0.16	NA	NA	0.06	0.18	0.07
	hard	NA	0.05	NA	0.05	NA	0.05	NA	NA	0.06	0.06	0.05
	mixed	NA	0.03	NA	0.04	NA	0.04	NA	NA	0.03	0.08	0.03
	soft	NA	0.06	NA	0.06	NA	0.06	NA	NA	0.07	0.06	0.05
	undefined	NA	0.28	0.21	0.21	NA	0.21	NA	NA	0.04	0.22	0.28
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Grand mean	All	NA	0.28	0.21	0.16	NA	0.16	NA	NA	0.06	0.18	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

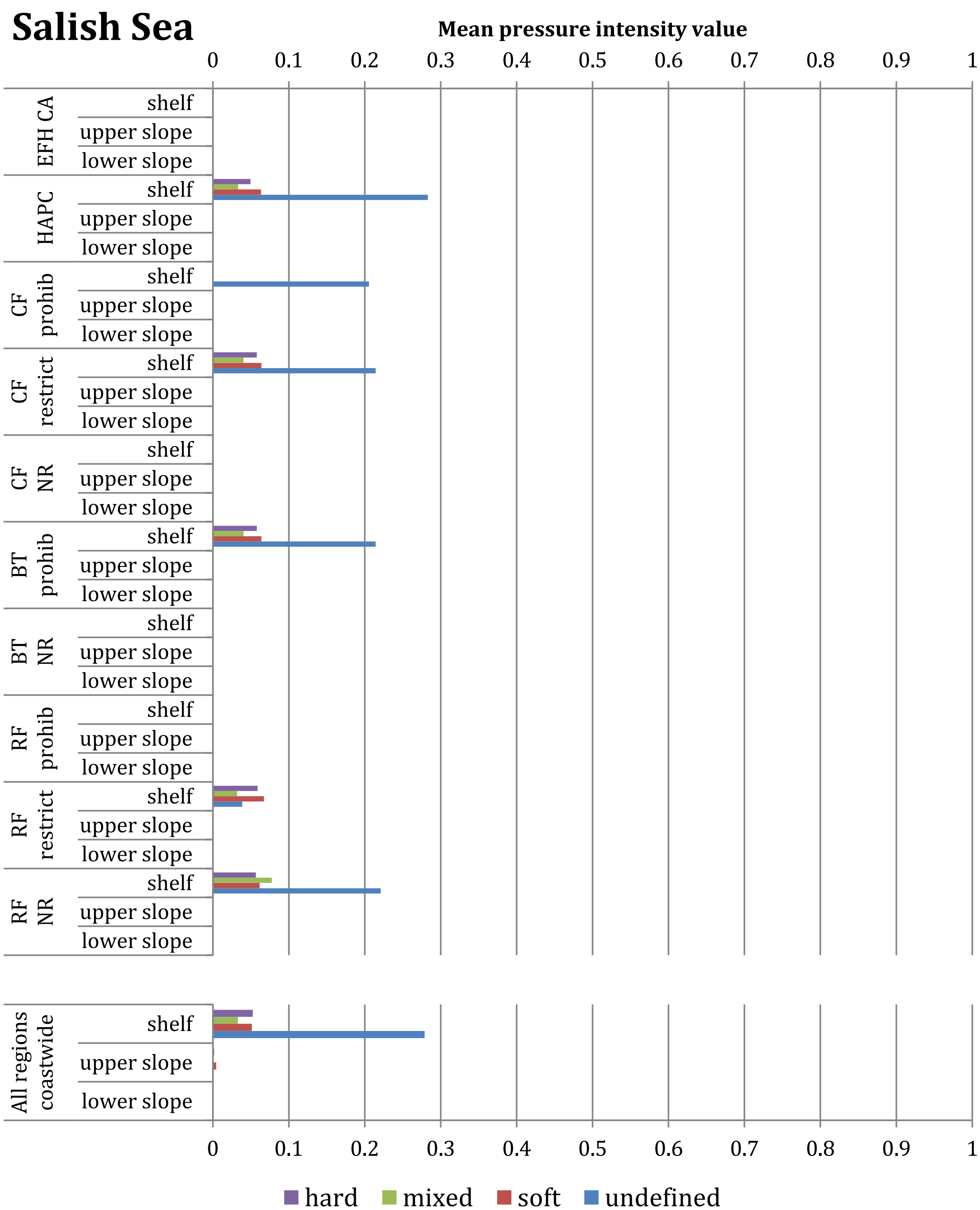


Figure A3b.17. Inorganic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.3 Organic pollution

Organic pollution encompass numerous classes of chemicals including pesticides, polycyclic aromatic hydrocarbons (PAHs) and other persistent organic pollutants (POPs) and is introduced to the marine environment via runoff to rivers, streams and groundwater, poor-disposal practices and the discharge of industrial wastewater. Pesticides can affect the health and productivity of biological populations in three basic ways: (1) direct toxicological impact on the health or performance of exposed individuals; (2) indirect impairment of the productivity of the ecosystem; and (3) loss or degradation of vegetation that provides physical structure for fish and invertebrates (Hanson et al. 2003, Johnson et al. 2008). For many marine organisms, the majority of effects from pesticide exposures are sublethal, meaning that the exposure does not directly lead to the mortality of individuals. Sublethal effects can be of concern, as they impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003, Johnson et al. 2008), but in general the sublethal impacts of pesticides on fish health are poorly understood. Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish (Gould et al. 1994, Moore and Waring 2001). The direct and indirect effects that pesticides have on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems (Preston 2002).

Petroleum products, including PAHs, consist of thousands of chemical compounds which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Johnson et al. 2008). PAHs have been found to be significantly higher in urbanized watersheds when compared to non-urbanized watersheds. Low-level chronic exposure to petroleum components and byproducts (i.e., polycyclic aromatic hydrocarbons [PAH]) have been shown in Atlantic salmon *Salmo salar* to increase embryo mortality, reduce growth (Heintz et al. 2000), and lower the return rates of adults returning to natal streams (Wertheimer et al. 2000). Effects of exposure to PAH in benthic species of fish include liver lesions, inhibited gonadal growth, inhibited spawning, reduced egg viability and reduced growth (Johnson et al. 2002). In general, the early life history stages of most species are most sensitive, juveniles are less sensitive, and adults least so.

Municipal wastewater treatment facilities have made great advances in treatment practices to eliminate pollutants prior to discharge, but any discharges will undoubtedly affect the quality of habitat in estuarine environments (Diaz and Rosenberg 1995, Kam et al. 2004). Several studies have shown that many benthic species increase in abundance and biomass in response to increased organic loading (Weston 1990, Savage et al. 2002, Alves et al. 2012). However, excessive nutrient enrichment can lead to hypoxia and potentially anoxic conditions, consequently leading to declines or shifts in biomass and diversity in the benthic community (Ysebaert et al. 1998, Essington and Paulsen 2010). Species richness among benthic communities has been shown to increase in relation to both temporal and spatial distance from organic loading sources (Savage et al. 2002, Wear and Tanner 2007). In addition to municipal wastewater treatment facilities, widely-distributed poorly-maintained septic systems contaminate shorelines in many places (Macdonald et al. 2002).

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, input rates of organic pollutants were calculated from national level statistics on pesticide use and land-use data. Pesticide data were distributed onto the landscape using dasymetric mapping techniques (Halpern et al. 2008) to get annual pesticide use per km^2. These values were then distributed to streams and river mouths in the watersheds and the diffusive 'spread' of these pollutants was modeled downstream.

Organic pollution intensity values were highest in the Salish Sea sub-region (Figs. A3b.18-19; Table A3b.17). Habitat within the northern sub-region was exposed to the lowest values of organic pollution. Similar to inorganic pollution and other land-based pressures, organic pollution was highest in shelf habitat and nearly absent from the slope habitats (Figs. A3b.18-20, Tables A3b.17-18). Organic pollution was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.20, Table A3b.18); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.21-24, Tables A3b.19-22).

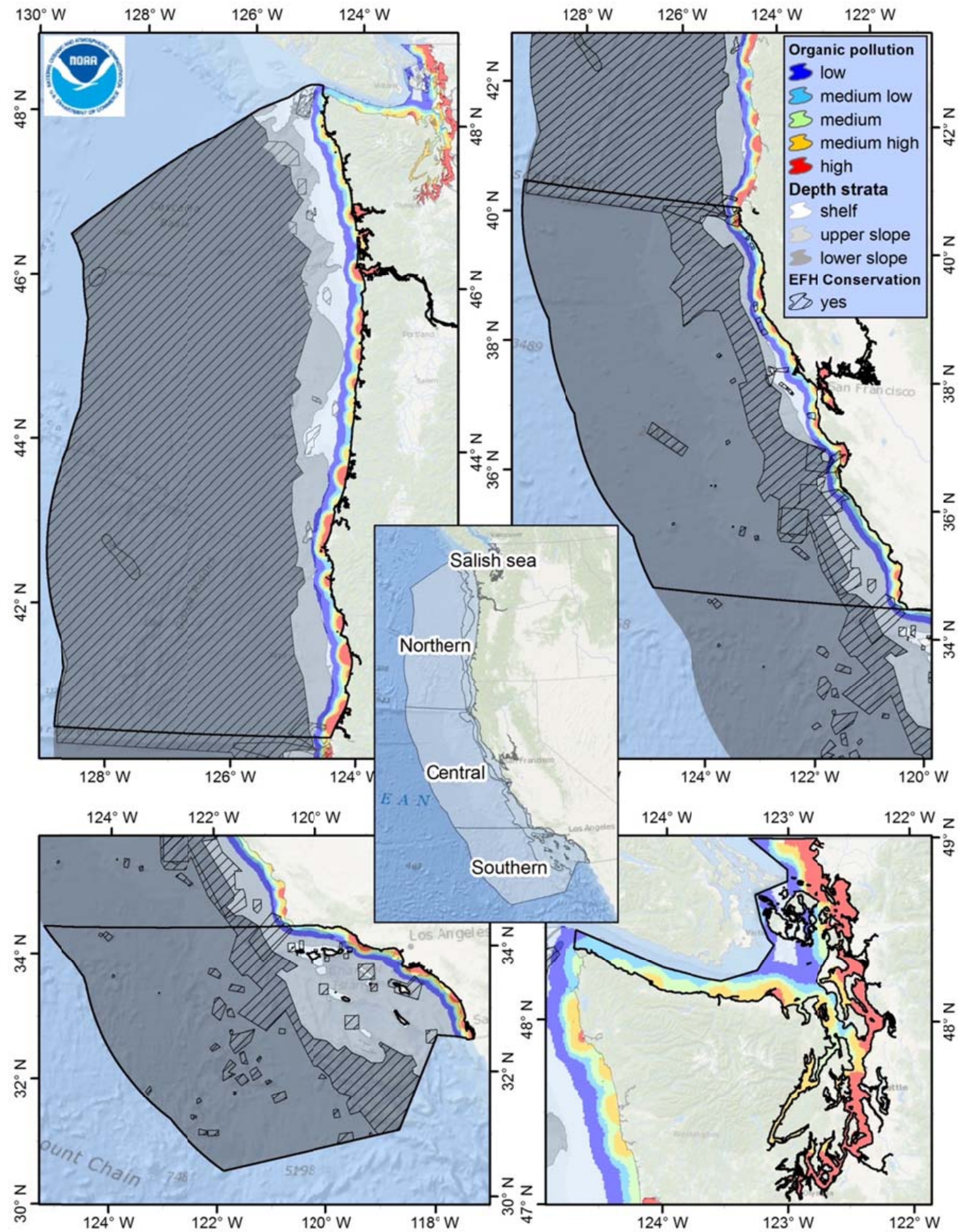


Figure A3b.18. Distribution of organic pollution intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Organic pollution data is from Halpern et al. 2009.

Table A3b.17. Mean intensity values for organic pollution by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

ORGANIC POLLUTION						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.12	0.19	0.15	0.27	0.16
	hard	0.08	0.22	0.11	0.14	0.12
	mixed	0.07	0.25	0.08	0.09	0.11
	soft	0.11	0.16	0.15	0.15	0.13
	undefined	0.65	0.57	0.26	0.33	0.39
Upper Slope[2]	All	0.00	0.01	0.01	NA	0.01
	hard	0.00	0.01	0.01	NA	0.00
	mixed	0.00	0.03	0.00	NA	0.00
	soft	0.00	0.01	0.01	NA	0.01
	undefined	NA	0.00	0.00	NA	0.00
Lower Slope[3]	All	0.00	0.00	0.00	NA	0.00
	hard	0.00	0.00	0.00	NA	0.00
	mixed	0.00	0.00	0.00	NA	0.00
	soft	0.00	0.00	0.00	NA	0.00
	undefined	0.00	0.00	0.00	NA	0.00
Grand mean	All	0.01	0.01	0.01	0.27	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

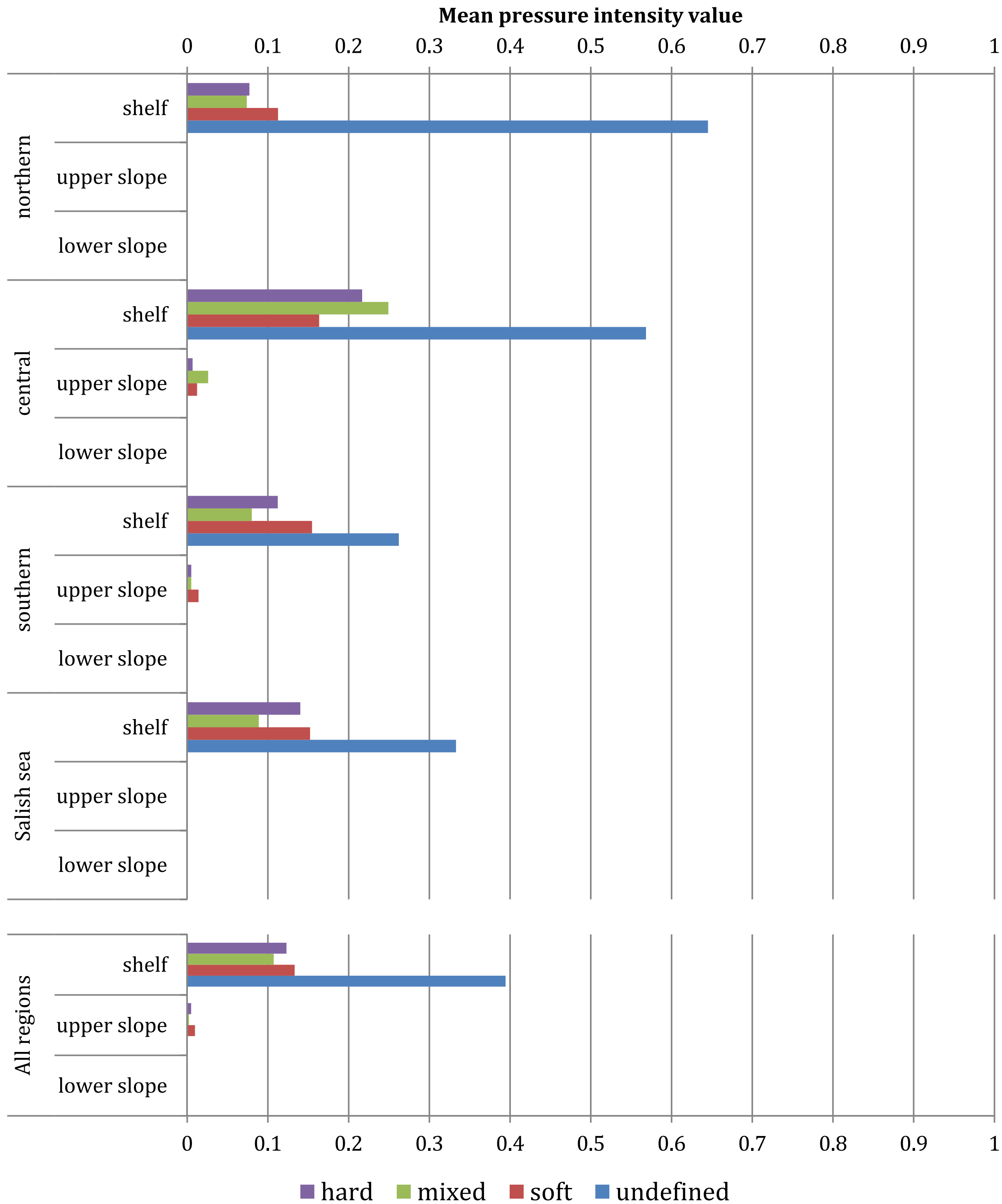


Figure A3b.19. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.18. Mean intensity values for organic pollution by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ORGANIC POLLUTION												
		EFH CA	***HAPC***	***Commercial fishing***			***Bottom trawling***		***Recreational fishing***			***Coastwide***
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.06**	**0.27**	**0.17**	**0.20**	**0.12**	**0.23**	**0.10**	**0.16**	**0.07**	**0.17**	**0.16**
	hard	0.05	0.09	0.22	0.13	0.11	0.14	0.10	0.21	0.10	0.12	0.12
	mixed	0.03	0.10	0.21	0.08	0.17	0.12	0.09	0.21	0.03	0.16	0.11
	soft	0.07	0.20	0.16	0.16	0.11	0.20	0.10	0.15	0.07	0.15	0.13
	undefined	0.05	0.49	0.33	0.38	0.62	0.38	0.62	0.12	0.08	0.40	0.39
Upper Slope[2]	**All**	**0.01**	**0.01**	**0.08**	**0.01**	**0.01**	**0.02**	**0.01**	**0.08**	**0.00**	**0.01**	**0.01**
	hard	0.01	0.00	0.13	0.01	0.00	0.01	0.00	0.13	0.00	0.01	0.00
	mixed	0.00	0.00	0.37	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.01	0.02	0.08	0.01	0.01	0.02	0.01	0.08	0.00	0.01	0.01
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	**All**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	**All**	**0.00**	**0.09**	**0.15**	**0.02**	**0.01**	**0.02**	**0.01**	**0.14**	**0.03**	**0.01**	**0.01**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

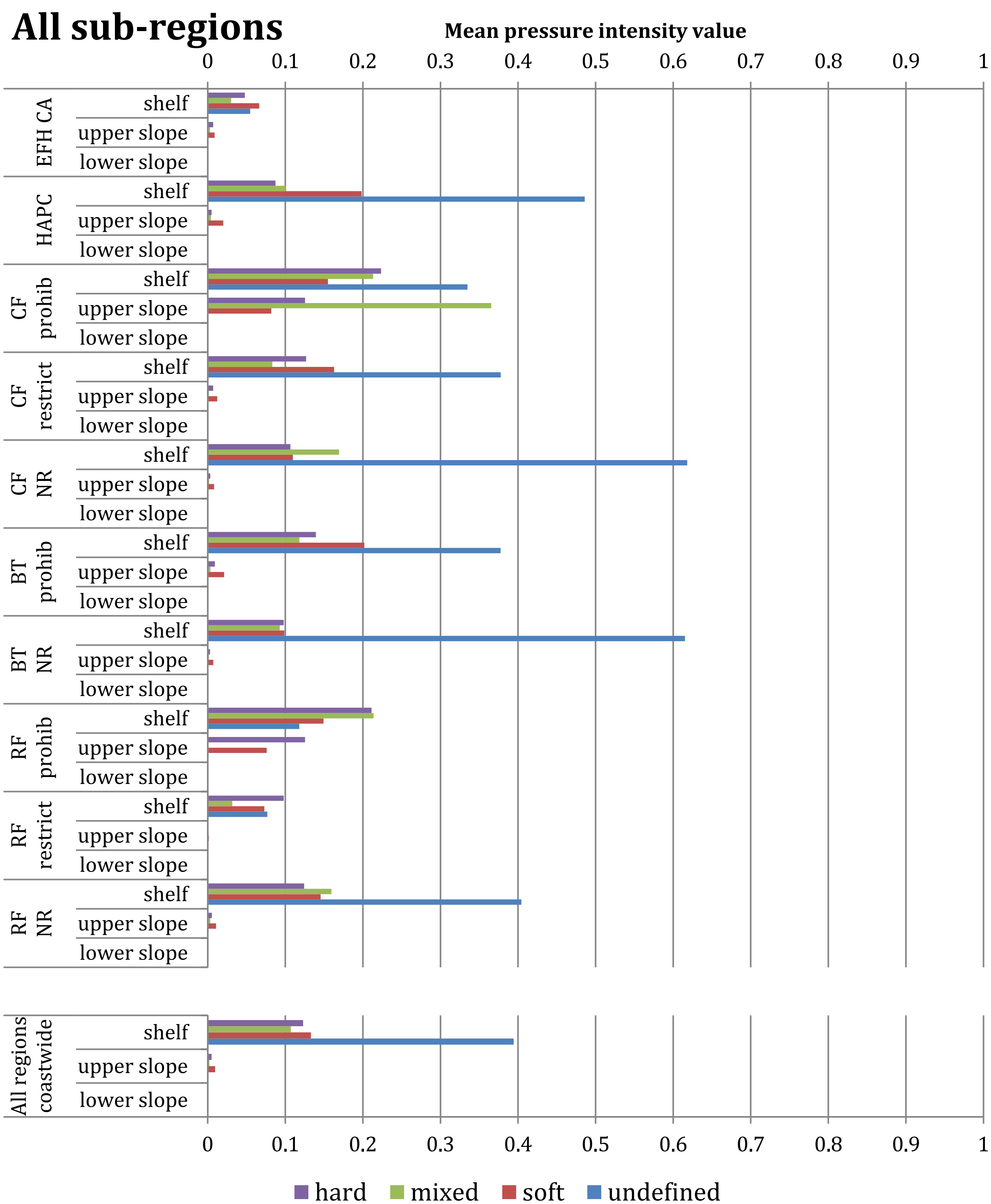


Figure A3b.20. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.19. Mean intensity values for organic pollution by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ORGANIC POLLUTION	**NORTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.00	0.23	0.52	0.12	0.11	0.21	0.10	0.52	0.07	0.13	0.16
	hard	0.00	0.05	NA	0.06	0.09	0.06	0.09	NA	0.12	0.07	0.12
	mixed	0.00	0.09	NA	0.03	0.17	0.04	0.09	NA	0.02	0.12	0.11
	soft	0.01	0.27	0.52	0.13	0.10	0.23	0.09	0.52	0.07	0.12	0.13
	undefined	NA	0.72	NA	0.67	0.64	0.68	0.64	NA	0.16	0.65	0.39
Upper Slope[2]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.01
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.01
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.10	0.52	0.01	0.05	0.00	0.05	0.52	0.06	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

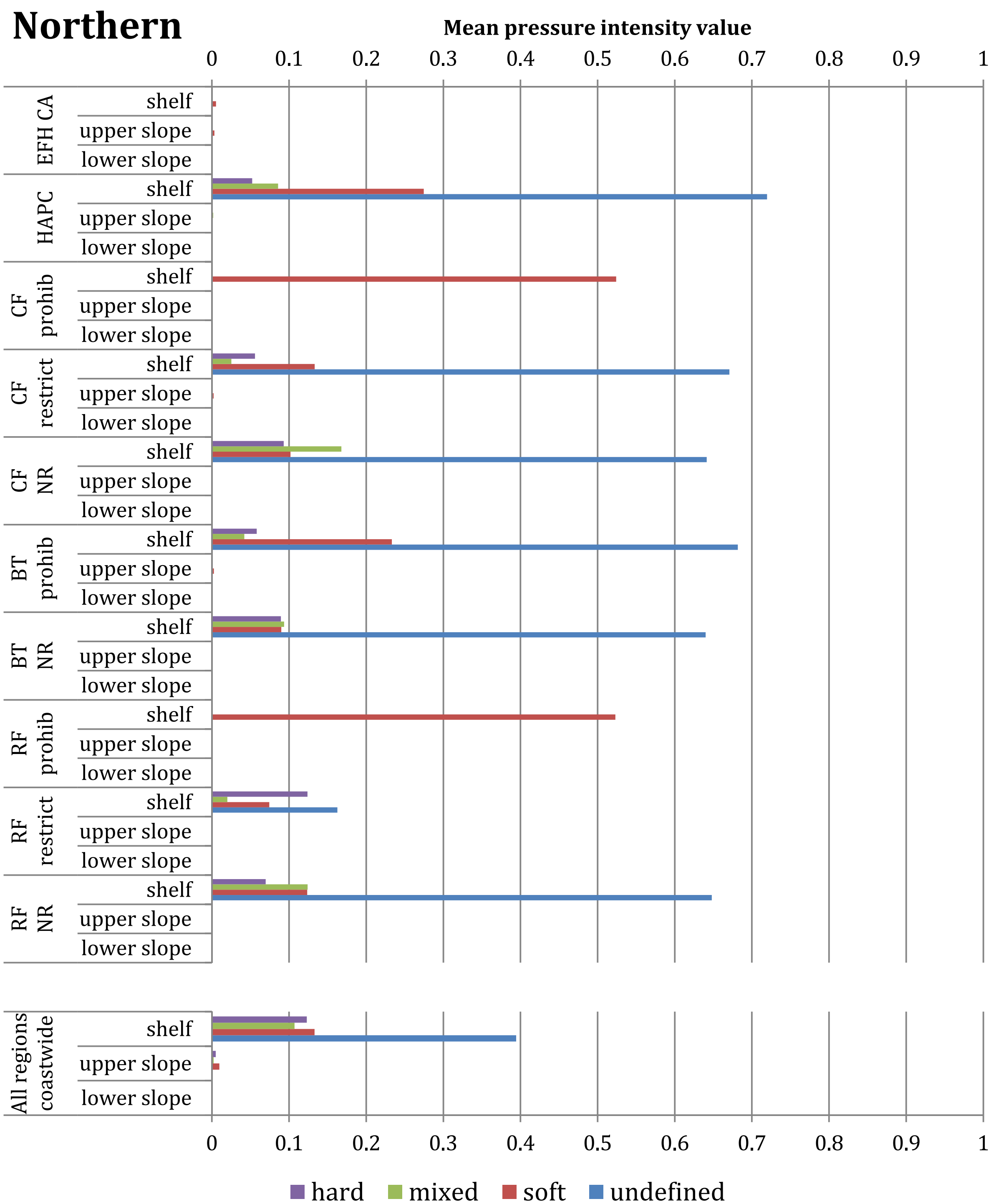


Figure A3b.21. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.20. Mean intensity values for organic pollution by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ORGANIC POLLUTION	CENTRAL BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
<u>*Depth Zone*</u>	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.13	0.34	0.29	0.28	0.11	0.28	0.11	0.29	0.24	0.19	0.16
	hard	0.13	0.18	0.26	0.23	0.12	0.23	0.12	0.26	0.30	0.21	0.12
	mixed	0.14	0.21	0.32	0.25	0.18	0.25	0.19	0.31	0.28	0.24	0.11
	soft	0.13	0.21	0.29	0.24	0.11	0.24	0.11	0.30	0.23	0.16	0.13
	undefined	0.14	0.59	0.41	0.57	0.45	0.57	0.44	0.09	0.29	0.57	0.39
Upper Slope[2]	All	0.02	0.03	0.21	0.02	0.01	0.02	0.01	0.20	0.24	0.01	0.01
	hard	0.01	0.01	NA	0.01	0.00	0.01	0.00	NA	0.28	0.01	0.00
	mixed	0.15	0.15	0.37	0.02	0.00	0.04	0.00	NA	NA	0.03	0.00
	soft	0.02	0.11	0.20	0.03	0.01	0.03	0.01	0.20	0.24	0.01	0.01
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.09	0.29	0.03	0.00	0.03	0.00	0.29	0.24	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

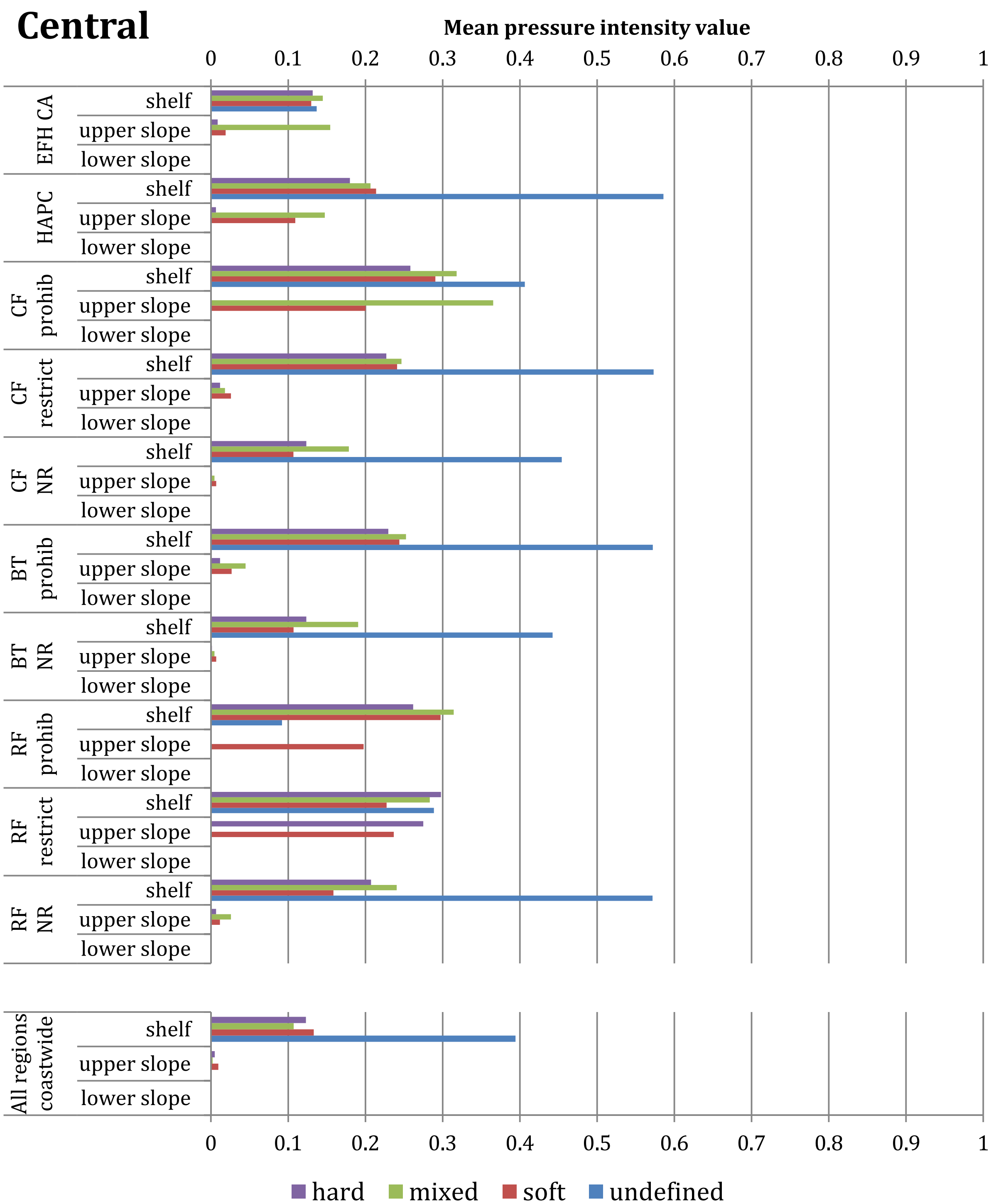


Figure A3b.22. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the “Central” biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.21. Mean intensity values for organic pollution by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ORGANIC POLLUTION	SOUTHERN BIOGEOGRAPHIC SUB-REGION										COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*		*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.00	0.03	0.07	0.14	0.24	0.14	0.18	0.05	0.02	0.20	0.16
	hard	0.00	0.07	0.18	0.08	0.26	0.10	0.14	0.14	0.01	0.16	0.12
	mixed	0.00	0.02	0.07	0.07	0.20	0.09	0.05	0.04	0.01	0.14	0.11
	soft	0.00	0.02	0.07	0.14	0.24	0.14	0.19	0.05	0.02	0.20	0.13
	undefined	0.00	0.28	0.17	0.28	0.18	0.27	0.18	0.17	0.11	0.28	0.39
Upper Slope[2]	All	0.00	0.00	0.07	0.01	0.02	0.03	0.01	0.06	0.00	0.02	0.01
	hard	0.00	0.00	0.13	0.00	0.01	0.00	0.01	0.13	0.00	0.01	0.00
	mixed	0.00	0.00	NA	0.00	0.04	0.00	0.01	NA	0.00	0.04	0.00
	soft	0.00	0.00	0.07	0.01	0.02	0.03	0.01	0.06	0.00	0.02	0.01
	undefined	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.01	0.07	0.02	0.01	0.02	0.00	0.06	0.00	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

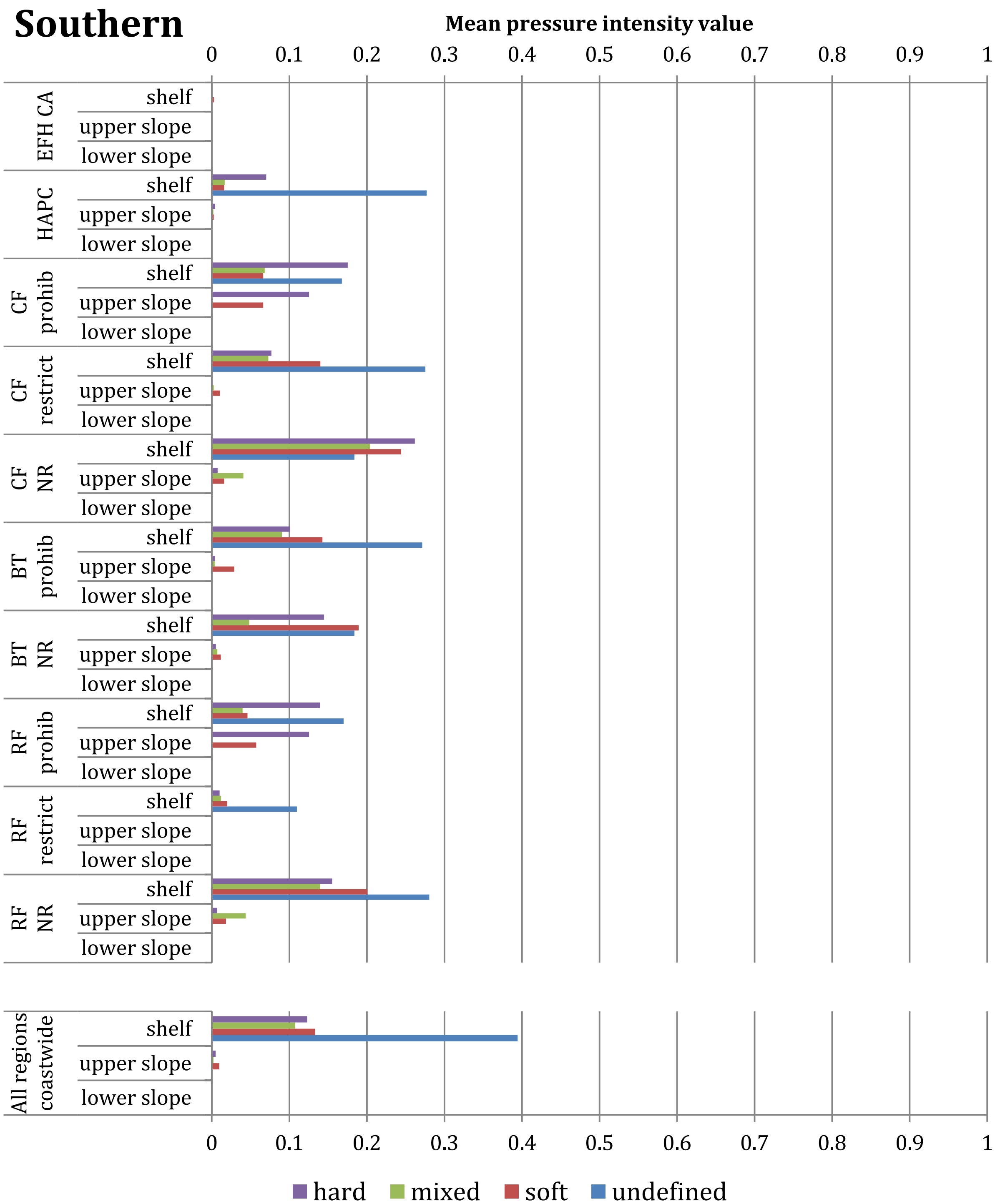


Figure A3b.23. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.22. Mean intensity values for organic pollution by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

ORGANIC POLLUTION	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	HAPC	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.41	0.29	0.27	0.33	0.27	0.33	NA	0.07	0.31	0.16
	hard	NA	0.26	NA	0.13	0.26	0.13	0.26	NA	0.05	0.25	0.12
	mixed	NA	0.12	NA	0.08	0.34	0.08	0.34	NA	0.06	0.21	0.11
	soft	NA	0.09	NA	0.15	0.22	0.15	0.22	NA	0.08	0.20	0.13
	undefined	NA	0.42	0.29	0.33	0.34	0.33	0.34	NA	0.06	0.34	0.39
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Grand mean	All	0.27	0.41	0.29	0.27	0.33	0.27	0.33	NA	0.07	0.31	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

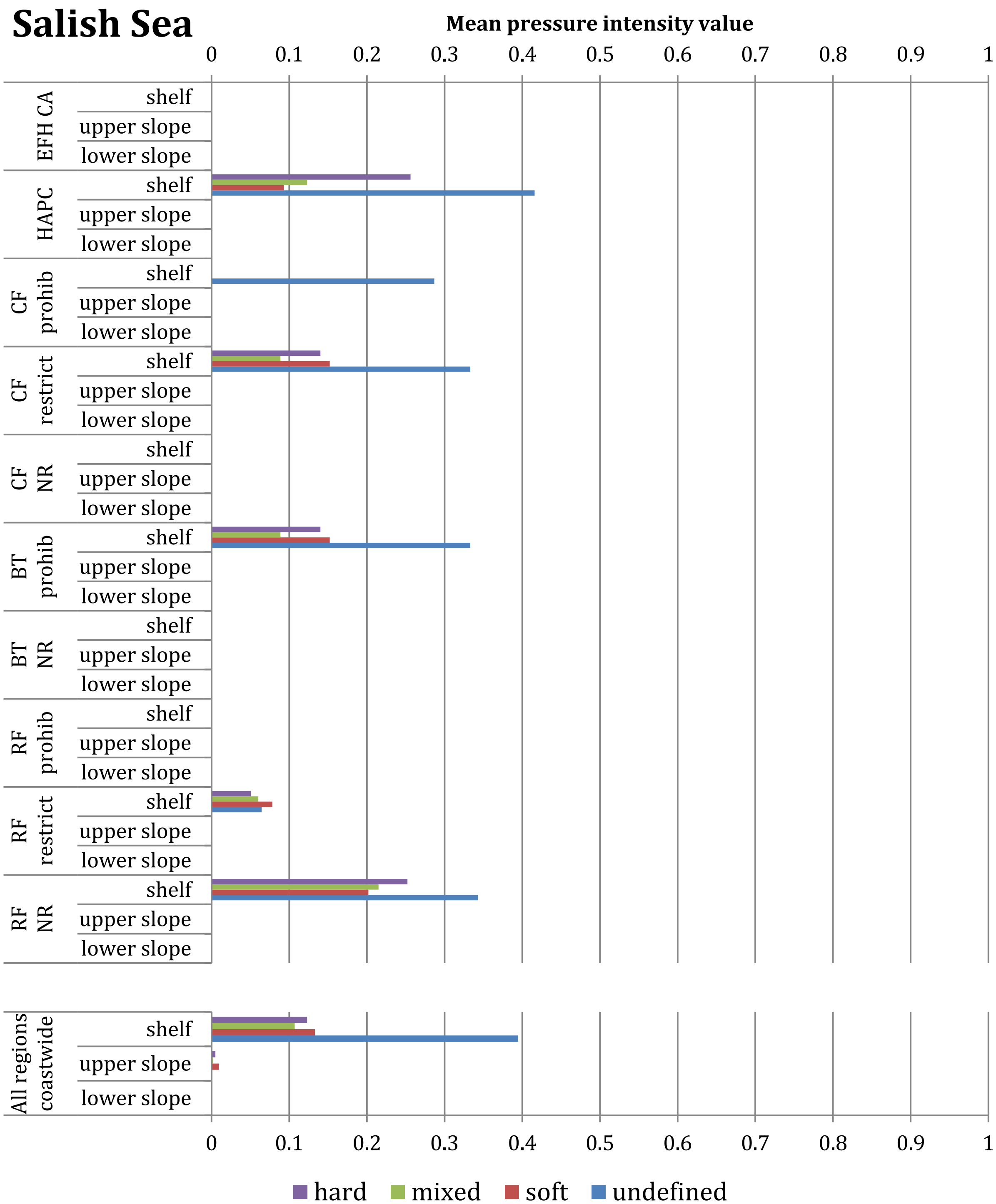


Figure A3b.24. Organic pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.4 Nutrient input

Elevated nutrient concentrations are a leading cause of contamination in streams, lakes, wetlands, estuaries, and ground water of the United States (USEPA 2002). Nutrients (primarily nitrogen and phosphorus) are chemical elements that are essential to plant and animal nutrition; in marine waters, either phosphorus of nitrogen can limit plant growth. However, in high concentrations they can be considered water contaminants (USEPA 1999a).

Excess nutrients in a body of water can have many detrimental effects on drinking water supplies, recreational use, aquatic life use, and fisheries, and there are multiple indirect effects of nutrient enrichment of surface waters on human health. However, excessive nutrients are more often a cause of concern because of their role in accelerating eutrophication, which produces a wide range of other impacts on aquatic ecosystems and fisheries. Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including: algae blooms; declines in submerged aquatic vegetation (SAV) populations through reduced light transmittance, epiphytic growth, and increased disease susceptibility; mass mortality of fish and invertebrates through poor water quality (e.g., via oxygen depletion and elevated ammonia levels); and alterations in long-term natural community dynamics (Dubrovsky et al. 2010). Algal toxins harmful to animal and human health can be produced from blooms of some cyanobacteria species. High algal biomass also is associated with hypoxia (low dissolved-oxygen concentrations), which can contribute to the release of toxic metals from bed sediments, increased availability of toxic substances like ammonia and hydrogen sulfide, and fish kills. In recent years, nitrate and other nutrients discharged from the Mississippi River Basin have been linked to a large zone of hypoxia in the Gulf of Mexico along the Louisiana-Texas coast (Sprague et al. 2009).

Nonpoint sources of nutrients which affect stream and groundwater concentrations include fertilizer use, livestock manure, and atmospheric deposition (Ruddy et al. 2006). Within some coastal regions of the U.S. (e.g., mid-Atlantic states), much of the excess nutrients originates from point sources, such as sewage treatment plants, whereas failing septic systems often contribute to non-point source pollution and are a negative consequence of urban development (Johnson et al. 2008). However, nutrient loading can be a complex indicator to interpret, as a variety of hydro-geomorphic features (basin slope, basin area, mean annual precipitation, stream flow, and soil type) may also interact with possible nutrient sources to complicate estimates of nutrient concentration and loading. As well, there often are multiple and possibly counteracting anthropogenic factors influencing nutrient source and transport in a watershed, and without detailed knowledge of all important factors in each watershed, it may be difficult to discern the specific cause(s) of a trend in concentration (Sprague et al. 2009). Best land-use practices are known to reduce nutrient loading. Protocols for establishing total maximum daily load (TMDL) values of nutrients have been developed for specific bodies of water throughout the country (USEPA 1999a); however, we uncovered few examples in the literature of TMDLs for marine systems on the Pacific coast of the US.

Despite some of the previous cautions, nutrient loading in freshwater systems is generally a well understood indicator with a long history of reporting, as evidenced by requirements under the Clean Water Act, intensive nationwide monitoring programs at the federal, state, and local level, and a variety of national and regional trend reports by USGS (Ruddy et al. 2006, Wise et al. 2007, Sprague et al. 2009, Dubrovsky et al. 2010, Kratzer et al. 2011).

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, nutrient input was calculated from nitrogen input from farming and atmospheric deposition. County-level nitrogen application data and atmospheric deposition data were summed independently across watersheds and plumed into coastal waters using a plume model (Halpern et al. 2008). Values were normalized and summed to create a single layer of nitrogen input.

Nutrient input intensity values were very similar to organic pollution: values were highest in the Salish Sea (Figs. A3b.25-26, Table A3b.23) and in shelf habitat (Figs. A3b.25-27; Tables A3b.23-24). Habitat within the northern sub-region was exposed to the lowest values of nutrient input, particularly in shelf habitat. Nutrient input was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.27, Table A3b.24); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.28-31, Tables A3b.25-28).

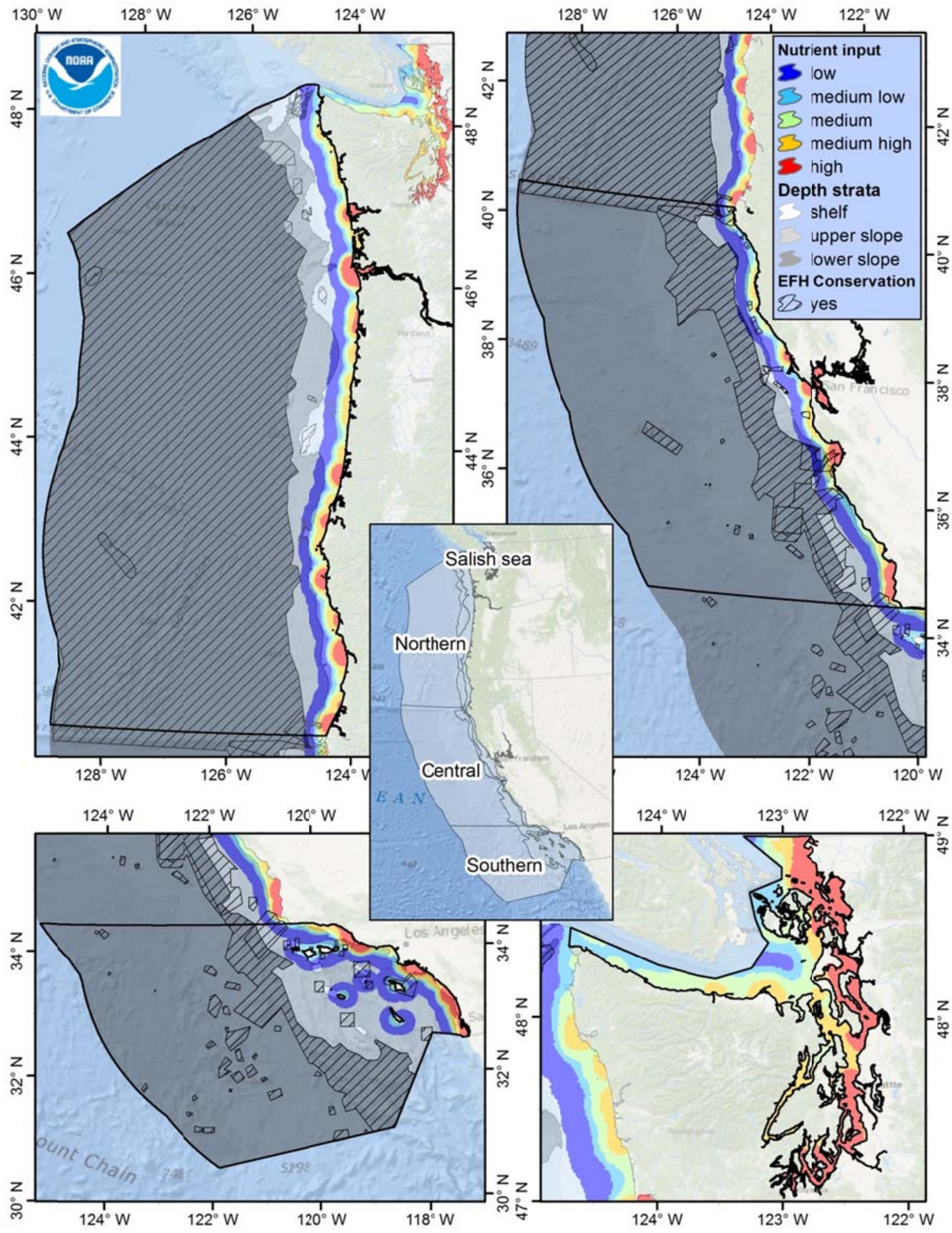


Figure A3b.25. Distribution of nutrient input intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Nutrient input data is from Halpern et al. 2009.

Table A3b.23. Mean intensity values for nutrient input by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

NUTRIENT INPUT						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.12	0.19	0.17	0.24	0.18
	hard	0.06	0.20	0.14	0.15	0.15
	mixed	0.06	0.20	0.09	0.11	0.13
	soft	0.11	0.16	0.18	0.16	0.16
	undefined	0.70	0.58	0.27	0.29	0.24
Upper Slope[2]	All	0.00	0.01	0.02	NA	0.06
	hard	0.00	0.01	0.01	NA	0.05
	mixed	0.00	0.02	0.01	NA	0.03
	soft	0.00	0.01	0.03	NA	0.06
	undefined	NA	0.00	0.00	NA	0.01
Lower Slope[3]	All	0.00	0.00	0.00	NA	0.00
	hard	0.00	0.00	0.00	NA	0.01
	mixed	0.00	0.00	0.00	NA	0.00
	soft	0.00	0.00	0.00	NA	0.01
	undefined	0.00	0.00	0.00	NA	0.00
Grand mean	All	0.01	0.01	0.01	0.24	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

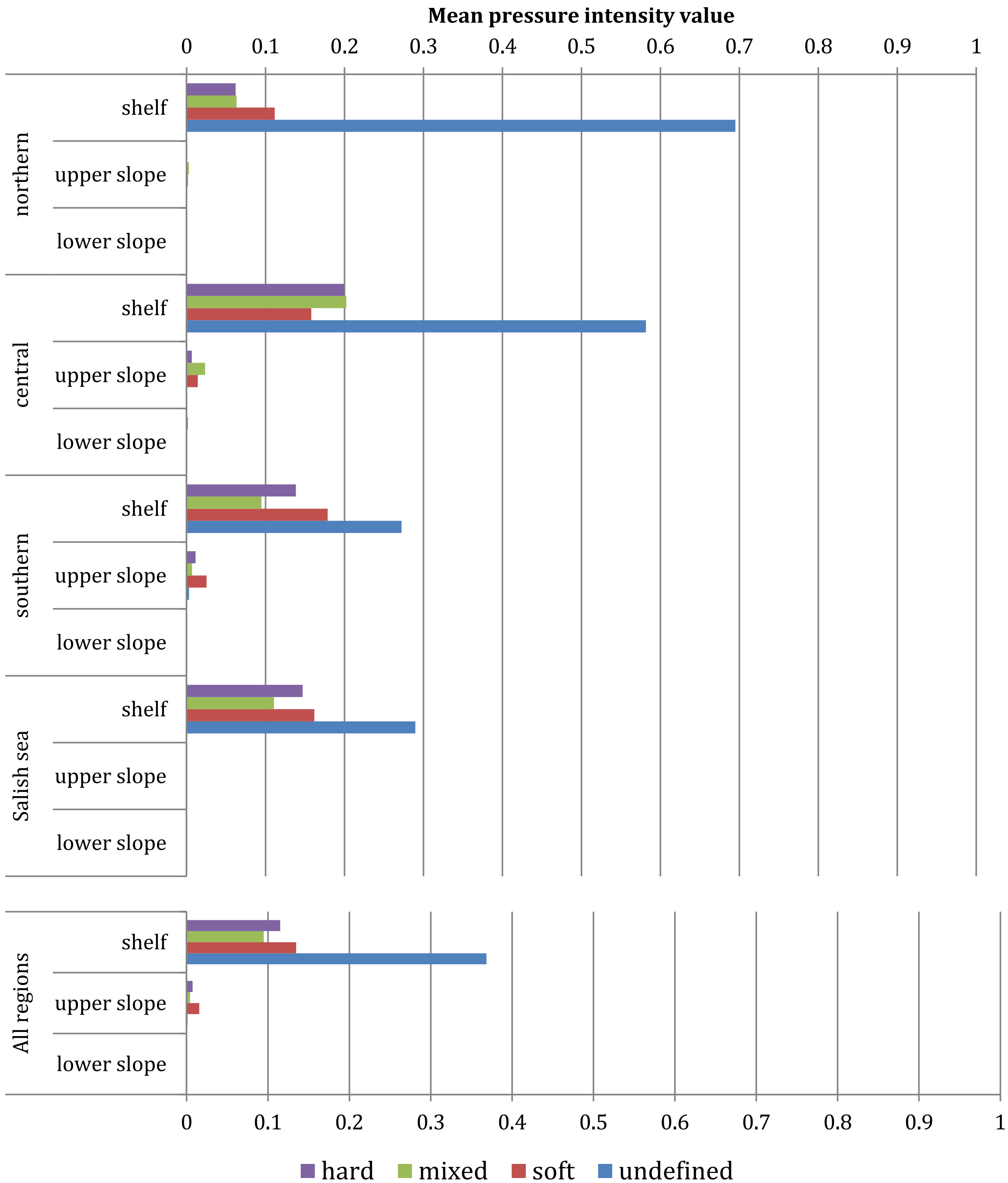


Figure A3b.26. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.24. Mean intensity values for nutrient input by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

NUTRIENT INPUT													
		EFH CA	***HAPC***	***Commercial fishing***			***Bottom trawling***		***Recreational fishing***			***Coastwide***
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.07**	**0.24**	**0.15**	**0.18**	**0.13**	**0.21**	**0.11**	**0.14**	**0.08**	**0.17**	**0.15**
	hard	0.06	0.09	0.19	0.12	0.10	0.13	0.09	0.18	0.10	0.12	0.11
	mixed	0.02	0.09	0.18	0.07	0.15	0.10	0.08	0.19	0.03	0.14	0.09
	soft	0.08	0.17	0.14	0.15	0.12	0.19	0.11	0.13	0.08	0.15	0.13
	undefined	0.10	0.45	0.31	0.35	0.66	0.35	0.66	0.09	0.15	0.38	0.37
Upper Slope[2]	**All**	**0.01**	**0.01**	**0.09**	**0.02**	**0.01**	**0.03**	**0.01**	**0.08**	**0.00**	**0.02**	**0.01**
	hard	0.01	0.01	0.10	0.01	0.01	0.01	0.00	0.11	0.00	0.01	0.01
	mixed	0.00	0.01	0.30	0.00	0.00	0.00	0.00	NA	0.00	0.01	0.00
	soft	0.01	0.03	0.09	0.02	0.01	0.03	0.01	0.08	0.00	0.02	0.02
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	**All**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	**All**	**0.00**	**0.08**	**0.14**	**0.02**	**0.01**	**0.02**	**0.01**	**0.13**	**0.03**	**0.01**	**0.01**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

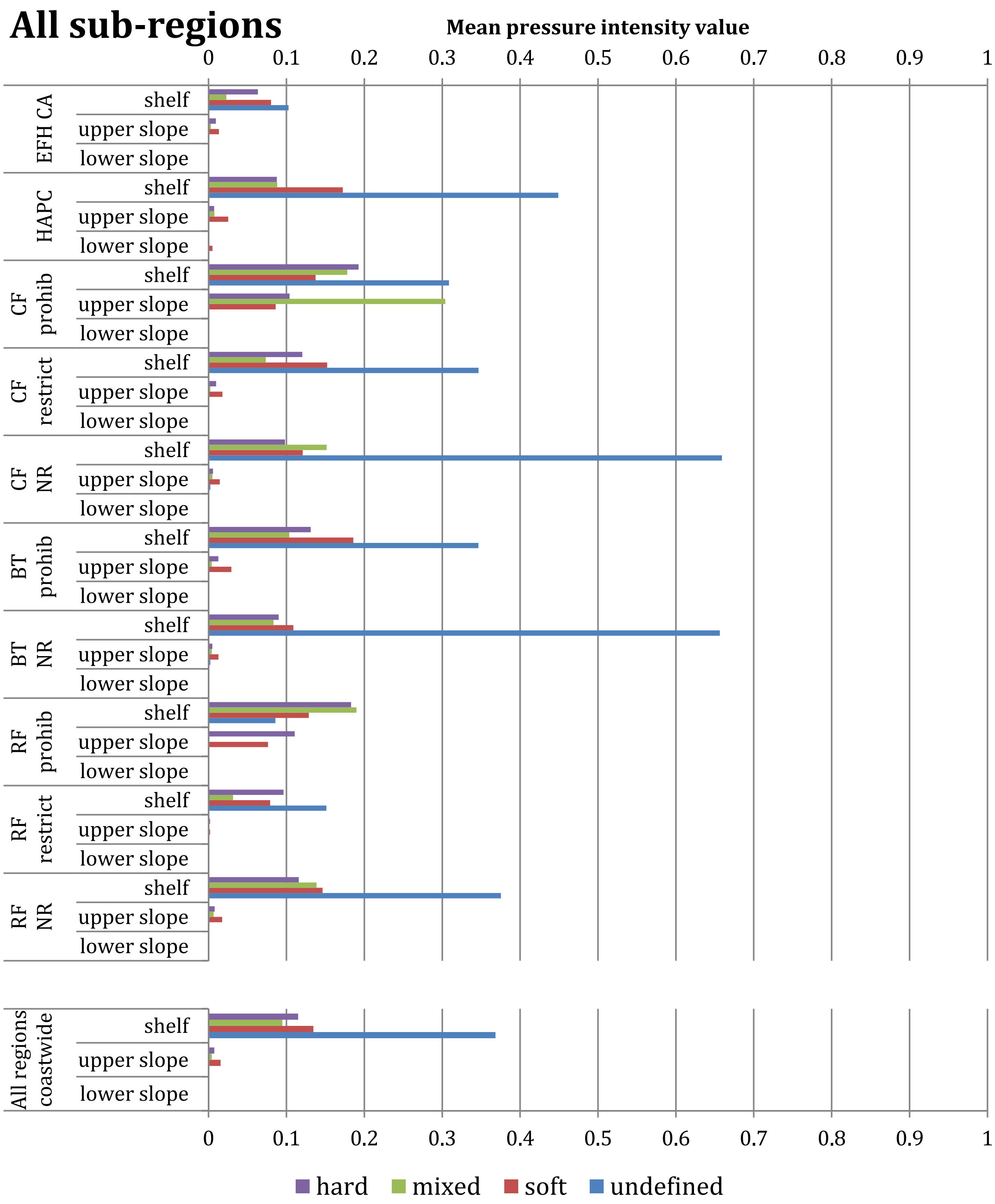


Figure A3b.27. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.25. Mean intensity values for nutrient input by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

NUTRIENT INPUT	NORTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.00	0.20	0.44	0.10	0.12	0.16	0.11	0.44	0.06	0.13	0.15
	hard	0.00	0.04	NA	0.04	0.08	0.04	0.08	NA	0.08	0.06	0.11
	mixed	0.00	0.07	NA	0.02	0.15	0.03	0.08	NA	0.01	0.11	0.09
	soft	0.01	0.21	0.44	0.11	0.11	0.18	0.10	0.44	0.07	0.12	0.13
	undefined	NA	0.78	NA	0.76	0.69	0.78	0.69	NA	0.10	0.70	0.37
Upper Slope[2]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.01
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.01
	mixed	0.00	0.01	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.02
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.08	0.44	0.00	0.06	0.00	0.05	0.44	0.05	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

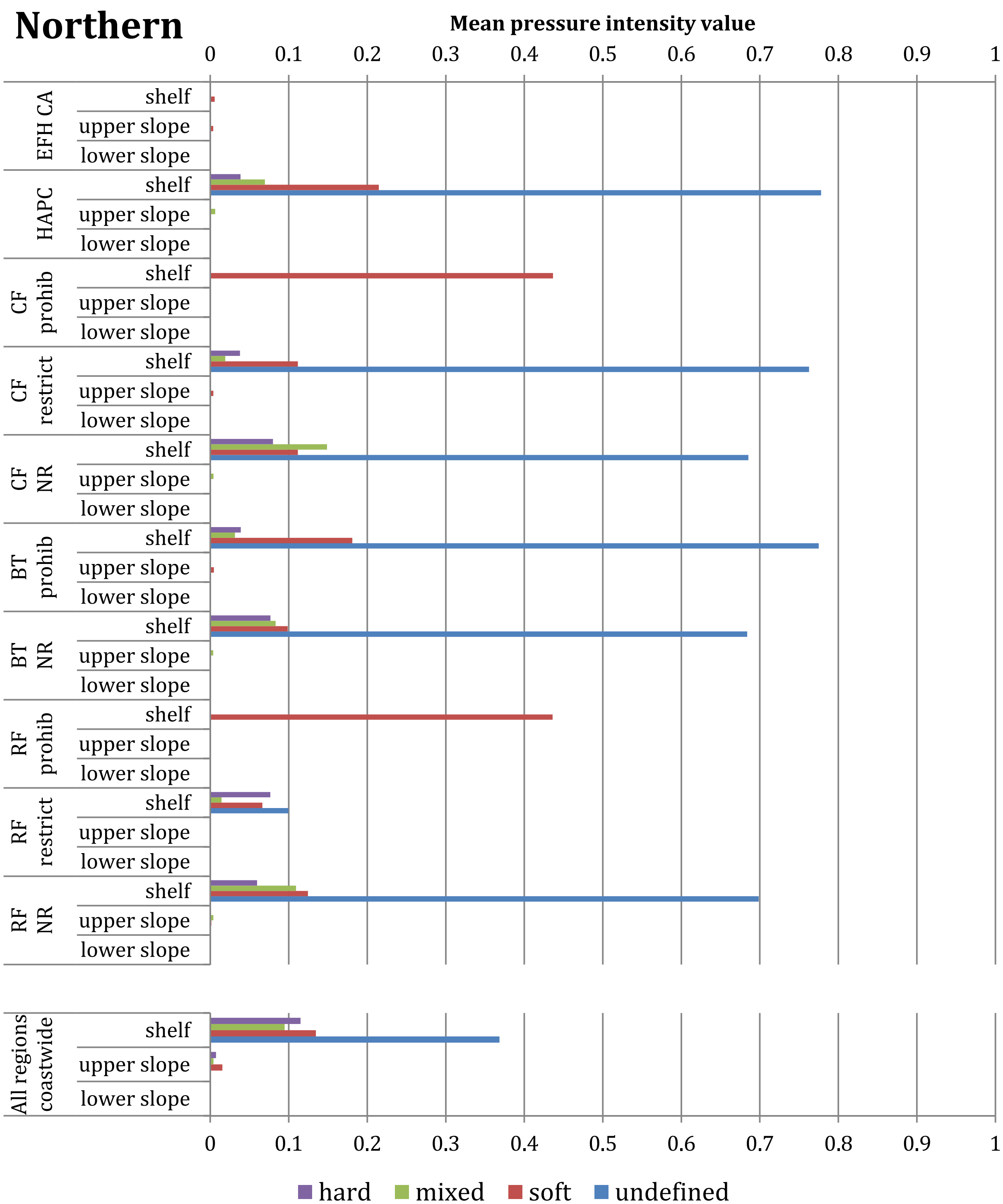


Figure A3b.28. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.26. Mean intensity values for nutrient input by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

NUTRIENT INPUT		**CENTRAL BIOGEOGRAPHIC SUB-REGION**										**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.14	0.36	0.22	0.26	0.12	0.26	0.12	0.23	0.25	0.18	0.15
	hard	0.17	0.20	0.20	0.21	0.12	0.21	0.12	0.21	0.32	0.19	0.11
	mixed	0.10	0.20	0.23	0.20	0.17	0.20	0.18	0.25	0.25	0.19	0.09
	soft	0.14	0.22	0.22	0.22	0.12	0.22	0.12	0.23	0.24	0.15	0.13
	undefined	0.19	0.60	0.38	0.59	0.46	0.59	0.45	0.03	0.27	0.59	0.37
Upper Slope[2]	All	0.02	0.03	0.09	0.03	0.01	0.03	0.01	0.08	0.24	0.01	0.01
	hard	0.01	0.01	NA	0.01	0.00	0.01	0.00	NA	0.55	0.01	0.01
	mixed	0.13	0.12	0.30	0.02	0.01	0.04	0.01	NA	NA	0.02	0.00
	soft	0.02	0.11	0.08	0.03	0.01	0.03	0.01	0.08	0.23	0.01	0.02
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.01	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.01	0.09	0.21	0.03	0.01	0.03	0.01	0.22	0.25	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

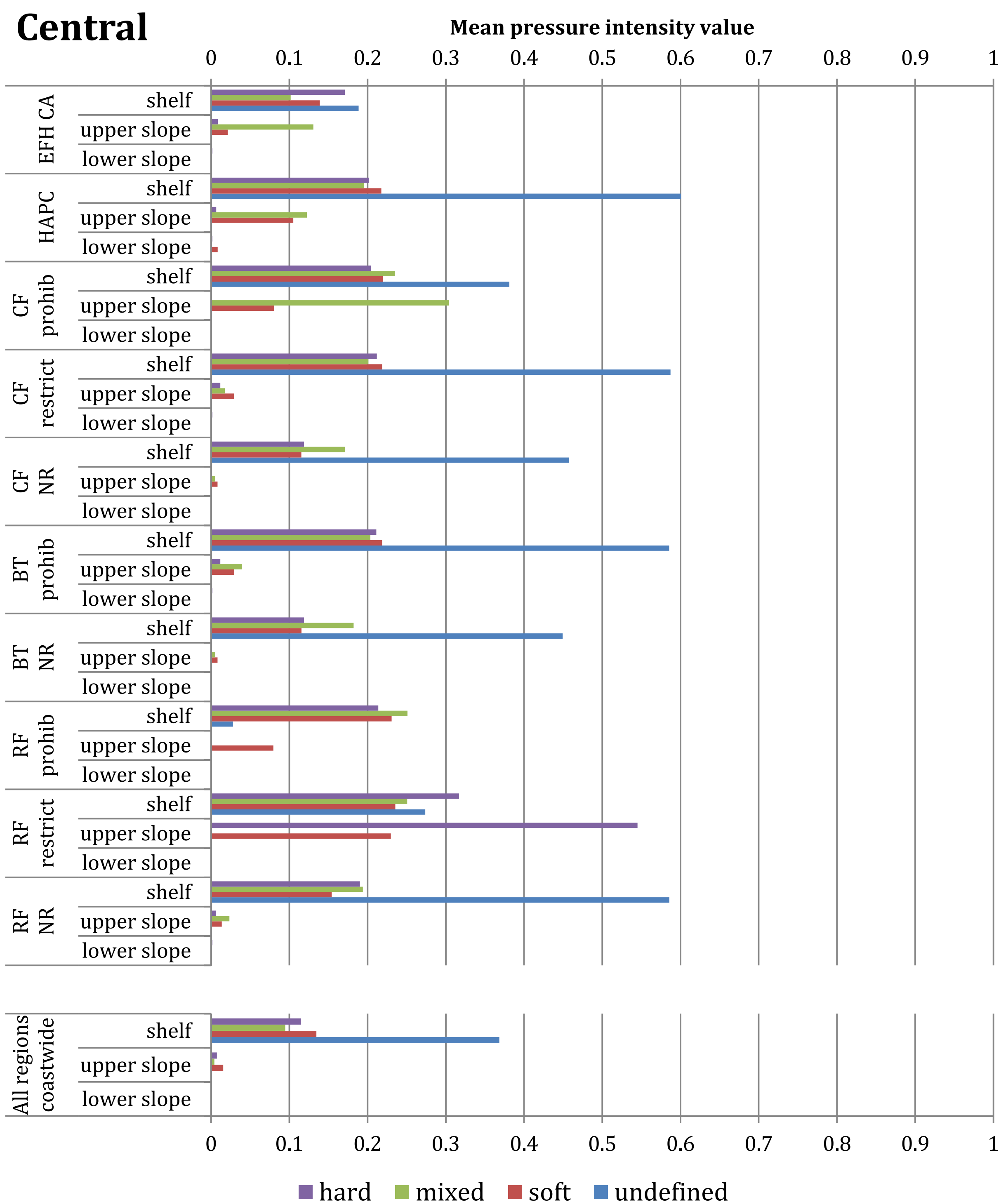


Figure A3b.29. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.27. Mean intensity values for nutrient input by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

NUTRIENT INPUT	SOUTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.03	0.06	0.09	0.15	0.29	0.16	0.22	0.07	0.04	0.22	0.15
	hard	0.01	0.10	0.18	0.10	0.31	0.13	0.17	0.14	0.02	0.19	0.11
	mixed	0.02	0.03	0.10	0.09	0.22	0.11	0.05	0.08	0.02	0.15	0.09
	soft	0.03	0.04	0.08	0.16	0.29	0.16	0.23	0.06	0.04	0.23	0.13
	undefined	0.05	0.26	0.18	0.28	0.22	0.28	0.22	0.20	0.15	0.29	0.37
Upper Slope[2]	All	0.01	0.01	0.09	0.02	0.03	0.04	0.02	0.08	0.00	0.03	0.01
	hard	0.02	0.01	0.10	0.01	0.01	0.02	0.01	0.11	0.00	0.01	0.01
	mixed	0.00	0.00	NA	0.00	0.04	0.01	0.01	NA	0.00	0.06	0.00
	soft	0.01	0.01	0.09	0.02	0.03	0.05	0.02	0.08	0.00	0.03	0.02
	undefined	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.01	0.09	0.02	0.01	0.02	0.01	0.07	0.01	0.01	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

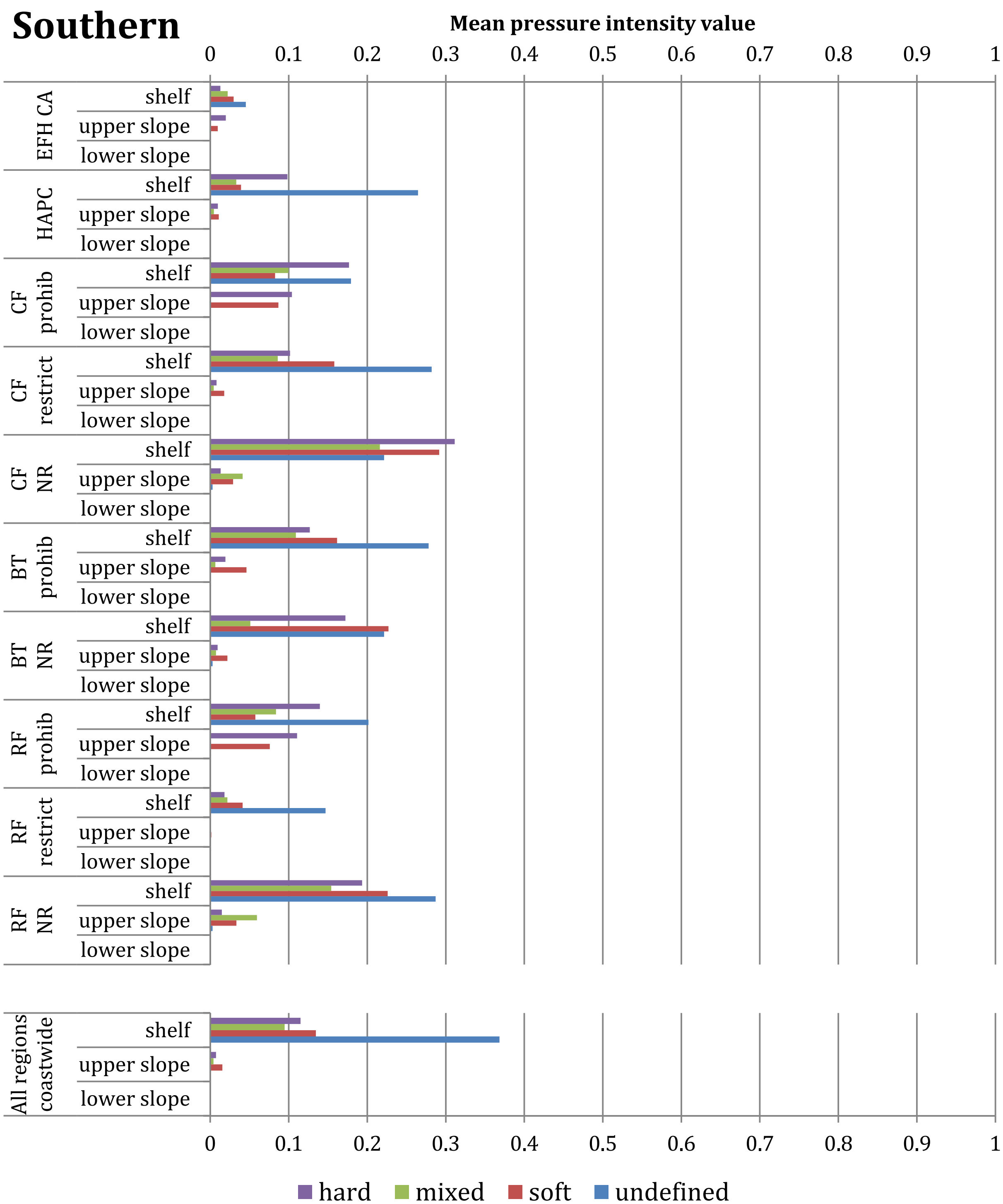


Figure A3b.30. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.28. Mean intensity values for nutrient input by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

NUTRIENT INPUT		**SALISH SEA BIOGEOGRAPHIC SUB-REGION**										**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.34	0.22	0.24	NA	0.24	NA	NA	0.16	0.26	0.15
	hard	NA	0.14	NA	0.15	NA	0.15	NA	NA	0.15	0.14	0.11
	mixed	NA	0.08	NA	0.11	NA	0.11	NA	NA	0.10	0.17	0.09
	soft	NA	0.11	NA	0.16	NA	0.16	NA	NA	0.17	0.16	0.13
	undefined	NA	0.34	0.22	0.29	NA	0.29	NA	NA	0.15	0.29	0.37
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Grand mean	All	NA	0.34	0.22	0.24	NA	0.24	NA	NA	0.16	0.26	0.01

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

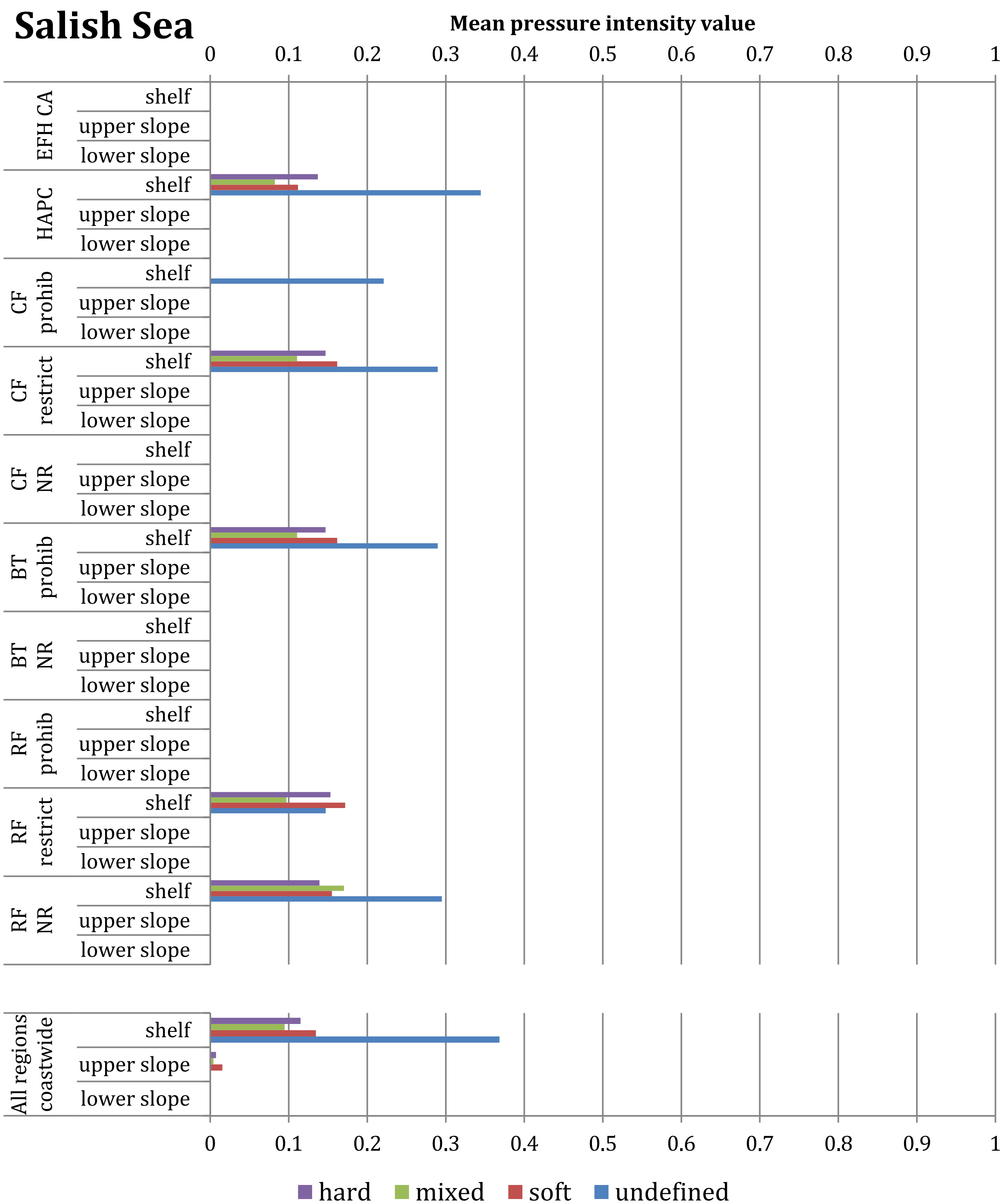


Figure A3b.31. Nutrient input. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.5 Sediment input (decreases and increases)

Sediment is a natural component in water bodies and the uses they support, but can also impair them in many ways (USEPA 1999b). Excessive sediments in waterways can cause direct physical harm to organisms (e.g. clogged gills), as well as impairment of aquatic feeding, rearing, spawning, and refuge habitats. As well, sediment deficits can result in stream channel scour and destruction of other habitat features. As a result, the federal Clean Water Act requires states, territories, and authorized tribes to identify and list impaired waters every two years and to develop total maximum daily loads (TMDLs) for sediment in these waters, with oversight from the U.S. Environmental Protection Agency. TMDLs establish the allowable pollutant loadings, thereby providing the basis for establishing water quality-based controls (USEPA 1999b).

Rivers are important conduits of large amounts of particulate and dissolved minerals and nutrients to the oceans, and play a key role in the global biogeochemical cycle (Dai et al. 2009). Humans are simultaneously increasing the river transport of sediment and dissolved constituents through soil erosion activities, and decreasing this flux to the coastal zone through sediment retention in reservoirs (Syvitski et al. 2005, Milliman et al. 2008). The net result is a global reduction in sediment flux by about 1.4 BT/year over pre-human loads. Rivers are globally getting dirtier and would otherwise move more sediment to the coast if not for the impact of reservoirs. The seasonal delivery of sediment to the coast affects the dynamics of nutrient fluxes to the coast and has serious implications to coastal fisheries, coral reefs, and seagrass communities (Syvitski et al. 2005). One example includes a reduction in natural dissolved silicate loads, which translates into silicon limitation in the coastal zone that discourages diatom blooms and favors nuisance and toxic phytoplankton, thereby compromising the integrity of coastal food webs (Vorosmarty and Sahagian 2000). Coastal retreat, which is directly influenced by the reduction of river-supplied sediment, has major implications for human habitat because >37% (2.1 billion people in 1994) of the world's population live within 100 km of a coastline (Syvitski et al. 2005). Dam removal restores the natural sediment transport regime and has become an increasingly adopted strategy to manage the environmental costs of these structures (Graf 1999, The Heinz Center 2002).

Changes in sediment supply can greatly influence the benthic environment of coastal estuaries, coral reefs, and seagrass communities, and are intimately tied to nutrient fluxes in these systems (Syvitski et al. 2005). Sediment delivery rates also affect harbor maintenance and pollutant burial or resuspension. Decreases in sediment input are largely the result of river damming or diversions, which directly influence the rate of coastal retreat. Dams affect the physical integrity of watersheds by fragmenting the lengths of rivers, changing their hydrologic characteristics, and altering their sediment regimes by trapping most of the sediment entering the reservoirs and disrupting the sediment budget of the downstream landscape (The Heinz Center 2002, Johnson et al. 2008). Because water released from dams is relatively free of sediment, downstream reaches of rivers may be altered by increased particle size, erosion, channel shrinkage, and deactivation of floodplains (The Heinz Center 2002). The consequence of reduced sediment also extends to long stretches of coastline where the erosive effect of waves is no longer sustained by sediment inputs from rivers (World Commission on Dams 2000). The effects to fishes of a reduced sediment regime would be indirect and primarily experienced through the long-term loss of soft-bottom habitat features and coastal landforms and/or changes to benthic habitat composition.

Increases in sediment input are largely due to land use practices that increase erosion rates (e.g., deforestation, wetland drainage, mining) or human activities in or near aquatic habitats (e.g., dredging) that re-suspend bottom sediments and create turbid conditions (Syvitski et al. 2005). Suspended sediments can elicit a variety of responses from aquatic biota; these responses may range from an active preference for turbid conditions, presumably to facilitate feeding and avoidance behaviors, to detrimental physical impacts that may result in egg abrasion, reduced bivalve pumping rates, and direct mortality (Wilber and Clarke 2001). Much of the available data on biological effects on organisms come from bioassays that measure acute responses and require high concentrations of suspended sediments to induce the measured response, usually mortality (Wilber and Clarke 2001). Although anadromous salmonids have received much attention, little is known of behavioral responses of many estuarine fishes to suspended sediment plumes. There is a high degree of species variability in response to sedimentation; reports of ''no effect'' were made at concentrations as great as 14,000 mg/L for durations of 3 d and more (oyster toadfish and spot) and mortality was observed at a concentration/duration combination of 580 mg/L for 1 d (Atlantic silversides). For both salmonid and estuarine fishes, the egg and larval stages are more sensitive to suspended sediment impacts than are the older life history stages.

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, sediment decrease and sediment increase data layers were calculated using a sediment release model (Syvitski et al. 2003) with the current location of dams and temperature (accounts for increases in precipitation correlated with rising temperatures). Increases in sediment occurred exclusively in watersheds without dams, while decreases in sediment occurred mostly in watersheds with dams.

Sediment runoff decrease intensity values were highest in the Salish Sea and lowest in the northern sub-region (Fig. A3b.32-33; Table A3b.29). Sediment decrease was highest in shelf habitat and was absent from all lower slope habitat (Fig. A3b.32-34, Tables A3b.29-30). Sediment runoff decrease was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.34, Table A3b.30); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.35-38, Tables A3b.31-34).

Sediment runoff increase intensity values were more evenly distributed along the West Coast than sediment runoff decreases, but the highest values were still located in the Salish Sea (Figs.

39-40, Table A3b.35). Sediment runoff increase intensity values were highest in shelf habitat, but there was some exposure to this pressure in the upper slope habitat particularly in the central and southern sub-regions, but values were still very low (Figs. 39-41, Tables A3b.35-36). Sediment runoff increase was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.41, Table A3b.36); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.42-45, Tables A3b.37-40).

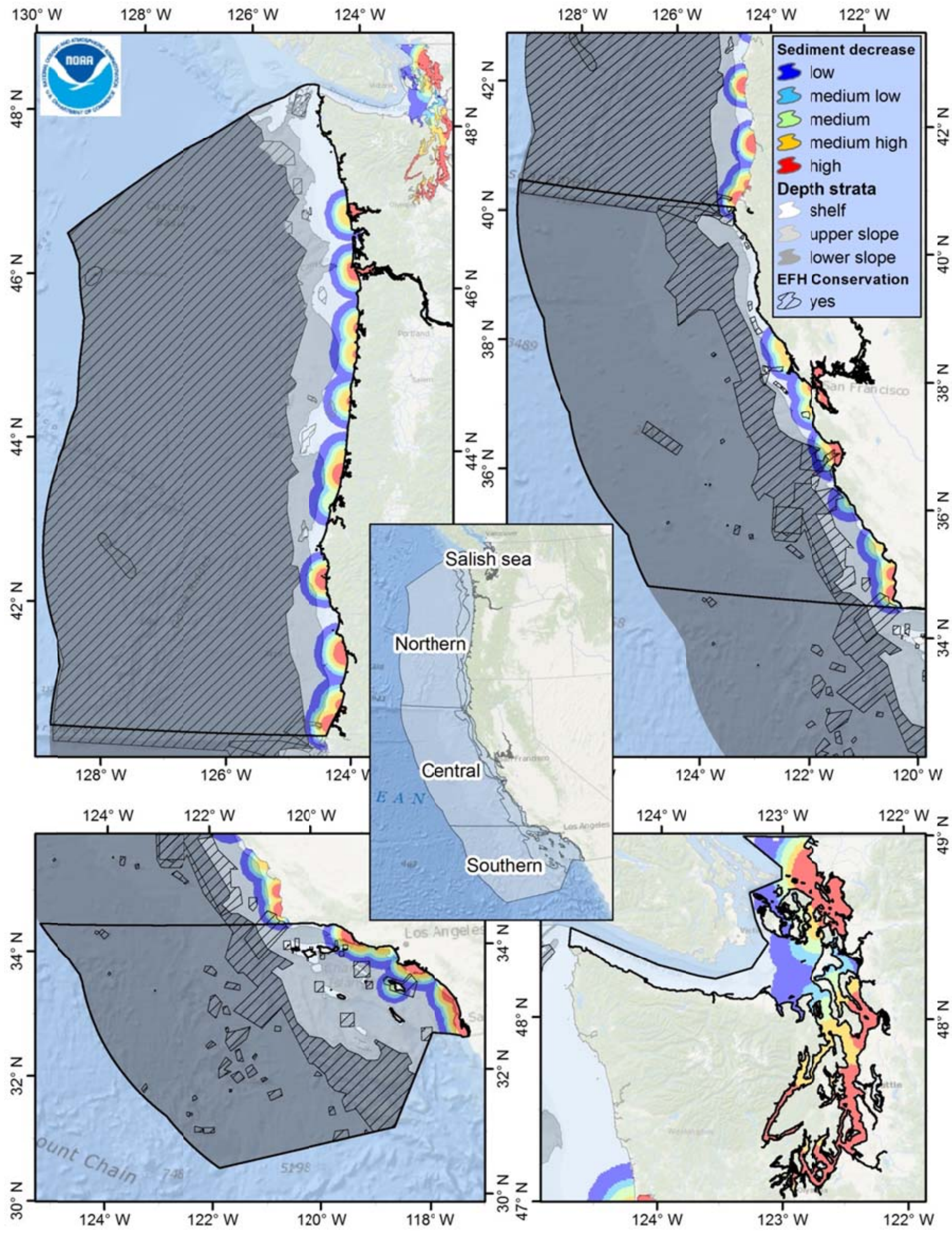


Figure A3b.32. Distribution of sediment runoff decrease intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Sediment decrease data is from Halpern et al. 2009.

Table A3b.29. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across 4 biogeographic regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from the sums of 16 pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

SEDIMENT RUNOFF DECREASE						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.16	0.25	0.24	0.32	0.21
	hard	0.06	0.27	0.20	0.10	0.14
	mixed	0.03	0.25	0.09	0.06	0.08
	soft	0.17	0.21	0.25	0.15	0.19
	undefined	0.73	0.74	0.43	0.42	0.49
Upper Slope[2]	All	0.01	0.02	0.05	NA	0.03
	hard	0.00	0.01	0.02	NA	0.01
	mixed	0.00	0.01	0.01	NA	0.00
	soft	0.01	0.03	0.05	NA	0.03
	undefined	NA	0.00	0.03	NA	0.01
Lower Slope[3]	All	0.00	0.00	0.00	NA	0.00
	hard	0.00	0.00	0.00	NA	0.00
	mixed	0.00	0.00	0.00	NA	0.00
	soft	0.00	0.00	0.00	NA	0.00
	undefined	0.00	0.00	0.00	NA	0.00
Grand mean	All	0.02	0.02	0.02	0.32	0.02

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

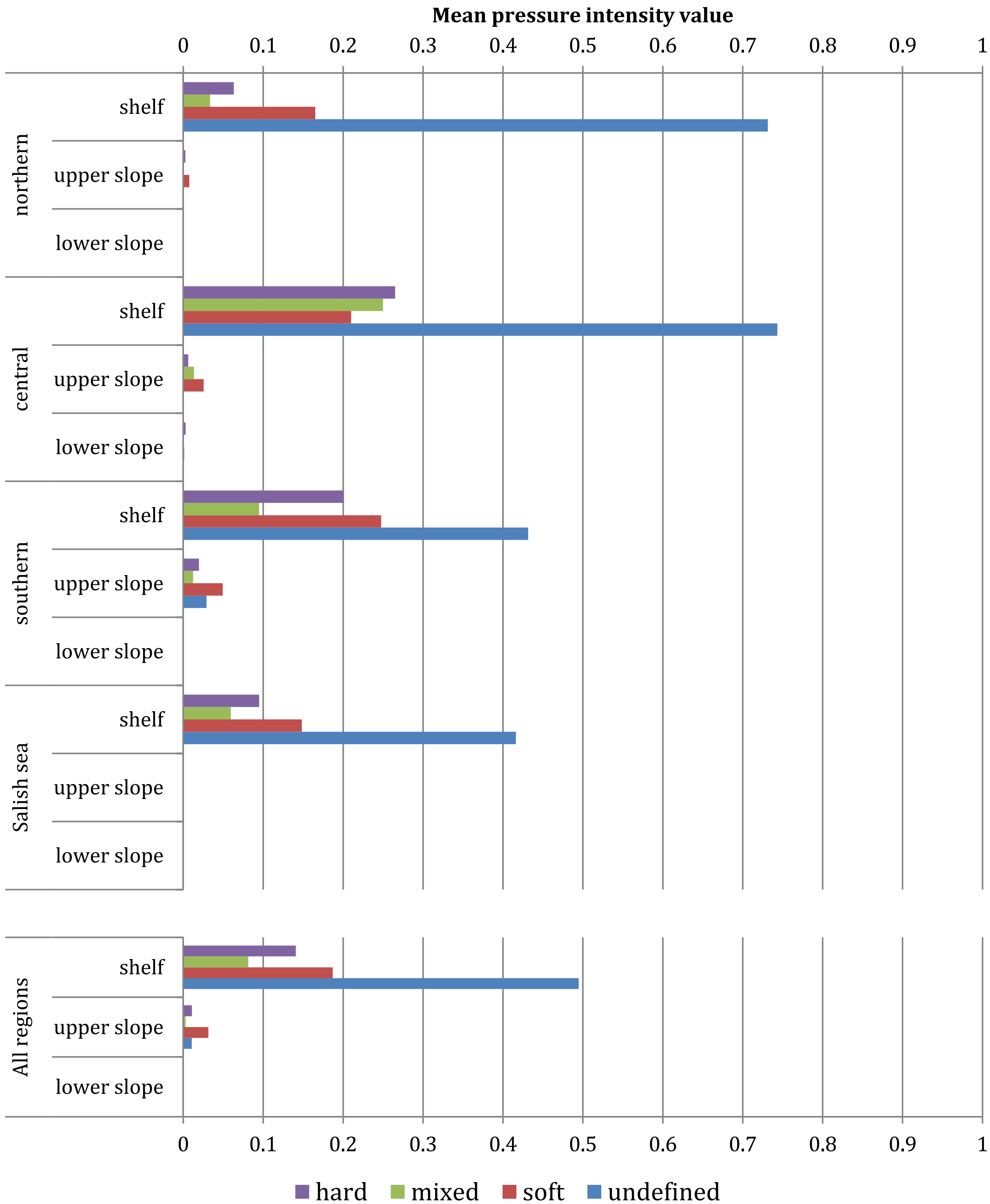


Figure A3b.33. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.30. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT RUNOFF DECREASE												
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawling*		*Recreational fishing*			*Coastwide*
Depth Zone	**Substrate**			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.10**	**0.31**	**0.17**	**0.22**	**0.20**	**0.26**	**0.18**	**0.14**	**0.07**	**0.24**	**0.21**
	hard	0.09	0.11	0.23	0.15	0.12	0.16	0.11	0.17	0.08	0.15	0.14
	mixed	0.03	0.06	0.19	0.08	0.07	0.11	0.04	0.15	0.03	0.12	0.08
	soft	0.11	0.17	0.16	0.17	0.20	0.21	0.17	0.14	0.07	0.21	0.19
	undefined	0.10	0.65	0.45	0.48	0.71	0.48	0.70	0.06	0.24	0.50	0.49
Upper Slope[2]	**All**	**0.02**	**0.02**	**0.20**	**0.03**	**0.03**	**0.05**	**0.03**	**0.18**	**0.00**	**0.03**	**0.03**
	hard	0.01	0.01	0.31	0.01	0.01	0.02	0.01	0.31	0.00	0.01	0.01
	mixed	0.00	0.00	0.18	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.02	0.03	0.20	0.03	0.03	0.06	0.03	0.18	0.00	0.04	0.03
	undefined	0.00	0.00	NA	0.00	0.02	0.00	0.02	NA	NA	0.01	0.01
Lower Slope[3]	**All**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.01	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	**All**	**0.00**	**0.10**	**0.17**	**0.02**	**0.02**	**0.02**	**0.02**	**0.15**	**0.03**	**0.02**	**0.02**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

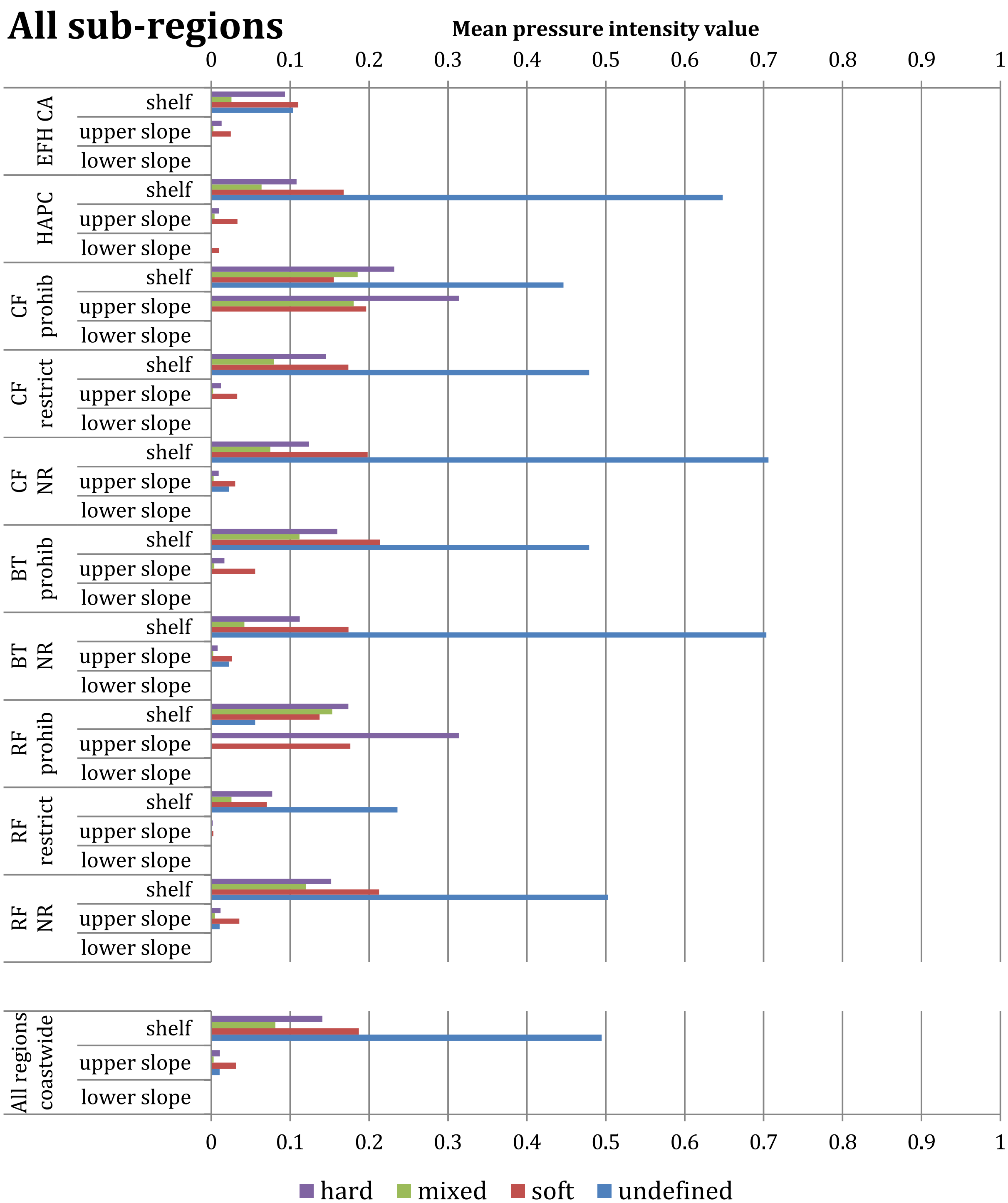


Figure A3b.34. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.31. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT DECREASE	**NORTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.01	0.16	0.68	0.11	0.19	0.17	0.16	0.68	0.04	0.20	0.21
	hard	0.01	0.03	NA	0.02	0.09	0.02	0.09	NA	0.01	0.07	0.14
	mixed	0.00	0.01	NA	0.02	0.07	0.03	0.04	NA	0.01	0.06	0.08
	soft	0.02	0.16	0.68	0.12	0.19	0.19	0.16	0.68	0.04	0.20	0.19
	undefined	NA	0.82	NA	0.77	0.73	0.79	0.73	NA	0.00	0.74	0.49
Upper Slope[2]	All	0.01	0.00	NA	0.01	0.01	0.02	0.01	NA	0.00	0.01	0.03
	hard	0.00	0.00	NA	0.01	0.00	0.01	0.00	NA	0.00	0.00	0.01
	mixed	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	soft	0.01	0.00	NA	0.02	0.01	0.02	0.01	NA	0.00	0.01	0.03
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.07	0.68	0.01	0.09	0.00	0.09	0.68	0.03	0.02	0.02

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

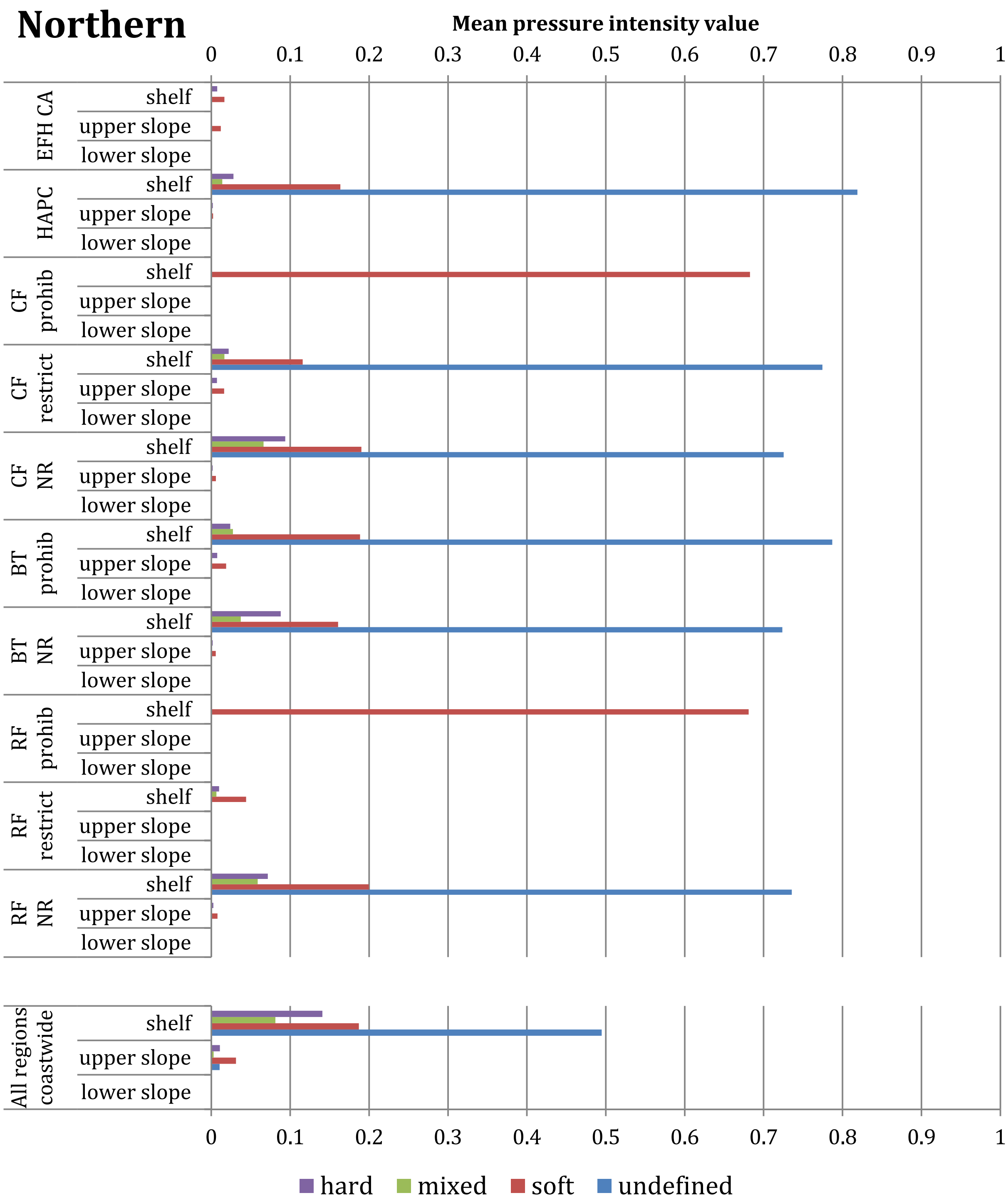


Figure A3b.35. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.32. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT DECREASE		CENTRAL BIOGEOGRAPHIC SUB-REGION										COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.18	0.47	0.25	0.33	0.17	0.32	0.17	0.25	0.29	0.24	0.21
	hard	0.24	0.29	0.22	0.28	0.18	0.28	0.18	0.17	0.38	0.26	0.14
	mixed	0.11	0.27	0.19	0.25	0.29	0.25	0.31	0.16	0.29	0.25	0.08
	soft	0.17	0.29	0.25	0.26	0.17	0.26	0.17	0.27	0.27	0.21	0.19
	undefined	0.26	0.77	0.52	0.75	0.55	0.75	0.54	0.01	0.37	0.75	0.49
Upper Slope[2]	All	0.02	0.02	0.30	0.04	0.02	0.04	0.02	0.30	0.31	0.02	0.03
	hard	0.01	0.01	NA	0.01	0.00	0.01	0.00	NA	0.69	0.01	0.01
	mixed	0.09	0.08	0.18	0.01	0.00	0.02	0.00	NA	NA	0.01	0.00
	soft	0.03	0.10	0.30	0.05	0.02	0.05	0.02	0.30	0.30	0.02	0.03
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.01
Lower Slope[3]	All	0.00	0.01	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.02	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.01	0.12	0.25	0.04	0.01	0.04	0.01	0.25	0.29	0.01	0.02

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

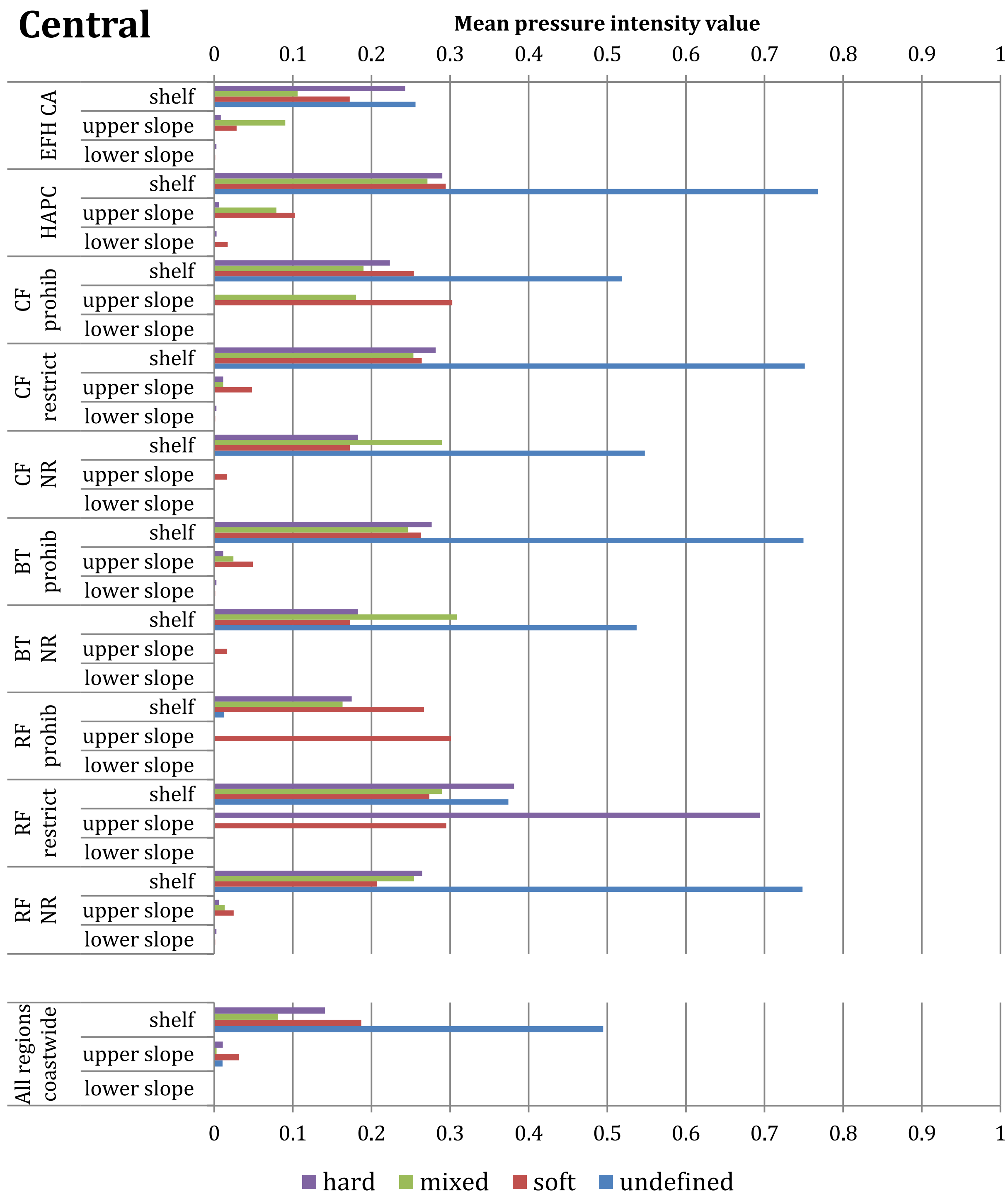


Figure A3b.36. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.33. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT DECREASE	SOUTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.06	0.09	0.10	0.20	0.47	0.21	0.35	0.06	0.04	0.32	0.21
	hard	0.01	0.14	0.24	0.15	0.44	0.19	0.24	0.17	0.02	0.29	0.14
	mixed	0.05	0.05	0.18	0.09	0.06	0.12	0.01	0.14	0.04	0.13	0.08
	soft	0.06	0.07	0.09	0.20	0.47	0.21	0.37	0.05	0.05	0.32	0.19
	undefined	0.00	0.47	0.15	0.44	0.42	0.43	0.42	0.14	0.22	0.46	0.49
Upper Slope[2]	All	0.03	0.02	0.18	0.03	0.06	0.08	0.04	0.16	0.00	0.06	0.03
	hard	0.05	0.02	0.31	0.01	0.02	0.04	0.02	0.31	0.00	0.03	0.01
	mixed	0.00	0.01	NA	0.01	0.10	0.01	0.02	NA	0.00	0.11	0.00
	soft	0.03	0.02	0.18	0.03	0.06	0.09	0.04	0.16	0.00	0.07	0.03
	undefined	NA	NA	NA	0.00	0.03	0.00	0.03	NA	NA	0.03	0.01
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.02	0.12	0.03	0.01	0.03	0.01	0.08	0.01	0.02	0.02

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

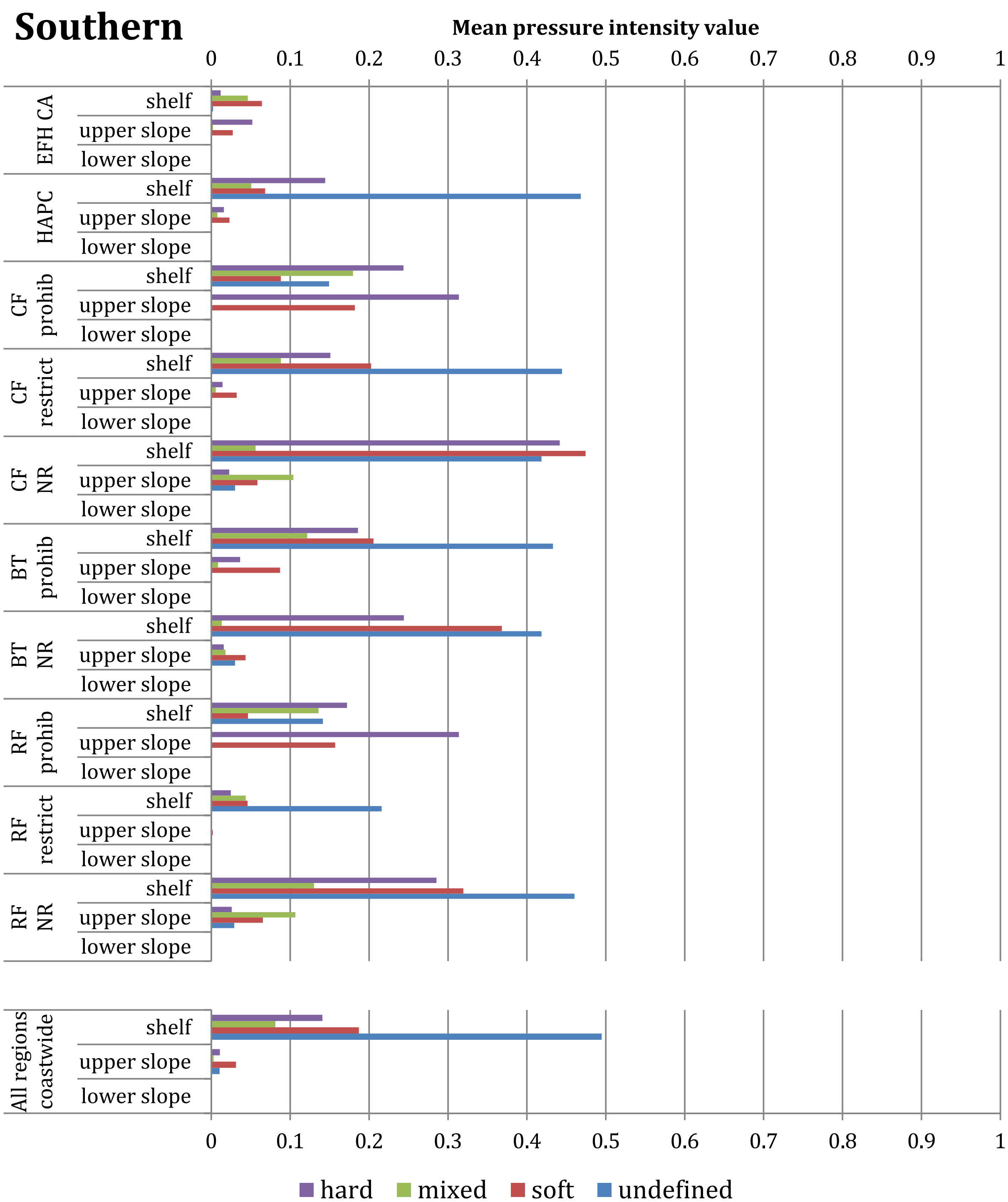


Figure A3b.37. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.34. Mean intensity values for sediment runoff decrease by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT DECREASE	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.57	0.53	0.32	NA	0.32	NA	NA	0.22	0.34	0.21
	hard	NA	0.00	NA	0.10	NA	0.10	NA	NA	0.17	0.00	0.14
	mixed	NA	0.00	NA	0.06	NA	0.06	NA	NA	0.06	0.05	0.08
	soft	NA	0.12	NA	0.15	NA	0.15	NA	NA	0.23	0.09	0.19
	undefined	NA	0.58	0.53	0.42	NA	0.42	NA	NA	0.23	0.42	0.49
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.03
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.03
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Grand mean	All	NA	0.57	0.53	0.32	NA	0.32	NA	NA	0.22	0.34	0.02

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

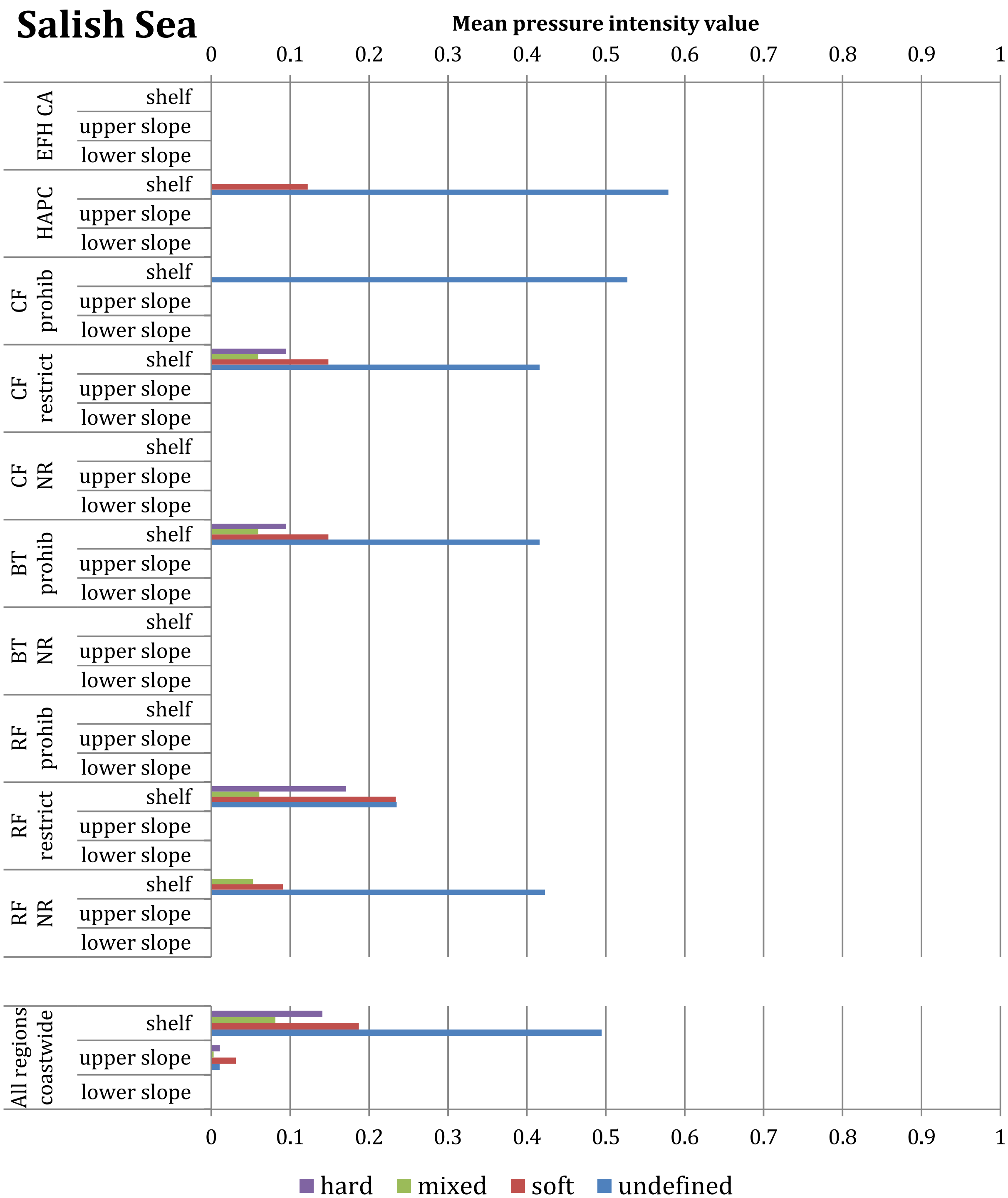


Figure A3b.38. Sediment runoff decrease. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

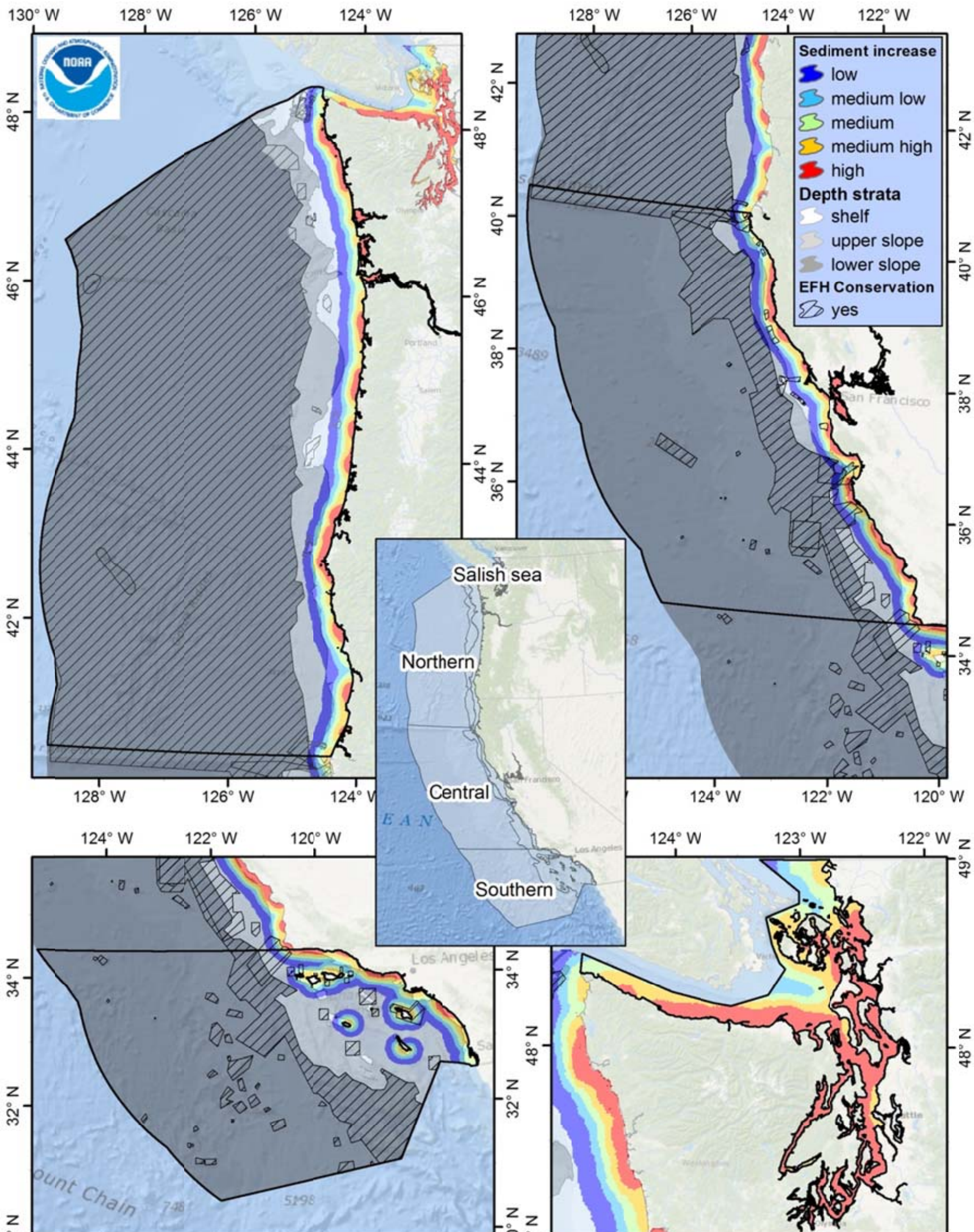


Figure A3b.39. Distribution of sediment runoff increase intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Sediment increase data is from Halpern et al. 2009.

Table A3b.35. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

SEDIMENT RUNOFF INCREASE						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.31	0.53	0.47	0.68	0.42
	hard	0.19	0.60	0.35	0.68	0.35
	mixed	0.21	0.63	0.38	0.52	0.33
	soft	0.31	0.50	0.48	0.65	0.40
	undefined	0.71	0.87	0.50	0.70	0.72
Upper Slope[2]	All	0.01	0.10	0.09	NA	0.07
	hard	0.00	0.02	0.07	NA	0.04
	mixed	0.02	0.10	0.03	NA	0.02
	soft	0.01	0.11	0.09	NA	0.07
	undefined	NA	0.00	0.03	NA	0.01
Lower Slope[3]	All	0.00	0.00	0.00	NA	0.00
	hard	0.00	0.00	0.00	NA	0.00
	mixed	0.00	0.01	0.00	NA	0.00
	soft	0.00	0.00	0.00	NA	0.00
	undefined	0.00	0.00	0.00	NA	0.00
Grand mean	All	0.03	0.04	0.04	0.68	0.04

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

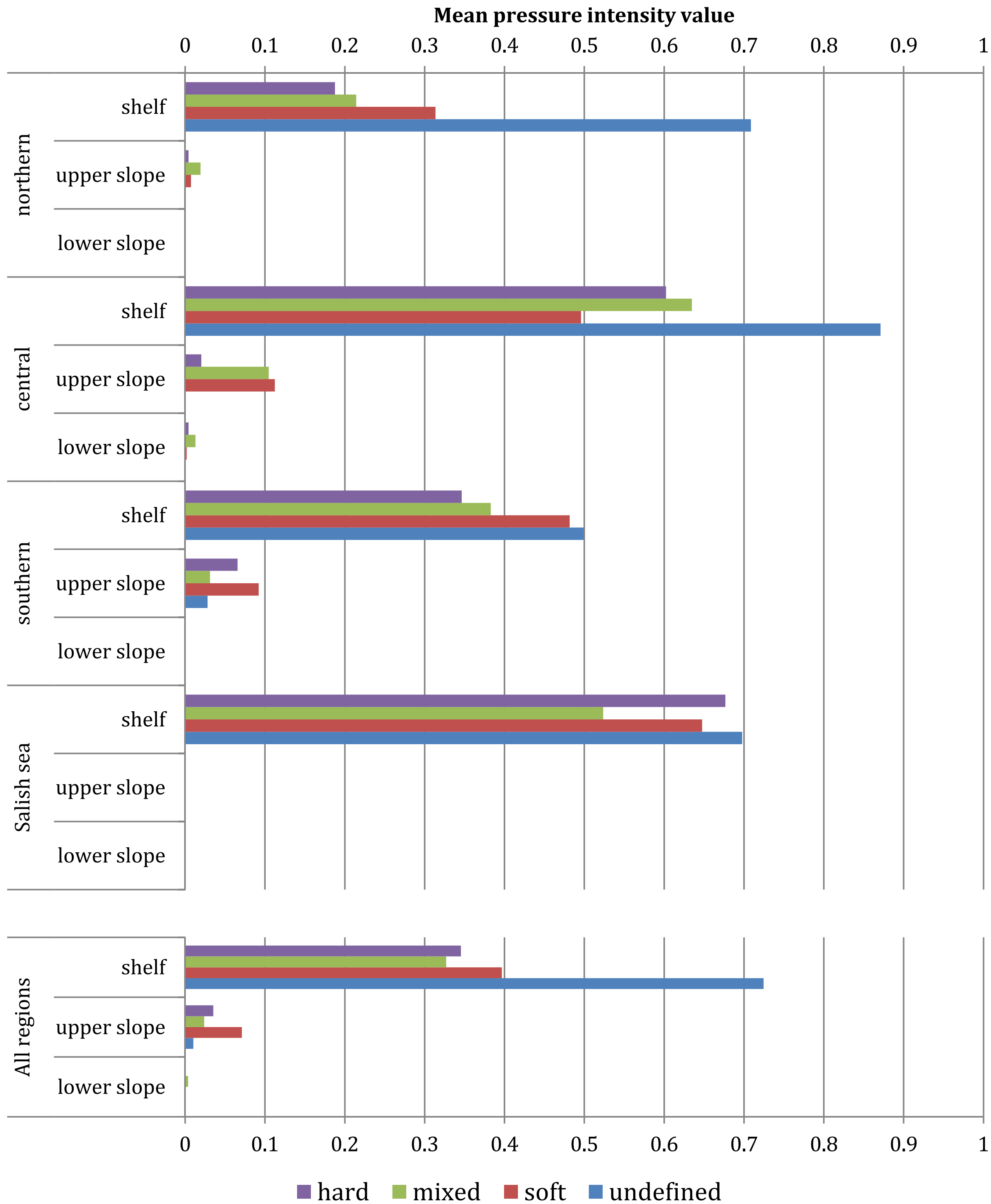


Figure A3b.40. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.36. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT RUNOFF INCREASE												
		EFH CA	***HAPC***	***Commercial fishing***			***Bottom trawling***		***Recreational fishing***			***Coastwide***
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.25**	**0.56**	**0.50**	**0.49**	**0.35**	**0.57**	**0.32**	**0.49**	**0.29**	**0.45**	**0.42**
	hard	0.16	0.26	0.56	0.39	0.26	0.42	0.24	0.55	0.36	0.33	0.35
	mixed	0.08	0.30	0.64	0.26	0.50	0.36	0.28	0.68	0.14	0.45	0.33
	soft	0.30	0.52	0.49	0.45	0.35	0.55	0.32	0.47	0.30	0.42	0.40
	undefined	0.42	0.82	0.68	0.73	0.69	0.73	0.69	0.47	0.51	0.73	0.72
Upper Slope[2]	**All**	**0.08**	**0.06**	**0.45**	**0.08**	**0.06**	**0.12**	**0.06**	**0.45**	**0.02**	**0.08**	**0.07**
	hard	0.04	0.03	0.68	0.05	0.02	0.06	0.02	0.70	0.01	0.04	0.04
	mixed	0.02	0.04	0.90	0.02	0.03	0.03	0.02	NA	0.01	0.03	0.02
	soft	0.08	0.11	0.44	0.09	0.06	0.13	0.06	0.44	0.02	0.08	0.07
	undefined	0.00	0.00	NA	0.00	0.02	0.00	0.02	NA	NA	0.01	0.01
Lower Slope[3]	**All**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**	**0.00**	**NA**	**0.00**	**0.00**	**0.00**
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.01	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.02	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	**All**	**0.01**	**0.19**	**0.49**	**0.04**	**0.04**	**0.04**	**0.04**	**0.48**	**0.14**	**0.04**	**0.04**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

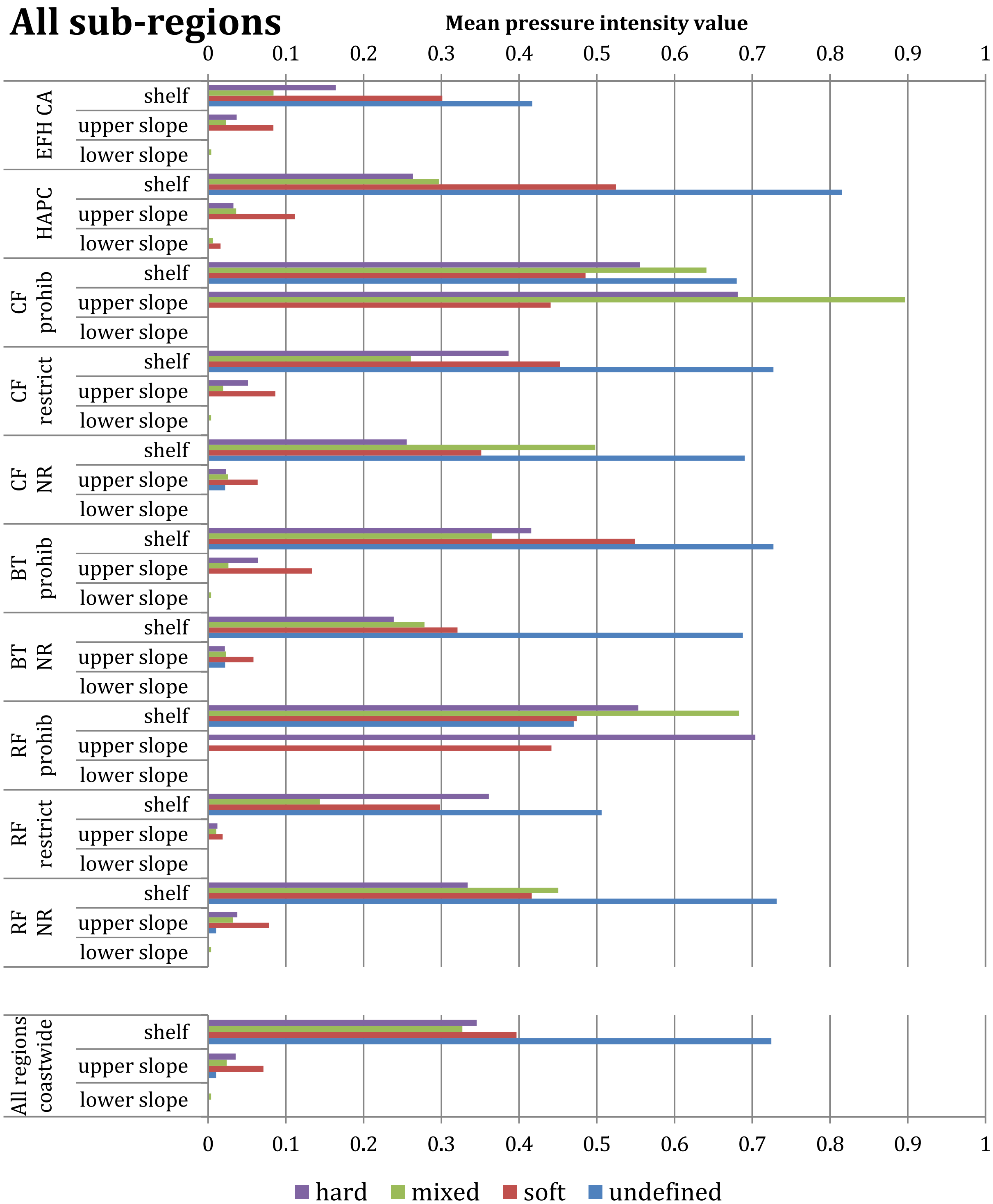


Figure A3b.41. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.37. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT INCREASE	NORTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.01	0.49	0.82	0.29	0.32	0.42	0.29	0.83	0.25	0.33	0.42
	hard	0.01	0.14	NA	0.16	0.21	0.16	0.21	NA	0.39	0.16	0.35
	mixed	0.00	0.26	NA	0.08	0.48	0.12	0.28	NA	0.07	0.35	0.33
	soft	0.03	0.65	0.82	0.31	0.31	0.47	0.28	0.83	0.25	0.33	0.40
	undefined	NA	0.79	NA	0.72	0.71	0.73	0.71	NA	0.50	0.71	0.72
Upper Slope[2]	All	0.01	0.01	NA	0.02	0.01	0.02	0.01	NA	0.01	0.01	0.07
	hard	0.00	0.00	NA	0.01	0.00	0.01	0.00	NA	0.03	0.00	0.04
	mixed	0.02	0.03	NA	0.01	0.02	0.01	0.02	NA	0.02	0.02	0.02
	soft	0.01	0.01	NA	0.02	0.01	0.02	0.01	NA	0.00	0.01	0.07
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.00	0.21	0.82	0.01	0.15	0.01	0.15	0.83	0.21	0.03	0.04

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

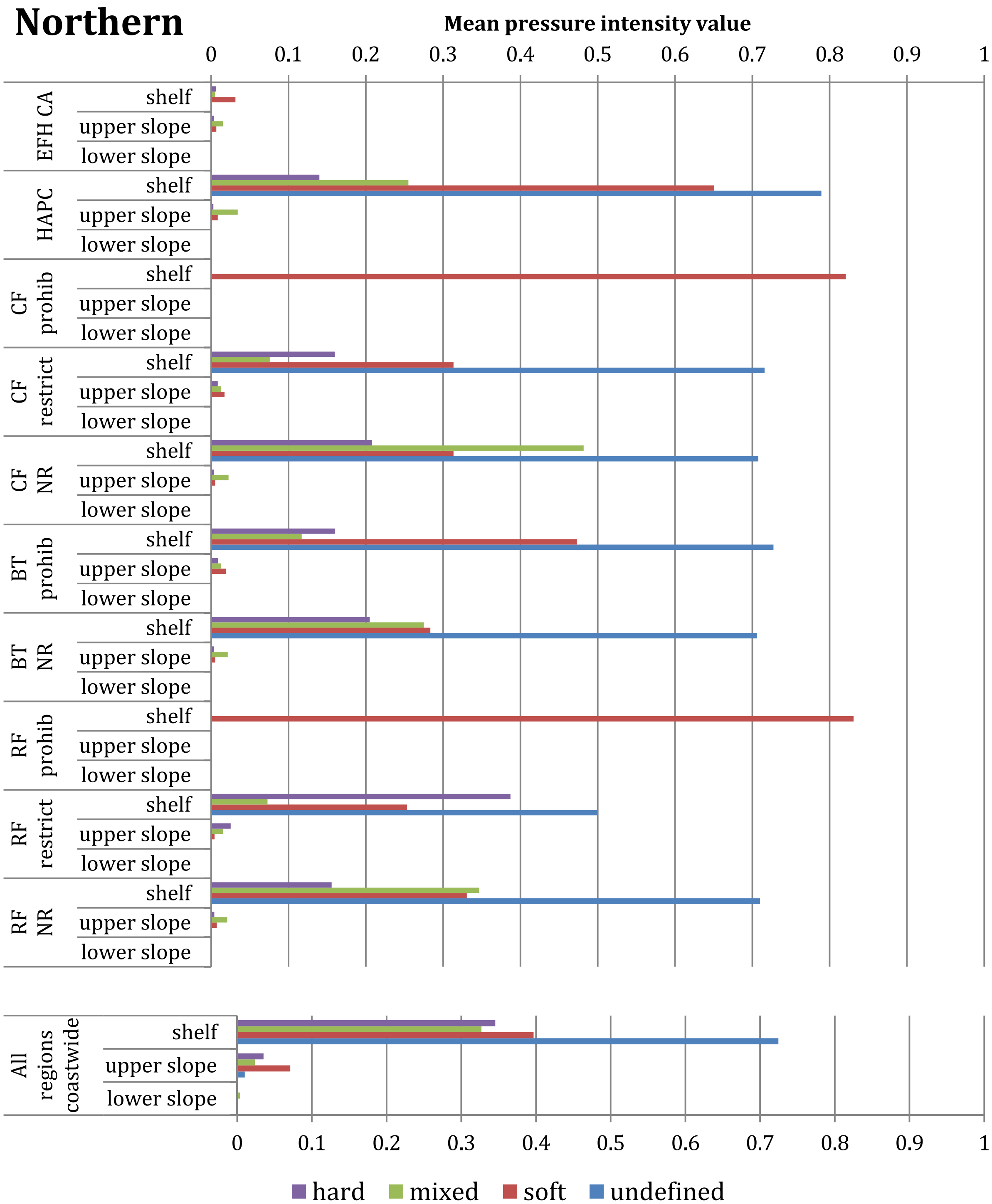


Figure A3b.42. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.38. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT INCREASE	CENTRAL BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		Efh Ca	*Hapc*	*Commercial Fishing*			*Bottom Trawl*		*Recreational Fishing*			*All*
Depth Zone	Substrate			Prohib	Restr	NR	Prohib	NR	Prohib	Restr	NR	
Shelf[1]	All	0.40	0.65	0.65	0.65	0.41	0.65	0.41	0.66	0.65	0.52	0.42
	hard	0.41	0.54	0.64	0.61	0.52	0.61	0.52	0.67	0.74	0.59	0.35
	mixed	0.34	0.50	0.81	0.62	0.65	0.63	0.66	0.84	0.77	0.61	0.33
	soft	0.40	0.48	0.64	0.62	0.41	0.62	0.41	0.65	0.64	0.49	0.40
	undefined	0.39	0.90	0.73	0.88	0.59	0.88	0.58	0.33	0.54	0.88	0.72
Upper Slope[2]	All	0.08	0.07	0.62	0.12	0.09	0.12	0.09	0.60	0.69	0.10	0.07
	hard	0.02	0.02	NA	0.03	0.01	0.03	0.01	NA	0.50	0.02	0.04
	mixed	0.39	0.43	0.90	0.09	0.05	0.15	0.05	NA	NA	0.10	0.02
	soft	0.10	0.30	0.60	0.15	0.10	0.15	0.10	0.60	0.70	0.11	0.07
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.01
Lower Slope[3]	All	0.00	0.01	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	hard	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	mixed	0.01	0.02	NA	0.01	NA	0.01	NA	NA	NA	0.01	0.00
	soft	0.00	0.03	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.02	0.18	0.65	0.08	0.02	0.08	0.02	0.65	0.66	0.04	0.04

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

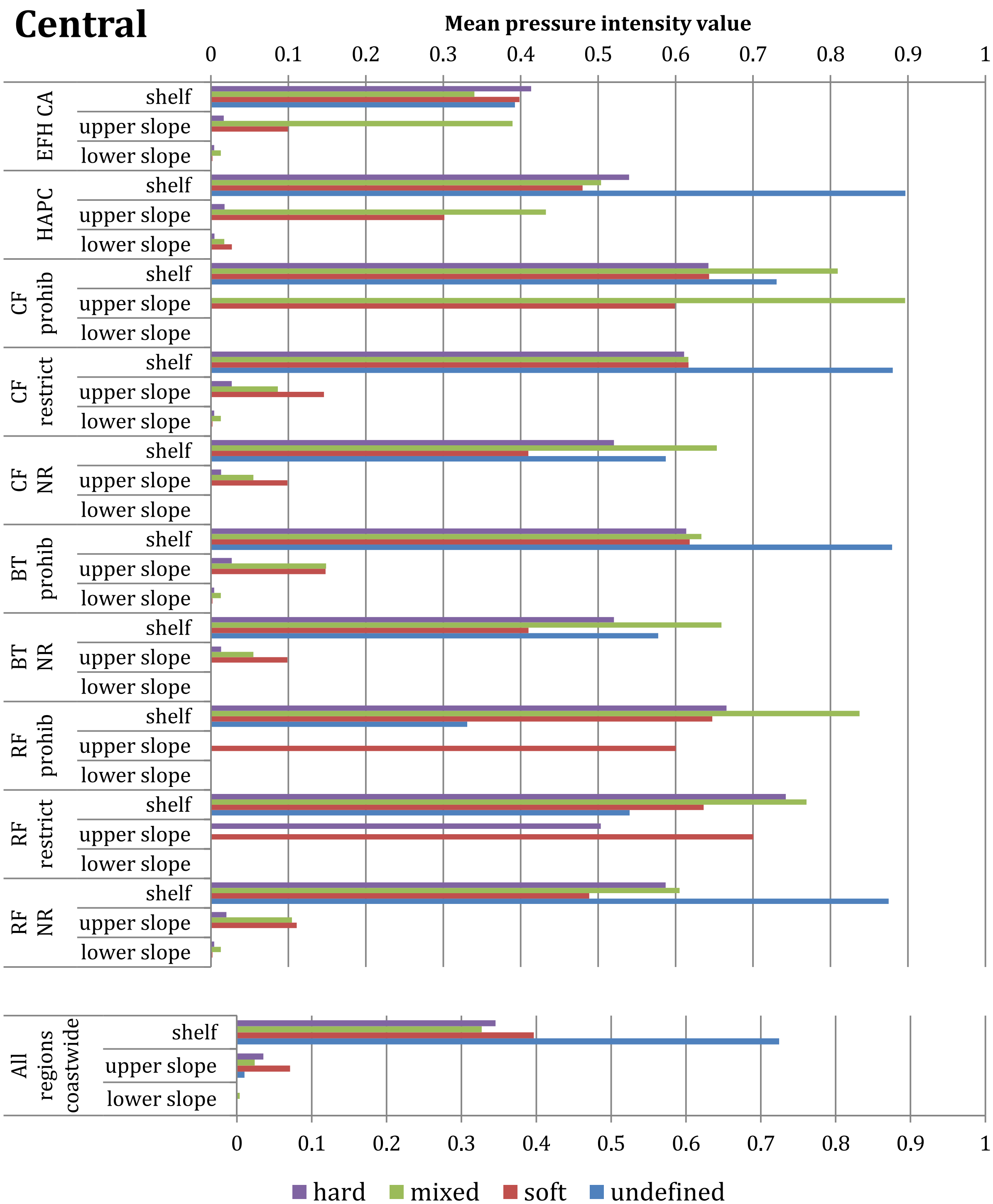


Figure A3b.43. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the “Central” biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.39. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT INCREASE	SOUTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.27	0.27	0.39	0.46	0.54	0.49	0.41	0.36	0.24	0.55	0.42
	hard	0.12	0.28	0.44	0.31	0.50	0.37	0.28	0.39	0.07	0.47	0.35
	mixed	0.13	0.17	0.41	0.35	0.80	0.45	0.19	0.42	0.12	0.59	0.33
	soft	0.29	0.28	0.38	0.48	0.54	0.50	0.43	0.35	0.26	0.55	0.40
	undefined	0.43	0.43	0.59	0.52	0.32	0.52	0.32	0.75	0.49	0.50	0.72
Upper Slope[2]	All	0.11	0.07	0.43	0.09	0.09	0.20	0.07	0.42	0.02	0.11	0.07
	hard	0.19	0.06	0.68	0.09	0.05	0.20	0.04	0.70	0.01	0.08	0.04
	mixed	0.02	0.02	NA	0.02	0.13	0.03	0.03	NA	0.00	0.26	0.02
	soft	0.11	0.09	0.42	0.09	0.09	0.20	0.08	0.42	0.02	0.12	0.07
	undefined	NA	NA	NA	0.00	0.03	0.00	0.03	NA	NA	0.03	0.01
Lower Slope[3]	All	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	hard	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	mixed	0.00	0.00	NA	0.00	NA	0.00	NA	NA	NA	0.00	0.00
	soft	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
	undefined	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
Grand mean	All	0.02	0.06	0.40	0.07	0.02	0.08	0.02	0.38	0.04	0.03	0.04

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

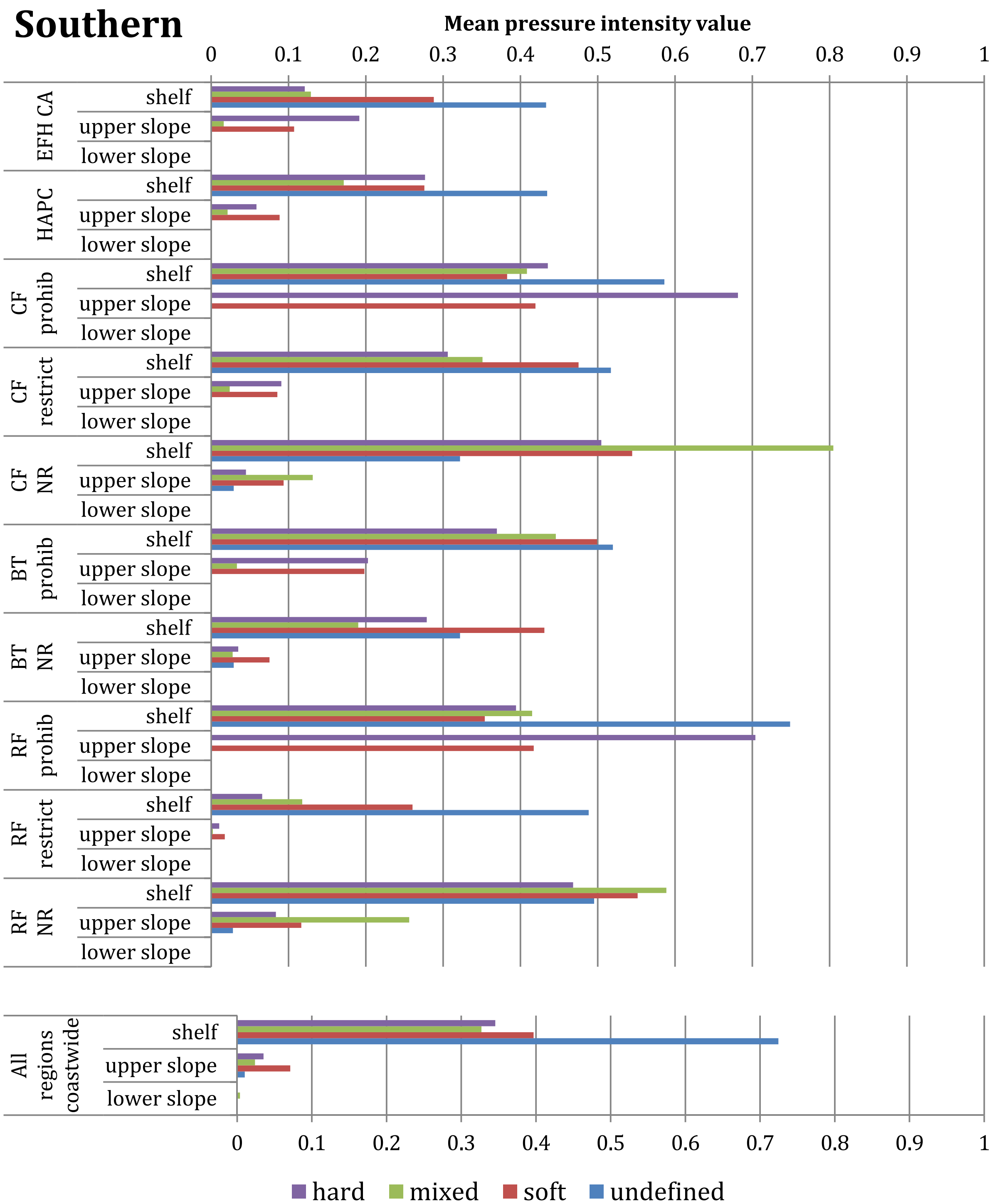


Figure A3b.44. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.40. Mean intensity values for sediment runoff increase by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

SEDIMENT INCREASE	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.79	0.62	0.68	NA	0.68	NA	NA	0.56	0.70	0.42
	hard	NA	0.79	NA	0.67	NA	0.67	NA	NA	0.59	0.79	0.35
	mixed	NA	0.57	NA	0.52	NA	0.52	NA	NA	0.49	0.68	0.33
	soft	NA	0.68	NA	0.65	NA	0.65	NA	NA	0.57	0.70	0.40
	undefined	NA	0.79	0.62	0.70	NA	0.70	NA	NA	0.51	0.70	0.72
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.07
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.04
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.07
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Grand mean	All	NA	0.79	0.62	0.68	NA	0.68	NA	NA	0.56	0.70	0.04

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

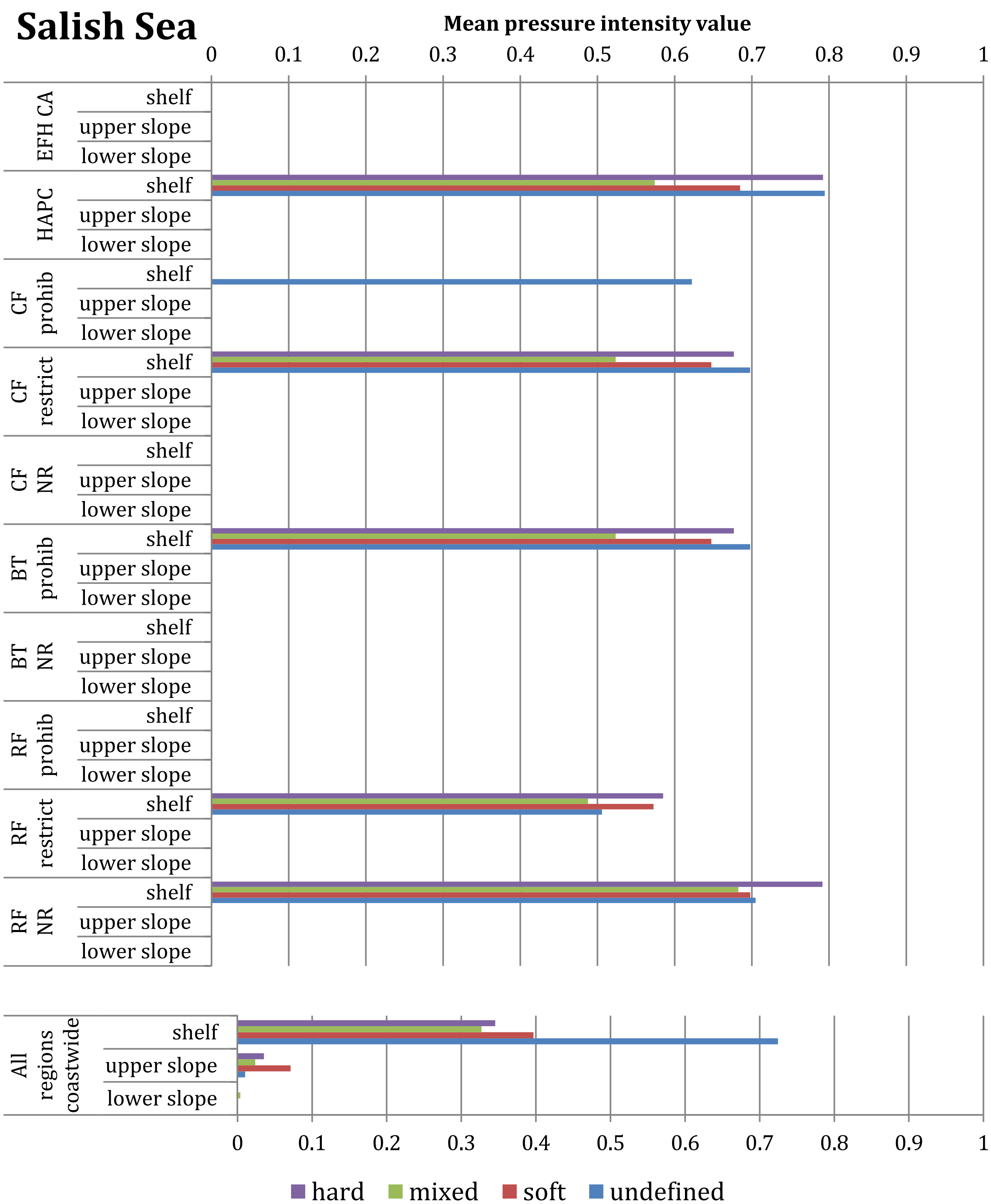


Figure A3b.45. Sediment runoff increase. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.6 Ocean-based pollution

The impact of ocean-based pollution is wide-spread as we include pollution from sea-going vessels and activity within ports throughout the California Current. Marine ports in the United States are major industrial centers providing jobs and steady revenue streams yet contributing significantly to pollution. Ships with huge engines running on bunker fuel without emission controls, thousands of diesel trucks per day, diesel locomotives, and other polluting equipment and activities at modern seaports cause an array of environmental impacts that can seriously affect local communities and marine and land-based ecosystems throughout a region (Bailey and Solomon 2004). As vessels transit within ports, along the coast, and along international shipping lanes, there are inevitable discharges of waste, leaks of oil and gas, loss of cargo during rough seas, and increased risk of oil spills from oil shipping vessels. Beaches close in proximity to oil shipping lanes have been observed to have high tar content related to the degree of oil pollution in the sea (Golik 1982).

The effects of oil pollution on components of the CCLME are both direct and indirect. Because seabirds and marine mammals require direct contact with the sea surface, these taxa experience high risk from floating oil (Loughlin 1994). Oiled seabirds and marine mammals lose the insulating capacity of their feathers and fur which can lead to death from hypothermia (Peterson et al. 2003). Chronic exposure to partially weathered oil is toxic to eggs of pink salmon *Oncorhynchus gorbuscha* and herring *Clupea pallasii* (Marty et al. 1997, Heintz et al. 2000). Many effects of exposure to oil and the associated polycyclic aromatic hydrocarbons (PAHs) are sublethal and have lasting effects on individual survival which may scale up to population-level responses. For example, embryos of zebrafish *Danio rerio* exposed to PAHs showed delayed changes in heart shape and reduced cardiac output (Hicken et al. 2011). Strandings of oiled seabirds have been used as an indicator of chronic oil pollution along heavily used shipping lanes in the North Sea and recent studies show declining oil-rates reflecting reduced oil spills(Camphuysen 1998, Camphuysen 2010).

In addition to the potential for pollution, other common impacts of vessel activities include vessel wake generation, anchor chain and propeller scour, vessel groundings, the introduction of invasive or nonnative species, and the discharge of contaminants and debris.

For specific details on the creation of each pressure data layer, see Halpern et al. (2008, 2009). Briefly, the ocean-based pollution data layer was calculated using vessel tracking data (from the World Meteorological Organization Voluntary Observing Ships Scheme and regional ferries) and port volume (proxy for the likelihood of pollutants in nearshore waters). These values were normalized and combined to develop a single layer for ocean-based pollution.

Ocean-based pollution intensity values were highest in the Salish Sea and lowest in the northern sub-region (Figs. A3b.46-47; Table A3b.41). Ocean-based pollution was highest in shelf habitat, most likely due to the influence of pollutants from ports on nearshore habitats (Figs. A3b.46-48, Tables A3b.41-42). Ocean-based pollution was generally higher in HAPCs and in areas prohibited to commercial and recreational fishing (Fig. A3b.48, Table A3b.42); however, this was likely because these management areas were in nearshore habitats that were more exposed to land-based pressures and had little to do with EFH-related management boundaries. These coastwide patterns were generally reflected within each biogeographic sub-region (Figs. A3b.49-52, Tables A3b.43-46).

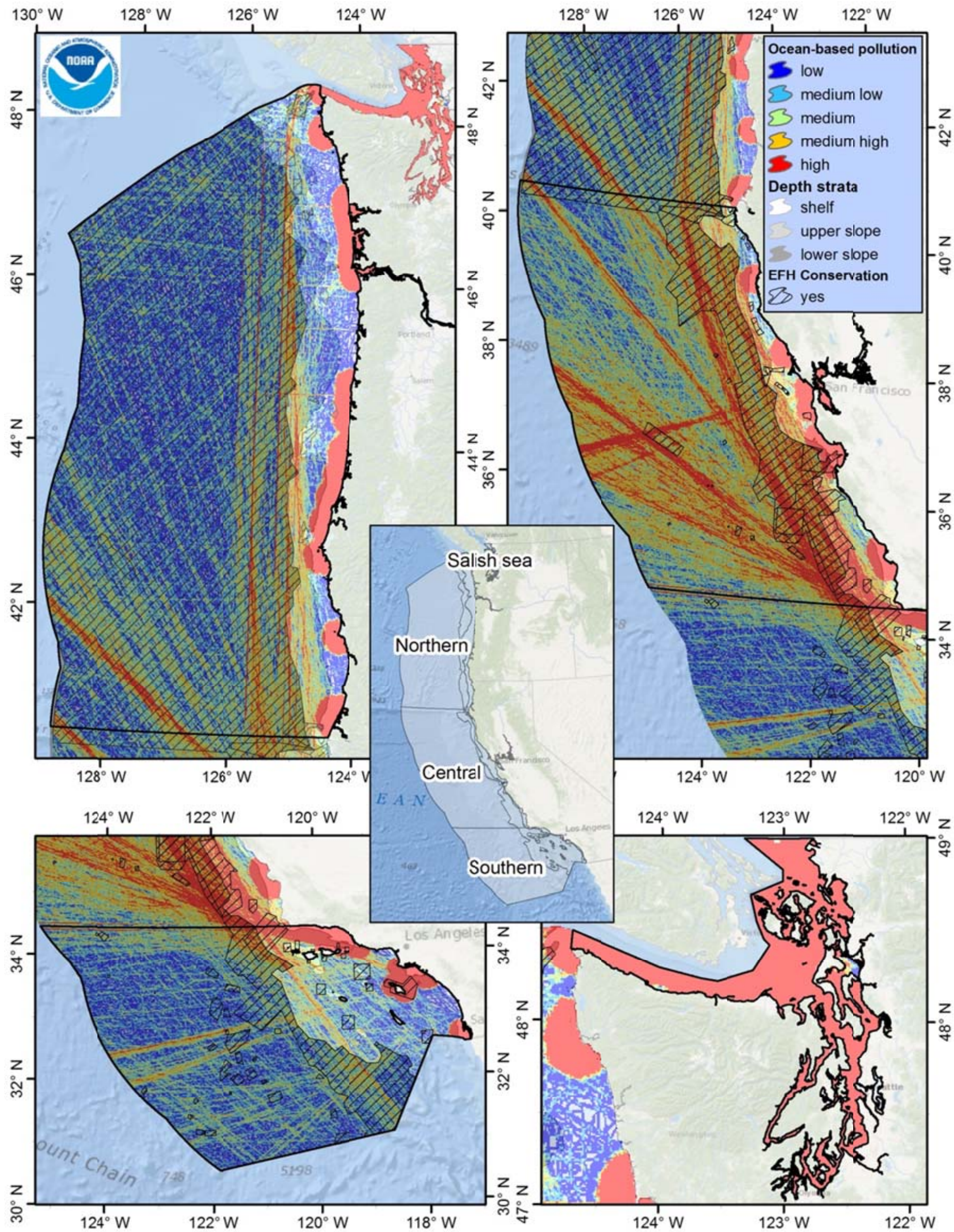


Figure A3b.46. Distribution of ocean-based pollution intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Ocean-based pollution data is from Halpern et al. 2009.

Table A3b.41. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across 4 biogeographic regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

OCEAN-BASED POLLUTION						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	0.23	0.31	0.32	0.55	0.29
	hard	0.16	0.35	0.28	0.50	0.25
	mixed	0.23	0.32	0.33	0.61	0.28
	soft	0.23	0.28	0.32	0.54	0.26
	undefined	0.58	0.68	0.36	0.56	0.58
Upper Slope[2]	All	0.11	0.17	0.14	NA	0.14
	hard	0.12	0.17	0.13	NA	0.15
	mixed	0.12	0.18	0.09	NA	0.12
	soft	0.11	0.17	0.14	NA	0.14
	undefined	NA	0.15	0.11	NA	0.13
Lower Slope[3]	All	0.09	0.13	0.09	NA	0.10
	hard	0.12	0.15	0.09	NA	0.11
	mixed	0.15	0.17	0.10	NA	0.12
	soft	0.11	0.15	0.11	NA	0.12
	undefined	0.08	0.13	0.08	NA	0.10
Grand mean	All	0.11	0.14	0.11	0.55	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

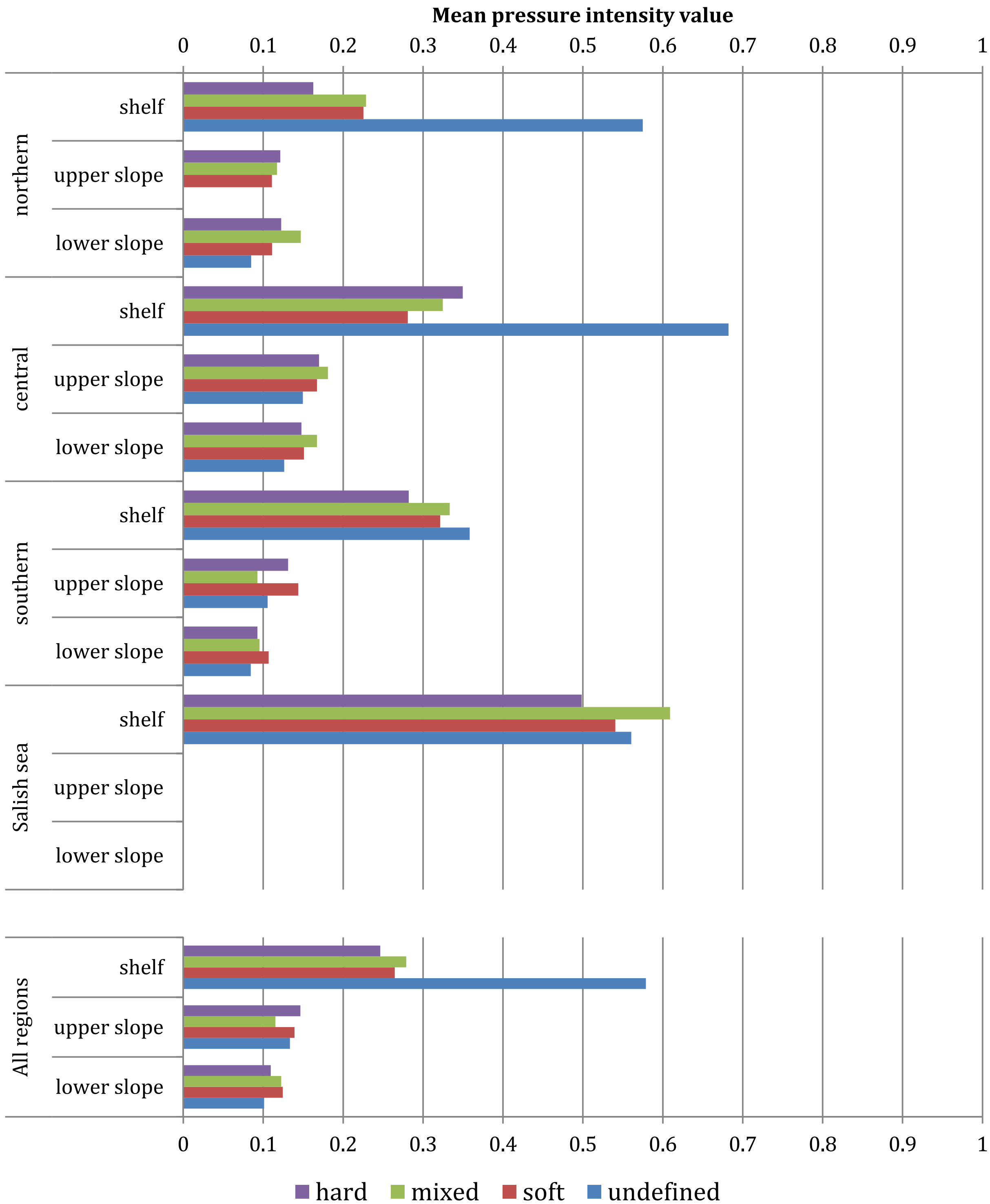


Figure A3b.47. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.42. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

OCEAN-BASED POLLUTION												
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawling*		*Recreational fishing*			*Coastwide*
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**0.20**	**0.41**	**0.23**	**0.33**	**0.26**	**0.37**	**0.24**	**0.23**	**0.20**	**0.31**	**0.29**
	hard	0.19	0.21	0.27	0.27	0.21	0.28	0.20	0.30	0.26	0.24	0.25
	mixed	0.14	0.27	0.25	0.25	0.38	0.29	0.26	0.30	0.22	0.33	0.28
	soft	0.21	0.35	0.22	0.28	0.25	0.32	0.23	0.22	0.19	0.28	0.26
	undefined	0.29	0.61	0.43	0.58	0.55	0.58	0.55	0.16	0.50	0.58	0.58
Upper Slope[2]	**All**	**0.17**	**0.15**	**0.29**	**0.15**	**0.14**	**0.18**	**0.13**	**0.29**	**0.09**	**0.15**	**0.14**
	hard	0.18	0.15	0.09	0.16	0.14	0.18	0.13	0.09	0.10	0.15	0.15
	mixed	0.11	0.13	0.47	0.11	0.12	0.12	0.12		0.11	0.12	0.12
	soft	0.17	0.16	0.29	0.15	0.14	0.18	0.13	0.29	0.09	0.15	0.14
	undefined	0.15	0.15		0.15	0.12	0.15	0.12			0.13	0.13
Lower Slope[3]	**All**	**0.10**	**0.12**		**0.10**	**0.11**	**0.10**	**0.11**		**0.10**	**0.10**	**0.10**
	hard	0.11	0.11		0.11	0.12	0.11	0.12		0.09	0.11	0.11
	mixed	0.12	0.12		0.12		0.12				0.12	0.12
	soft	0.13	0.15		0.13	0.11	0.13	0.11		0.11	0.12	0.12
	undefined	0.09	0.12		0.09	0.11	0.09	0.11			0.10	0.10
Grand mean	All	0.10	0.22	0.24	0.12	0.12	0.12	0.12	0.24	0.14	0.12	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

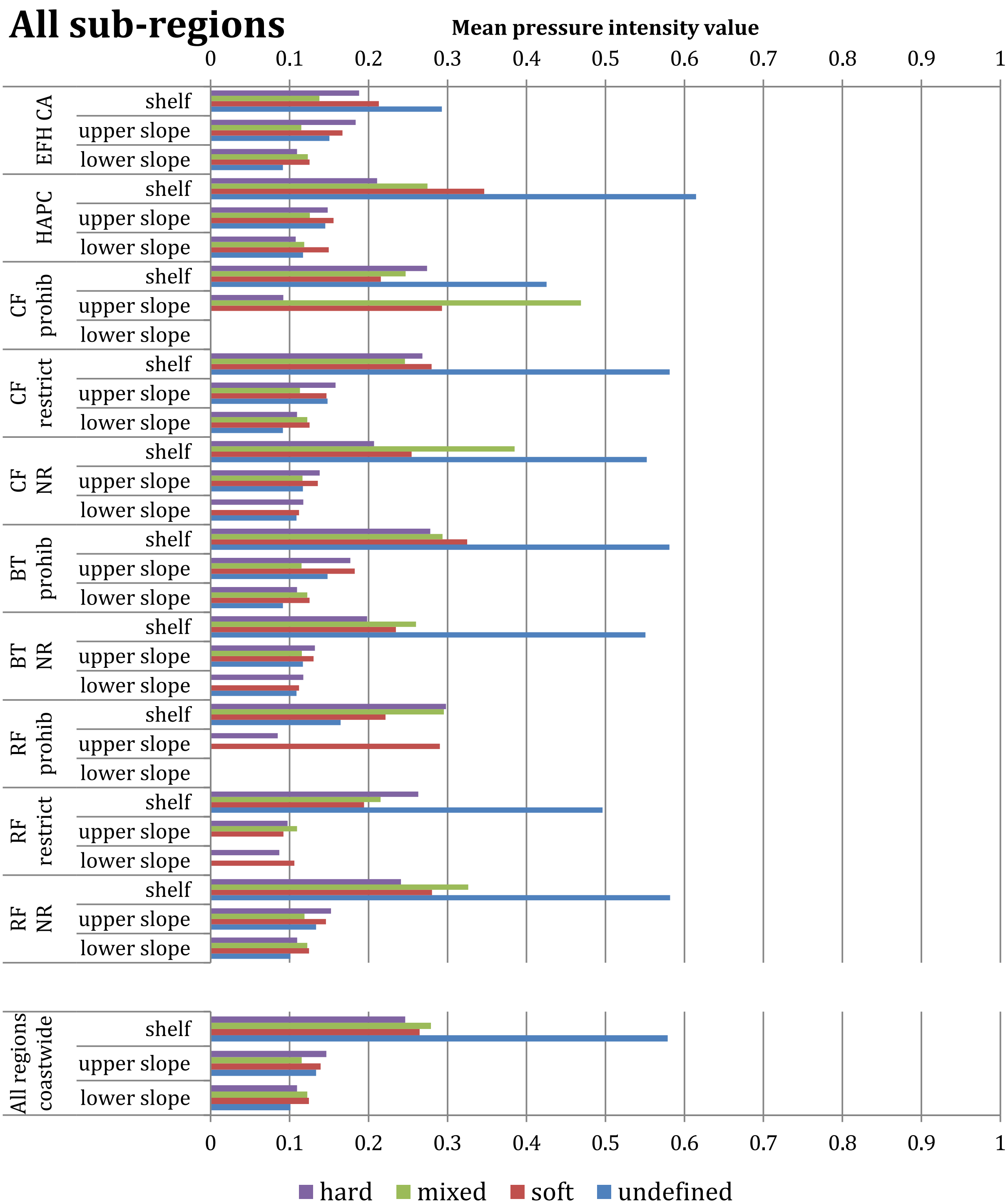


Figure A3b.48. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.43. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

OCEAN-BASED POLLUTION		NORTHERN BIOGEOGRAPHIC SUB-REGION										COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.11	0.34	0.60	0.20	0.24	0.27	0.22	0.62	0.15	0.25	0.29
	hard	0.10	0.15	NA	0.15	0.17	0.15	0.17	NA	0.20	0.16	0.25
	mixed	0.11	0.27	NA	0.15	0.37	0.18	0.26	NA	0.16	0.29	0.28
	soft	0.12	0.40	0.60	0.21	0.23	0.29	0.21	0.62	0.15	0.25	0.26
	undefined	NA	0.64	NA	0.66	0.56	0.67	0.56	NA	0.35	0.58	0.58
Upper Slope[2]	All	0.11	0.13	NA	0.11	0.11	0.11	0.11	NA	0.10	0.11	0.14
	hard	0.13	0.12	NA	0.13	0.12	0.13	0.12	NA	0.12	0.12	0.15
	mixed	0.12	0.14	NA	0.12	0.11	0.12	0.12	NA	0.13	0.11	0.12
	soft	0.11	0.13	NA	0.11	0.11	0.11	0.11	NA	0.09	0.11	0.14
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.13
Lower Slope[3]	All	0.09	0.11	NA	0.09	0.10	0.09	0.10	NA	NA	0.09	0.10
	hard	0.12	0.12	NA	0.12	0.13	0.12	0.13	NA	NA	0.12	0.11
	mixed	0.15	0.15	NA	0.15	NA	0.15	NA	NA	NA	0.15	0.12
	soft	0.11	0.12	NA	0.11	0.12	0.11	0.12	NA	NA	0.11	0.12
	undefined	0.08	0.09	NA	0.08	0.09	0.08	0.09	NA	NA	0.08	0.10
Grand mean	All	0.09	0.21	0.60	0.09	0.17	0.09	0.17	0.62	0.14	0.10	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

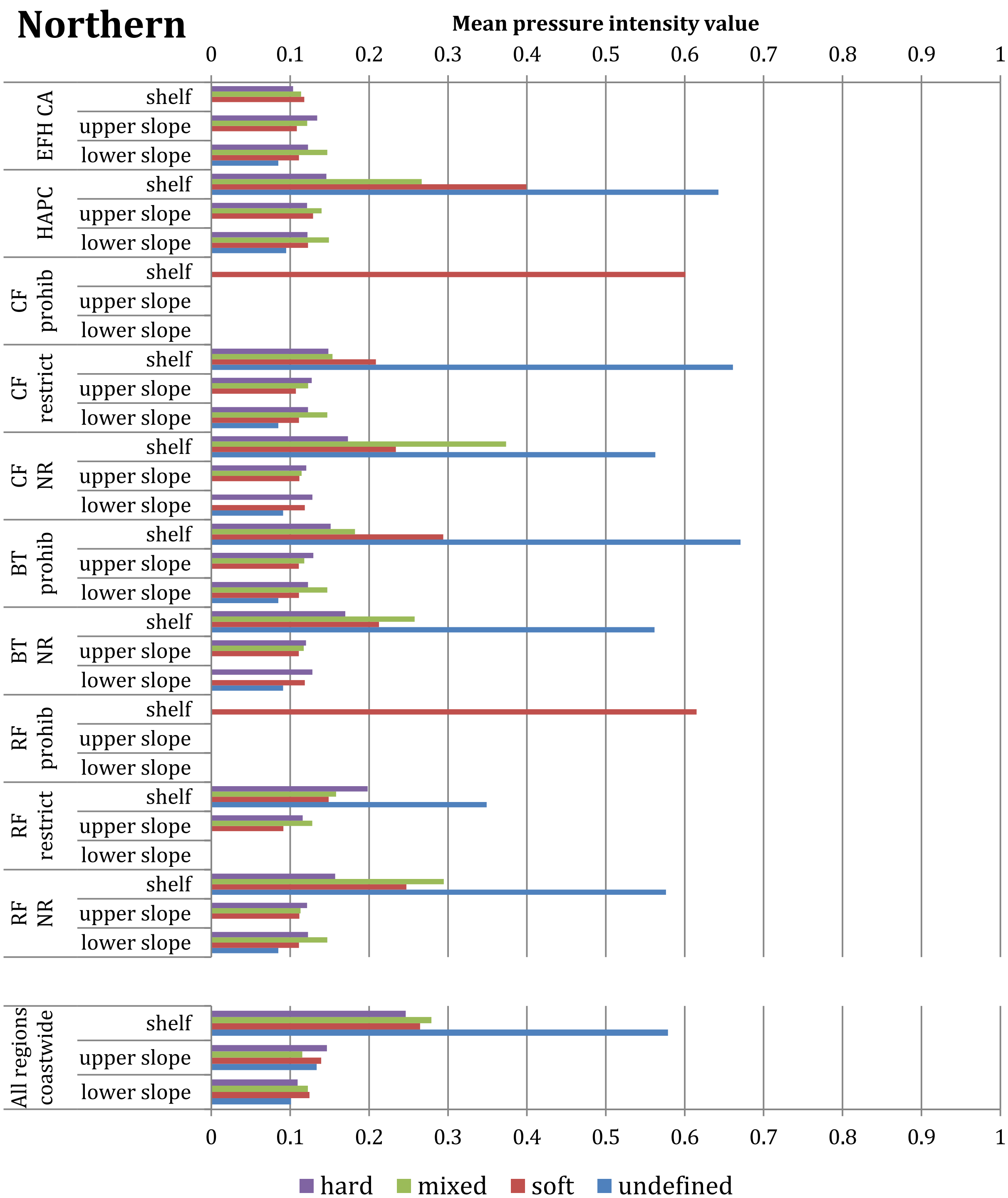


Figure A3b.49. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the “Northern” biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.44. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

OCEAN-BASED POLLUTION		CENTRAL BIOGEOGRAPHIC SUB-REGION										COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.24	0.47	0.22	0.37	0.27	0.36	0.27	0.23	0.39	0.31	0.29
	hard	0.33	0.35	0.30	0.37	0.27	0.36	0.27	0.34	0.47	0.34	0.25
	mixed	0.21	0.31	0.22	0.33	0.45	0.32	0.45	0.31	0.40	0.32	0.28
	soft	0.22	0.32	0.20	0.31	0.26	0.30	0.26	0.21	0.38	0.28	0.26
	undefined	0.37	0.71	0.47	0.69	0.48	0.69	0.48	0.09	0.34	0.69	0.58
Upper Slope[2]	All	0.17	0.19	0.11	0.18	0.16	0.18	0.16	0.09	0.32	0.17	0.14
	hard	0.17	0.17	NA	0.17	0.17	0.17	0.17	NA	0.61	0.17	0.15
	mixed	0.29	0.26	0.47	0.16	0.18	0.19	0.18	NA	NA	0.18	0.12
	soft	0.17	0.26	0.09	0.18	0.16	0.18	0.16	0.09	0.31	0.17	0.14
	undefined	0.15	0.15	NA	0.15	0.15	0.15	0.15	NA	NA	0.15	0.13
Lower Slope[3]	All	0.14	0.15	NA	0.14	0.12	0.14	0.12	NA	NA	0.13	0.10
	hard	0.15	0.15	NA	0.15	NA	0.15	NA	NA	NA	0.15	0.11
	mixed	0.17	0.16	NA	0.17	NA	0.17	NA	NA	NA	0.17	0.12
	soft	0.15	0.17	NA	0.15	0.16	0.15	0.16	NA	NA	0.15	0.12
	undefined	0.14	0.14	NA	0.14	0.12	0.14	0.12	NA	NA	0.13	0.10
Grand mean	All	0.15	0.24	0.22	0.17	0.13	0.17	0.13	0.23	0.38	0.14	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

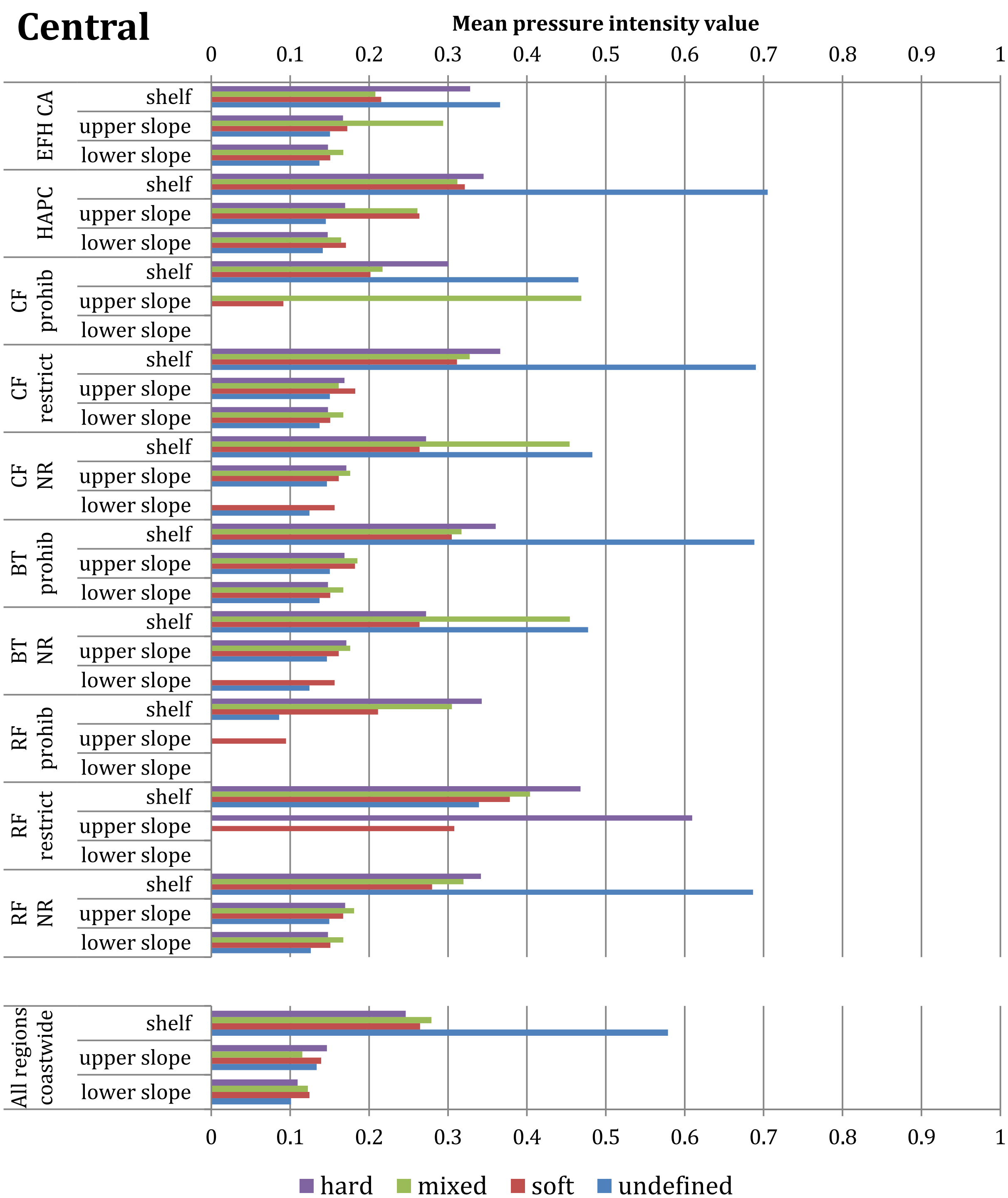


Figure A3b.50. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.45. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

OCEAN-BASED POLLUTION	SOUTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	0.24	0.25	0.22	0.28	0.50	0.29	0.40	0.23	0.15	0.38	0.29
	hard	0.14	0.24	0.24	0.24	0.56	0.25	0.36	0.24	0.13	0.36	0.25
	mixed	0.17	0.20	0.29	0.32	0.65	0.37	0.23	0.28	0.17	0.47	0.28
	soft	0.26	0.25	0.22	0.28	0.50	0.29	0.41	0.23	0.15	0.38	0.26
	undefined	0.24	0.41	0.29	0.36	0.35	0.36	0.35	0.32	0.33	0.36	0.58
Upper Slope[2]	All	0.19	0.13	0.31	0.15	0.14	0.23	0.13	0.31	0.09	0.16	0.14
	hard	0.32	0.13	0.09	0.15	0.12	0.22	0.11	0.09	0.10	0.14	0.15
	mixed	0.10	0.09	NA	0.09	0.12	0.10	0.08	NA	0.08	0.19	0.12
	soft	0.19	0.13	0.32	0.15	0.14	0.23	0.13	0.32	0.09	0.16	0.14
	undefined	NA	NA	NA	0.06	0.11	0.06	0.11	NA	NA	0.11	0.13
Lower Slope[3]	All	0.10	0.09	NA	0.10	0.08	0.10	0.08	NA	0.10	0.09	0.10
	hard	0.09	0.09	NA	0.09	0.08	0.09	0.08	NA	0.09	0.09	0.11
	mixed	0.09	0.09	NA	0.10	NA	0.10	NA	NA	NA	0.10	0.12
	soft	0.11	0.10	NA	0.11	0.10	0.11	0.10	NA	0.11	0.11	0.12
	undefined	0.09	0.08	NA	0.09	0.08	0.09	0.08	NA	NA	0.08	0.10
Grand mean	All	0.11	0.13	0.25	0.13	0.10	0.14	0.10	0.25	0.10	0.11	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

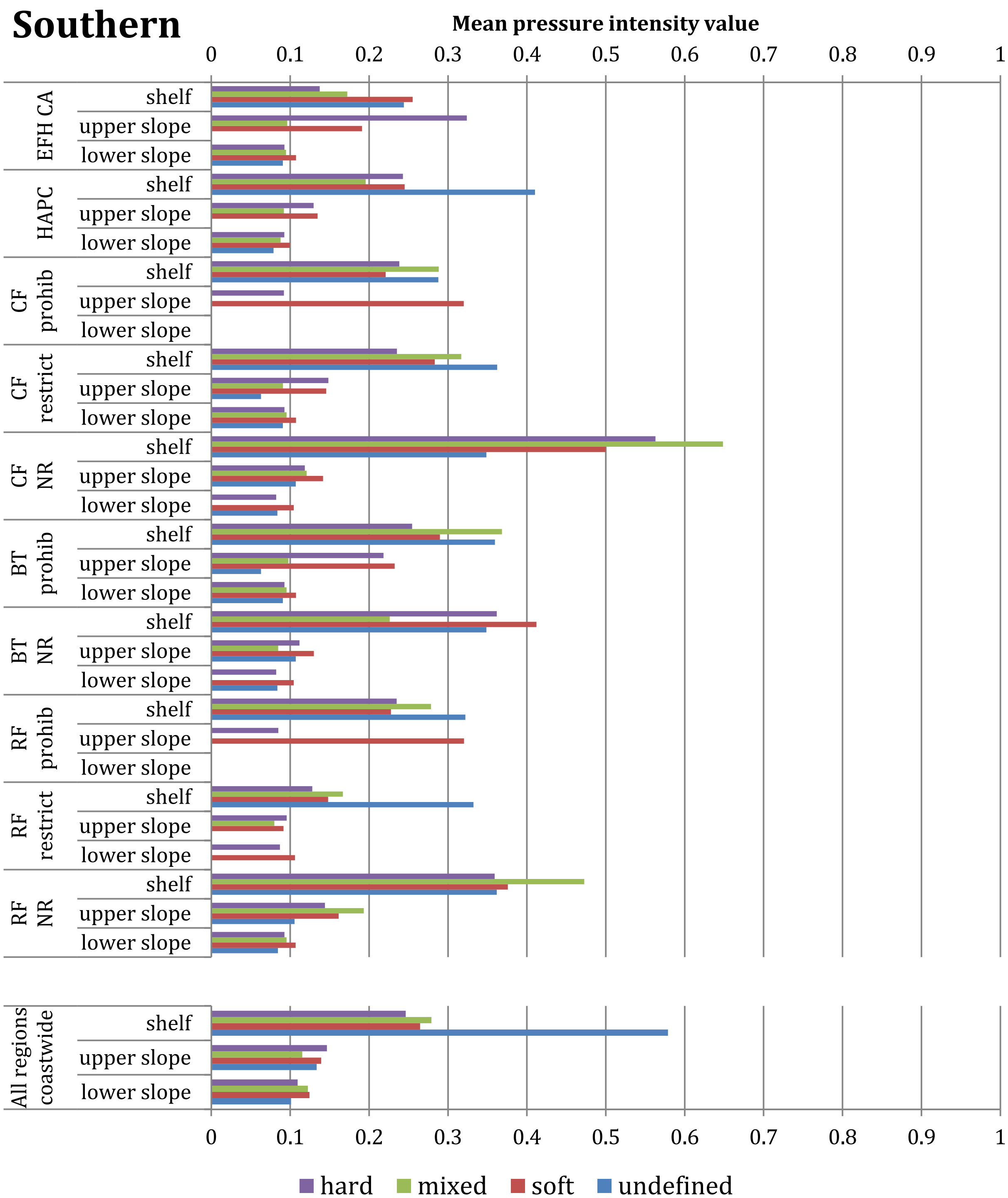


Figure A3b.51. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the “Southern” biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.46. Mean intensity values for ocean-based pollution by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone and ranged from 0 to 1. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

OCEAN-BASED POLLUTION	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	0.58	0.44	0.55	NA	0.55	NA	NA	0.56	0.55	0.29
	hard	NA	0.36	NA	0.50	NA	0.50	NA	NA	0.58	0.40	0.25
	mixed	NA	0.64	NA	0.61	NA	0.61	NA	NA	0.61	0.58	0.28
	soft	NA	0.52	NA	0.54	NA	0.54	NA	NA	0.56	0.53	0.26
	undefined	NA	0.58	0.44	0.56	NA	0.56	NA	NA	0.52	0.56	0.58
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.14
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.15
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.12
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.14
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.13
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.10
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.11
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.12
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.12
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.10
Grand mean	All	NA	0.58	0.44	0.55	NA	0.55	NA	NA	0.56	0.55	0.12

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

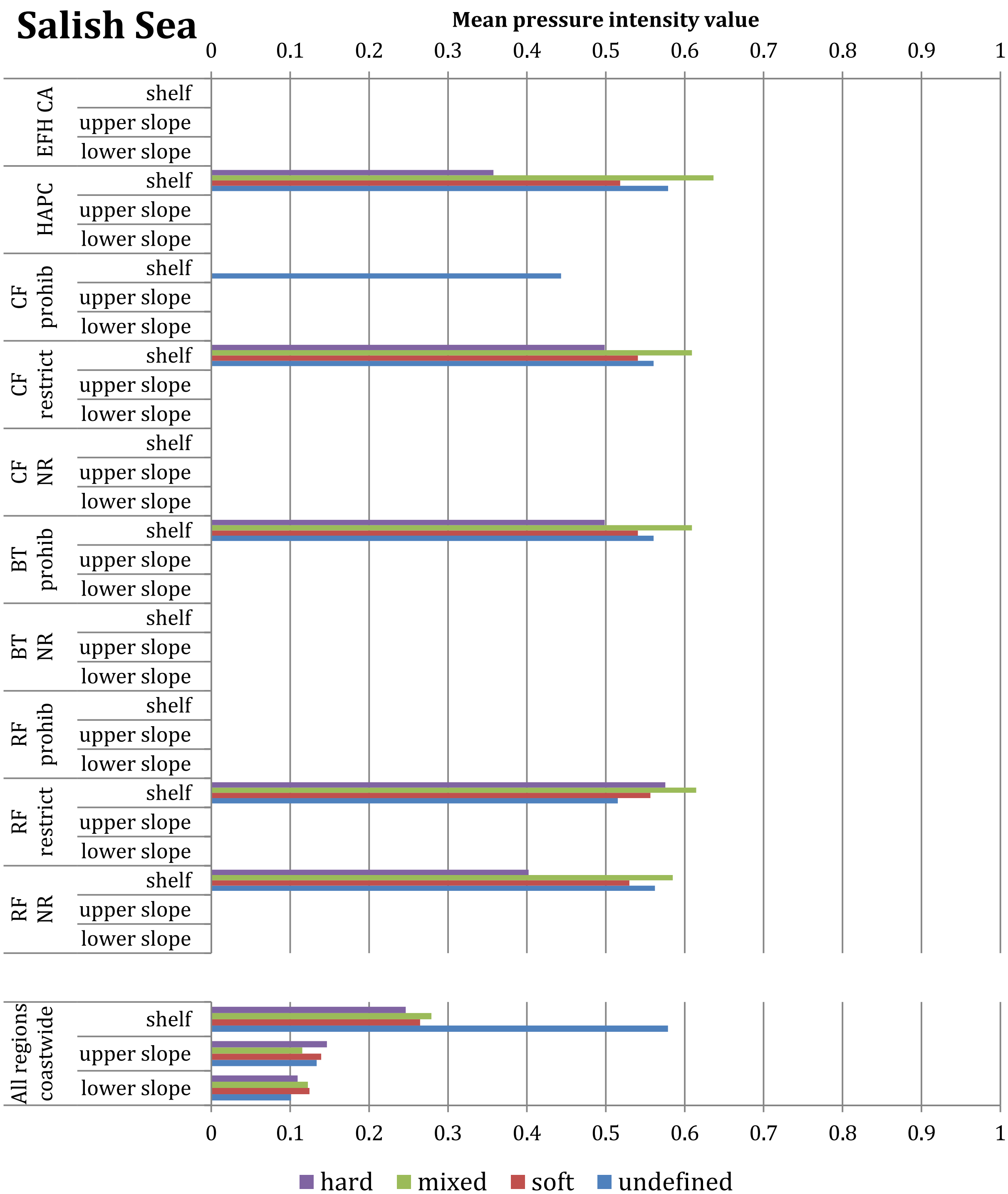


Figure A3b.52. Ocean-based pollution. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.2.4.7 Combined pressures

Importantly, the pressures identified above do not act upon groundfish EFH individually, but collectively. Pressures from terrestrial-based pollution, shipping, offshore energy development, fisheries and coastal development exert cumulative effects on the ecosystem and should be managed in a holistic way (Vinebrooke et al. 2004, Crain et al. 2008, Halpern et al. 2008, Curtin and Prellezo 2010, Stelzenmüller et al. 2010). However, quantifying the cumulative effects of these pressures is a difficult task. Previous studies developing cumulative impact metrics have used qualitative risk metrics (Stelzenmüller et al. 2010) or expert-based scoring systems (Halpern et al. 2008, 2009, Teck et al. 2010) that weight the relative importance of each pressure prior to summing scores across pressures. However, qualitative risk and expert-based scoring systems have been heavily criticized for two reasons. First, the weighting of pressures qualitatively or by expert surveys may be heavily influenced by a range of heuristic and cognitive biases that may lead to arbitrary or misleading results (Hubbard 2009). Second, our understanding of whether the effects of multiple pressures are additive, synergistic, or antagonistic is relatively poor (Darling and Côté 2008, Hoegh-Guldberg and Bruno 2010). Several studies have suggested that multiple pressures interact on various ecosystem components in non-additive ways, either causing effects greater than (synergistic) or less than (antagonistic) that explained by the sum of individual pressures (Sala and Knowlton 2006, Darling and Côté 2008, Griffith et al. 2012, Sunda and Cai 2012). Thus, linear combinations of weighted pressures will not account for these interactions. Because of these unknowns and time constraints, we did not try to calculate cumulative effects values of non-fisheries pressures on groundfish EFH; instead, we used a simplified approach which simply summed the pressure intensity values of all 16 non-fisheries pressures (Table A3b.1) for each 1 km^2 cell within the U.S. EEZ to calculate a "combined pressures" data layer. The values for each individual pressure layer range between 0 and 1, so the maximum value for this layer was 16. This data layer simply shows the additive sum of all overlapping pressures within each cell; it is not intended to describe the cumulative impacts of all pressures present in each cell.

The distribution of combined pressures showed the distinct influence of land-based pollution pressures in nearshore habitats and the exposure of offshore habitats to ocean-based pollution and commercial shipping activity (Fig. A3b.53). Overall, mean intensity values were highest in the Salish Sea biogeographic sub-region and in the shelf depth strata (Figs. A3b.2a, A3b.53-55, Tables A3b.47-48). The Salish Sea was most exposed because the vast majority of the region was exposed to highly populated areas and had only shelf habitat, which was the most exposed depth stratum. The northern sub-region was the next most-greatly exposed region, but this varied among depth strata (Table A3b.47). For example, pressure intensity values were highest in lower slope habitat in the north, but pressures were higher in the southern sub-region in shelf and upper slope habitat. High values in the lower slope of the northern sub-region were most likely the result of high atmospheric pollution values (see *'Atmospheric pollution'*), whereas multiple land-based pressures (see *Individual pressures)* were responsible for high values in the shelf and upper-slope in the southern sub-region. Within each depth stratum, pressure intensity values varied across habitat types, but showed no clear trend.

Differences in pressure intensity values among management boundaries were more difficult to determine, but it seemed that HAPCs and areas that were prohibited to commercial and recreational fishing had higher pressure intensity values than other EFH-related management areas (Fig. A3b.2b, A3b.55, Table A3b.48). This result was likely due to HAPCs and many prohibited fishing areas being located nearshore or inside bays where pressure intensity values were relatively high because of numerous land-based pressures. These coastwide patterns were generally reflected within biogeographic sub-regions (Figs. A3b.56-59, Tables A3b.49-52).

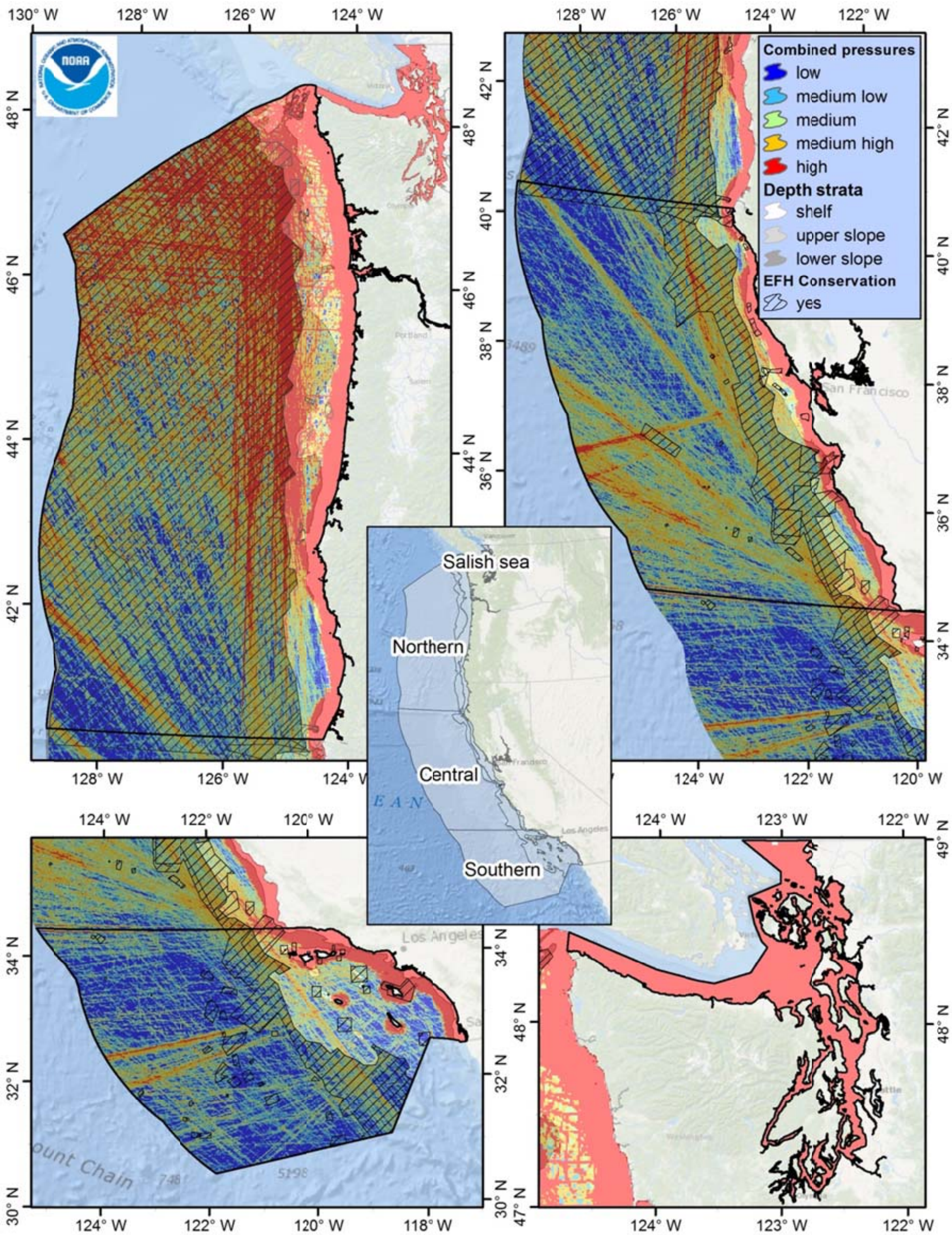


Figure A3b.53. Distribution of combined pressure intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Combined pressure data is the sum of 16 non-fisheries pressures identified in Table A3b.1. Data for each pressure was derived from Halpern et al. 2009.

Table A3b.47. Mean intensity values for atmospheric pollution by depth zones and seabed substrate types across 4 biogeographic sub-regions: "Northern" (i.e., Cape Flattery, WA to Cape Mendocino, CA), "Central" (i.e., Cape Mendocino, CA to Point Conception, CA), "Southern" (i.e., Point Conception, CA to U.S.-Mexico maritime border) and "Salish Sea" (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from the sums of 16 pressure intensity values (data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone which ranged from 0 to 1.

COMBINED PRESSURES						
Depth Zone	*Substrate*	*Northern*	*Central*	*Southern*	*Salish Sea*	*Coastwide*
Shelf[1]	All	2.20	2.71	2.92	4.31	2.63
	hard	1.76	3.00	2.57	3.57	2.30
	mixed	1.98	3.04	2.41	3.55	2.31
	soft	2.18	2.45	2.93	3.64	2.40
	undefined	5.85	6.27	4.71	4.67	5.03
Upper Slope[2]	All	1.22	1.22	1.28	NA	1.25
	hard	1.28	1.15	1.17	NA	1.18
	mixed	1.34	1.37	0.98	NA	1.29
	soft	1.21	1.23	1.29	NA	1.25
	undefined	NA	1.05	1.00	NA	1.03
Lower Slope[3]	All	1.08	0.98	0.88	NA	1.00
	hard	1.26	1.05	0.90	NA	1.03
	mixed	1.10	1.09	0.91	NA	0.99
	soft	1.26	1.06	0.95	NA	1.10
	undefined	1.06	0.97	0.87	NA	0.98
Grand mean	All	1.22	1.10	1.04	4.31	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

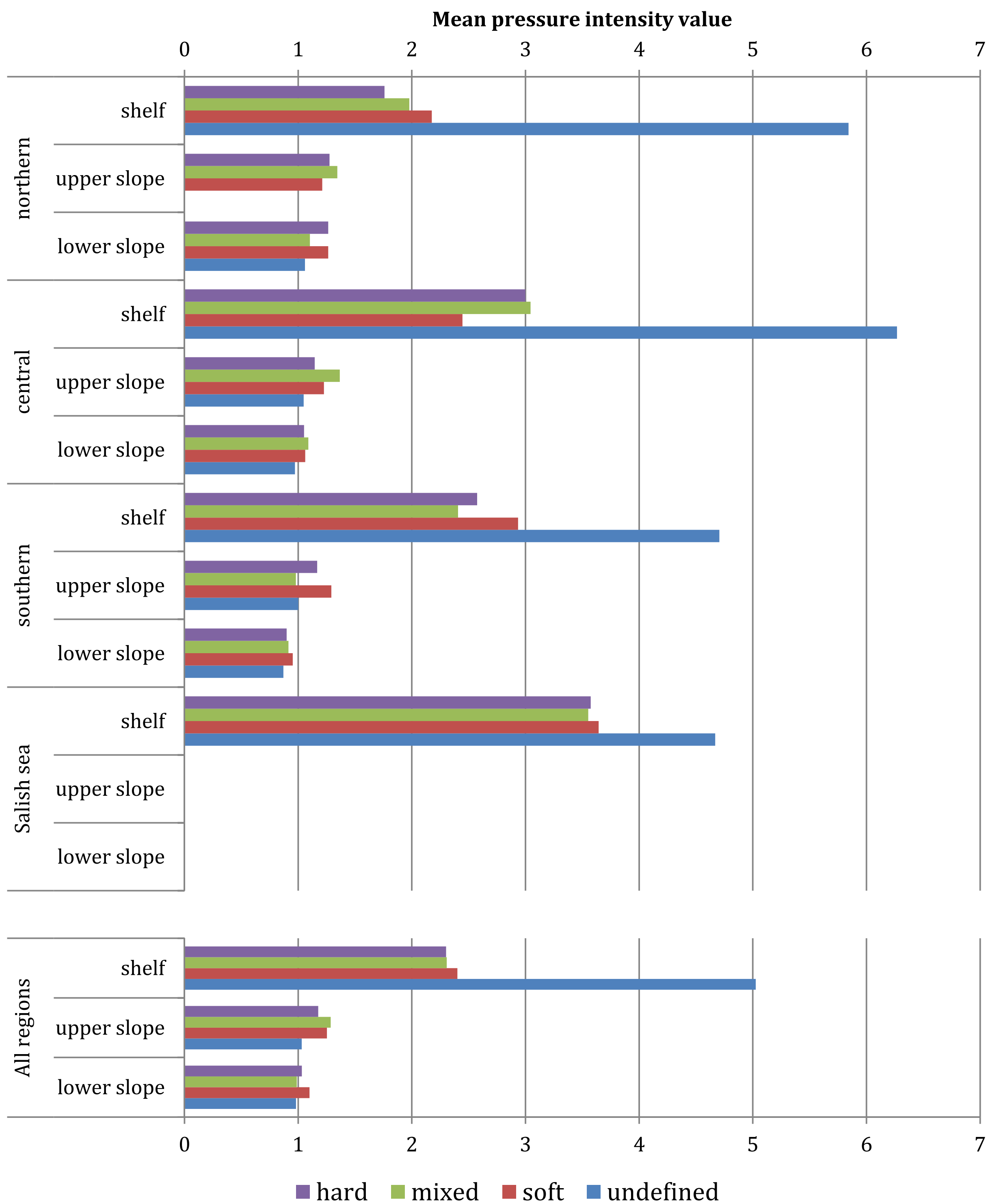


Figure A3b.54. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones across 4 biogeographic sub-regions: “Northern” (i.e., Cape Flattery, WA to Cape Mendocino, CA), “Central” (i.e., Cape Mendocino, CA to Point Conception, CA), “Southern” (i.e., Point Conception, CA to U.S.-Mexico maritime border) and “Salish Sea” (i.e., Straits of Juan de Fuca, Georgia and Puget Sound).

Table A3b.48. Mean intensity values for combined pressures by depth zones and seabed substrate types across various management boundaries. Mean intensity values were calculated from the sum of 16 non-fisheries pressures' intensity values (Table A3b.1; data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" was prohibited, so they have the same mean intensity values. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing; NA = no habitat present in this category. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions.

COMBINED PRESSURES												
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawling*		*Recreational fishing*			*Coastwide*
Depth Zone	***Substrate***			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	**All**	**1.78**	**3.61**	**2.50**	**3.01**	**2.27**	**3.31**	**2.17**	**2.40**	**2.05**	**2.76**	**2.63**
	hard	1.67	2.00	3.12	2.41	2.04	2.52	1.97	2.94	2.25	2.28	2.30
	mixed	1.52	2.19	2.83	2.17	2.69	2.46	2.11	2.88	1.89	2.60	2.31
	soft	1.86	2.87	2.38	2.63	2.23	2.93	2.14	2.31	2.02	2.48	2.40
	undefined	2.66	5.69	4.39	4.97	5.75	4.97	5.73	2.48	3.43	5.08	5.03
Upper Slope[2]	**All**	**1.31**	**1.23**	**2.42**	**1.28**	**1.23**	**1.45**	**1.20**	**2.35**	**1.01**	**1.28**	**1.25**
	hard	1.22	1.16	2.53	1.18	1.17	1.24	1.14	2.52	0.98	1.20	1.18
	mixed	1.28	1.32	4.22	1.29	1.28	1.31	1.27	NA	1.28	1.29	1.29
	soft	1.33	1.32	2.40	1.29	1.24	1.49	1.21	2.34	1.00	1.29	1.25
	undefined	1.04	1.05	NA	1.03	1.03	1.03	1.03	NA	NA	1.03	1.03
Lower Slope[3]	**All**	**1.06**	**1.05**	**NA**	**1.06**	**0.93**	**1.06**	**0.93**	**NA**	**0.97**	**0.99**	**1.00**
	hard	1.03	1.00	NA	1.03	1.13	1.03	1.13	NA	0.89	1.03	1.03
	mixed	0.99	0.96	NA	0.99	NA	0.99	NA	NA	NA	0.99	0.99
	soft	1.11	1.16	NA	1.11	0.95	1.11	0.95	NA	0.98	1.10	1.10
	undefined	1.05	1.05	NA	1.05	0.93	1.05	0.93	NA	NA	0.98	0.98
Grand mean	**All**	**1.08**	**1.89**	**2.49**	**1.23**	**1.08**	**1.23**	**1.09**	**2.39**	**1.46**	**1.14**	**1.15**

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

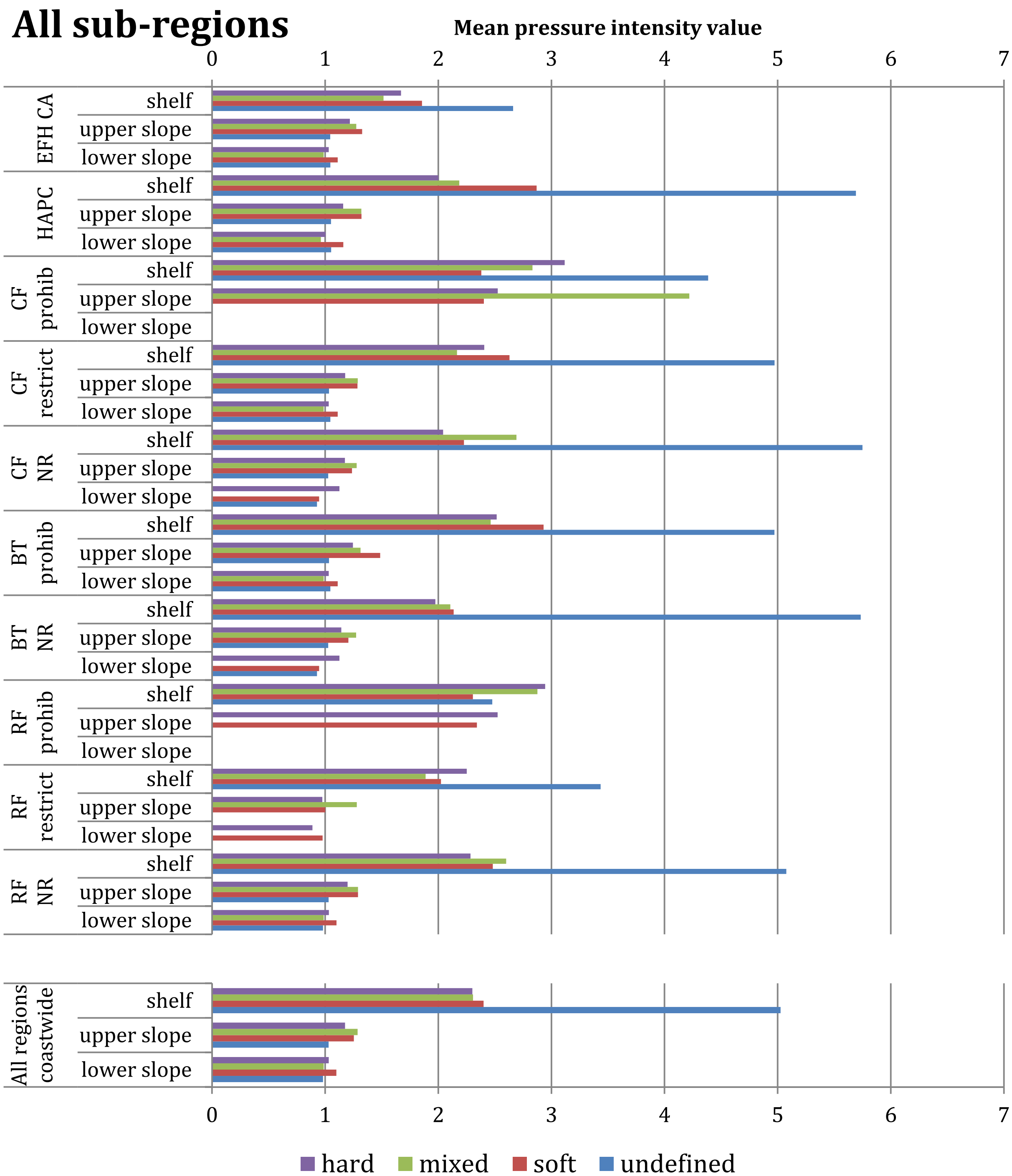


Figure A3b.55. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries across all biogeographic regions. EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.49. Combined pressure mean intensity values by depth zones and seabed substrate types across various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). Mean intensity values were calculated from the sum of 16 non-fisheries pressures' intensity values (Table A3b.1; data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone. Values for each pressure ranged from 0 to 1. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" is prohibited, so these management areas all have the same mean intensity values. NA = no habitat present in this category.

COMBINED PRESSURES	NORTHERN BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	1.32	2.98	5.00	2.15	2.22	2.60	2.11	5.08	1.87	2.29	2.63
	hard	1.23	1.57	NA	1.62	1.86	1.63	1.85	NA	2.13	1.70	2.30
	mixed	1.39	2.06	NA	1.63	2.64	1.76	2.12	NA	1.67	2.26	2.31
	soft	1.36	3.34	5.00	2.20	2.16	2.76	2.07	5.08	1.88	2.26	2.40
	undefined	NA	6.40	NA	5.98	5.84	6.06	5.83	NA	2.90	5.87	5.03
Upper Slope[2]	All	1.39	1.34	NA	1.32	1.20	1.32	1.20	NA	1.41	1.21	1.25
	hard	1.32	1.28	NA	1.30	1.27	1.31	1.27	NA	1.48	1.27	1.18
	mixed	1.47	1.49	NA	1.48	1.28	1.46	1.31	NA	1.53	1.27	1.29
	soft	1.39	1.34	NA	1.31	1.19	1.31	1.20	NA	1.37	1.21	1.25
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.03
Lower Slope[3]	All	1.08	1.21	NA	1.08	1.10	1.08	1.10	NA	NA	1.08	1.00
	hard	1.26	1.25	NA	1.26	1.22	1.26	1.22	NA	NA	1.26	1.03
	mixed	1.10	1.11	NA	1.10	NA	1.10	NA	NA	NA	1.10	0.99
	soft	1.26	1.28	NA	1.26	1.33	1.26	1.33	NA	NA	1.26	1.10
	undefined	1.06	1.09	NA	1.06	0.93	1.06	0.93	NA	NA	1.06	0.98
Grand mean	All	1.09	1.98	5.00	1.14	1.67	1.12	1.67	5.08	1.80	1.20	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

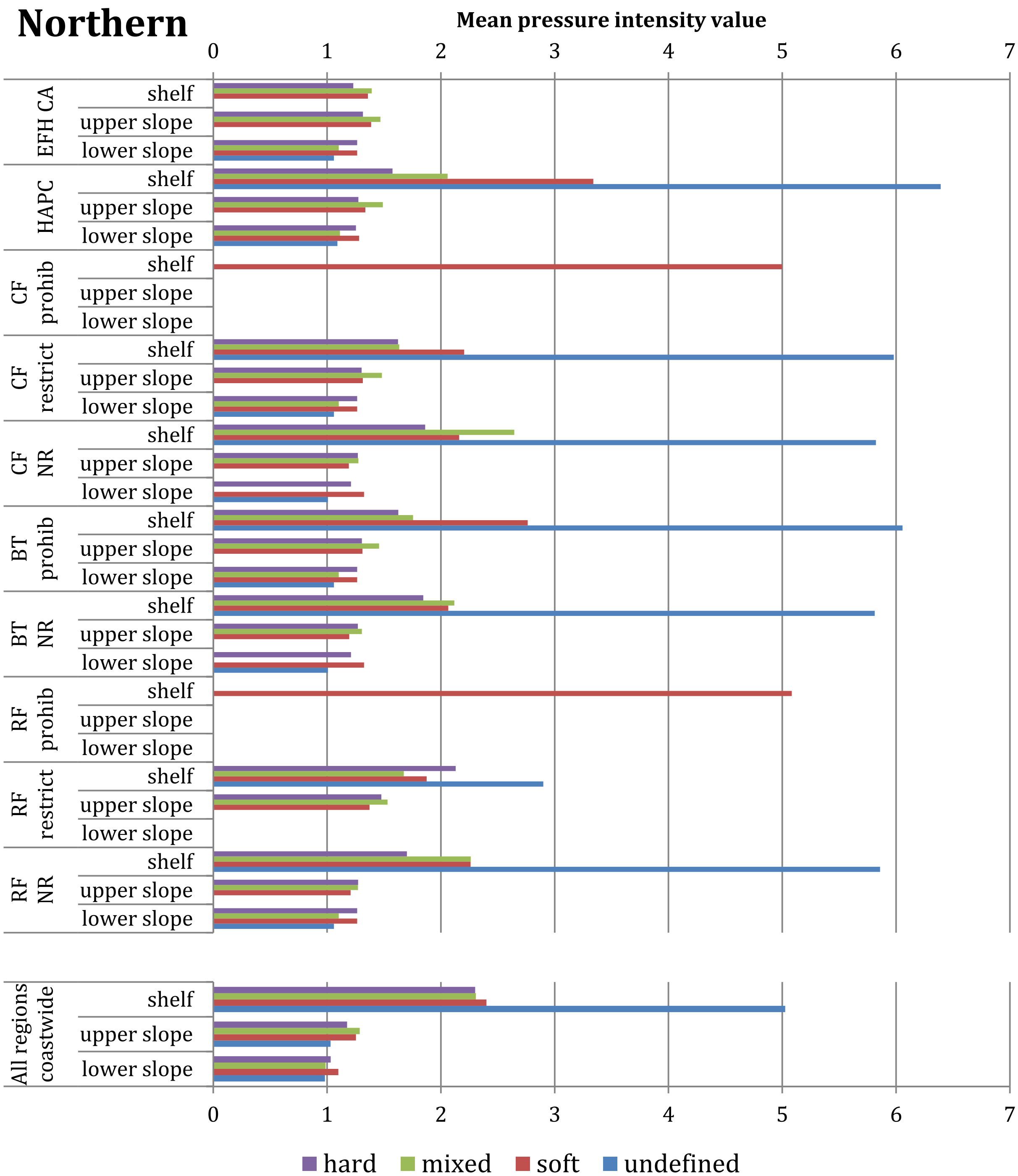


Figure A3b.56. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Northern" biogeographic region (i.e., Cape Flattery, WA to Cape Mendocino, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.50. Combined pressure mean intensity values by depth zones and seabed substrate types across various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). Mean intensity values were calculated from the sum of 16 non-fisheries pressures' intensity values (Table A3b.1; data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone. Values for each pressure ranged from 0 to 1. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" is prohibited, so these management areas all have the same mean intensity values. NA = no habitat present in this category.

COMBINED PRESSURES		**CENTRAL BIOGEOGRAPHIC SUB-REGION**										**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	2.13	4.17	2.96	3.37	2.14	3.34	2.14	2.94	2.69	2.71	2.63
	hard	2.45	2.91	3.29	3.08	2.26	3.10	2.26	3.26	2.92	3.00	2.30
	mixed	1.99	2.91	3.20	3.03	3.01	3.04	3.09	3.28	2.98	3.04	2.31
	soft	2.06	2.83	2.83	2.91	2.12	2.90	2.12	2.87	2.42	2.45	2.40
	undefined	3.06	6.42	4.64	6.31	5.55	6.30	5.47	1.59	6.31	6.27	5.03
Upper Slope[2]	All	1.22	1.28	2.04	1.31	1.18	1.31	1.18	1.88	1.21	1.22	1.25
	hard	1.12	1.14	NA	1.15	1.14	1.15	1.14	NA	1.14	1.15	1.18
	mixed	2.31	2.20	4.22	1.24	1.25	1.47	1.25	NA	1.37	1.37	1.29
	soft	1.26	1.88	1.89	1.35	1.18	1.35	1.18	1.88	1.22	1.23	1.25
	undefined	1.04	1.05	NA	1.04	1.08	1.04	1.08	NA	1.05	1.05	1.03
Lower Slope[3]	All	1.04	1.07	NA	1.04	0.96	1.04	0.96	NA	0.98	1.04	1.00
	hard	1.05	1.05	NA	1.05	NA	1.05	NA	NA	1.05	1.05	1.03
	mixed	1.09	1.08	NA	1.09	NA	1.09	NA	NA	1.09	1.09	0.99
	soft	1.06	1.11	NA	1.06	1.09	1.06	1.09	NA	1.06	1.06	1.10
	undefined	1.02	1.03	NA	1.02	0.96	1.02	0.96	NA	0.97	1.02	0.98
Grand mean	All	1.08	1.88	2.91	1.30	1.03	1.31	1.03	2.88	1.09	1.36	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

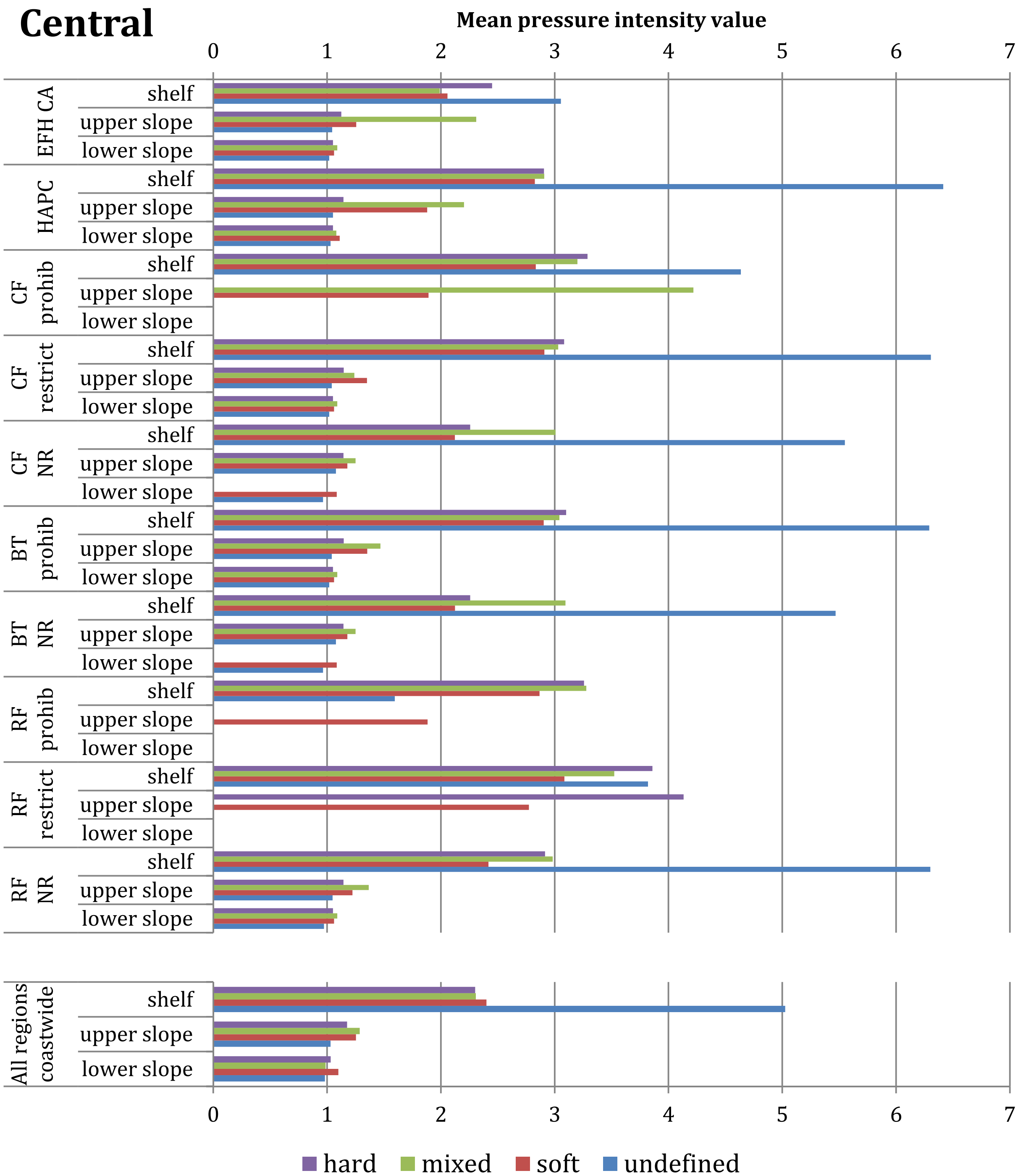


Figure A3b.57. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Central" biogeographic region (i.e., Cape Mendocino, CA to Point Conception, CA). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.51. Combined pressure mean intensity values by depth zones and seabed substrate types across various management boundaries in the “Southern” biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). Mean intensity values were calculated from the sum of 16 non-fisheries pressures’ intensity values (Table A3b.1; data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone. Values for each pressure ranged from 0 to 1. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where “Commercial fishing” is prohibited, so these management areas all have the same mean intensity values. NA = no habitat present in this category.

COMBINED PRESSURES	**SOUTHERN BIOGEOGRAPHIC SUB-REGION**											**COASTWIDE**
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	1.74	1.95	2.15	2.76	3.87	2.84	3.16	1.97	3.40	2.92	2.63
	hard	1.20	2.13	2.88	2.25	4.15	2.51	2.75	2.50	3.21	2.57	2.30
	mixed	1.38	1.53	2.33	2.32	3.73	2.67	1.61	2.18	3.25	2.41	2.31
	soft	1.80	1.82	2.07	2.78	3.86	2.83	3.23	1.91	3.39	2.93	2.40
	undefined	2.40	4.86	4.06	4.87	3.58	4.84	3.58	4.24	4.87	4.71	5.03
Upper Slope[2]	All	1.38	1.16	2.47	1.25	1.30	1.71	1.22	2.41	1.39	1.28	1.25
	hard	1.79	1.15	2.53	1.20	1.14	1.54	1.08	2.52	1.24	1.17	1.18
	mixed	0.94	0.95	NA	0.95	1.45	0.99	0.97	NA	1.75	0.98	1.29
	soft	1.37	1.18	2.47	1.25	1.31	1.74	1.22	2.41	1.40	1.29	1.25
	undefined	NA	NA	NA	0.76	1.01	0.76	1.01	NA	1.00	1.00	1.03
Lower Slope[3]	All	0.92	0.90	NA	0.92	0.87	0.92	0.87	NA	0.88	0.92	1.00
	hard	0.90	0.90	NA	0.90	0.85	0.90	0.85	NA	0.90	0.90	1.03
	mixed	0.91	0.88	NA	0.91	NA	0.91	NA	NA	0.91	0.91	0.99
	soft	0.96	0.93	NA	0.96	0.92	0.96	0.92	NA	0.95	0.96	1.10
	undefined	0.89	0.85	NA	0.89	0.87	0.89	0.87	NA	0.87	0.89	0.98
Grand mean	All	0.99	1.14	2.23	1.19	0.98	1.25	0.98	2.08	1.04	1.27	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

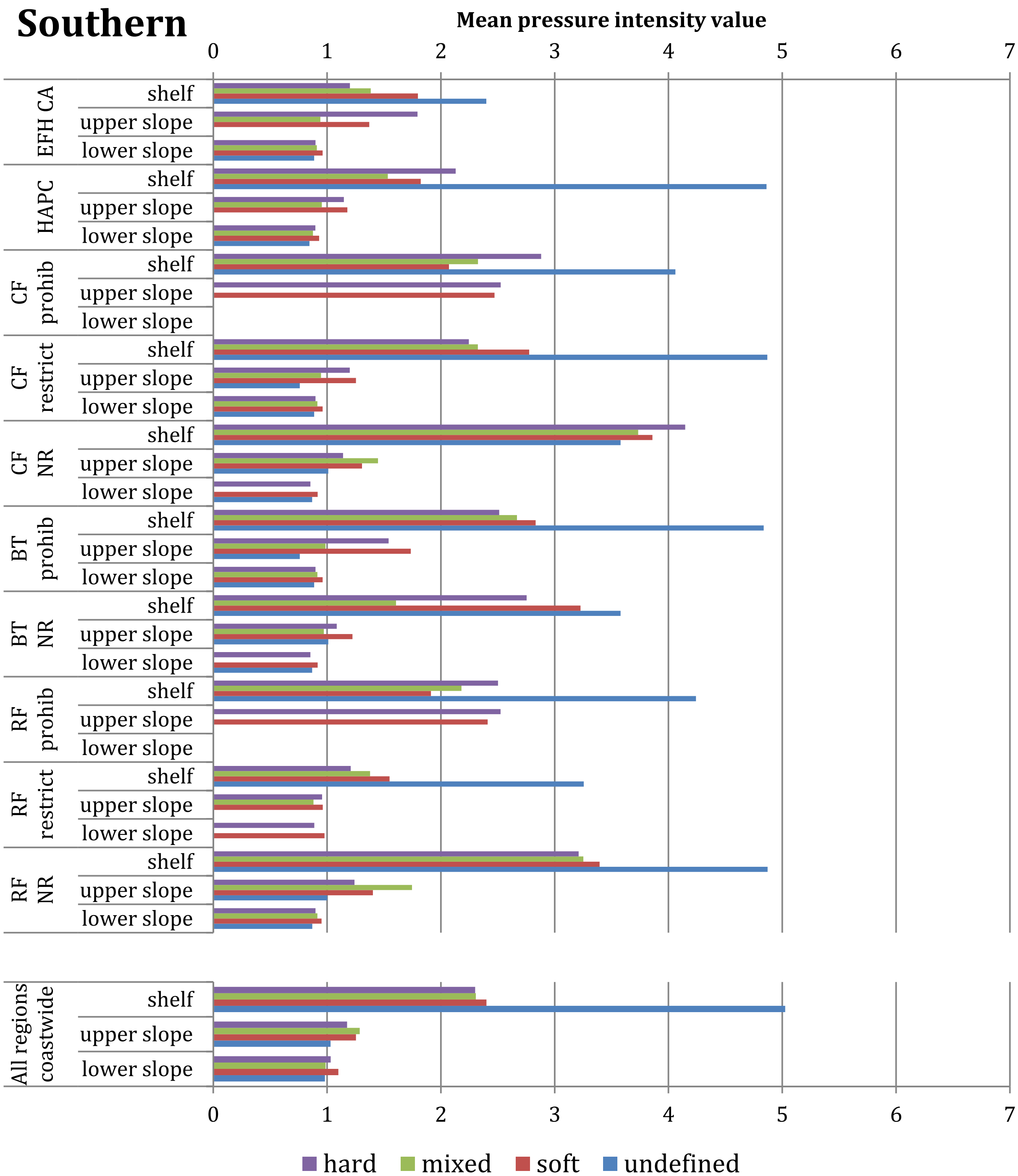


Figure A3b.58. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Southern" biogeographic region (i.e., Point Conception, CA to U.S.-Mexico maritime border). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

Table A3b.52. Combined pressure mean intensity values by depth zones and seabed substrate types across various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). Mean intensity values were calculated from the sum of 16 non-fisheries pressures' intensity values (Table A3b.1; data from Halpern et al. 2009) assigned to 1 km^2 cells across the entire U.S. Exclusive Economic Zone. Values for each pressure ranged from 0 to 1. EFH CA = essential fish habitat conservation areas; HAPC = habitat areas of particular concern; Prohib = type of fishing is prohibited; Restr = type of fishing is restricted; NR = no restrictions for this type of fishing. Fishing restrictions included areas within EFH CA, rockfish conservation areas and state territorial sea restrictions. Fixed gear fishing (e.g., pots and longlines) and mid-water trawling were prohibited where "Commercial fishing" is prohibited, so these management areas all have the same mean intensity values. NA = no habitat present in this category.

COMBINED PRESSURES	SALISH SEA BIOGEOGRAPHIC SUB-REGION											COASTWIDE
		EFH CA	*HAPC*	*Commercial fishing*			*Bottom trawl*		*Recreational fishing*			*ALL*
Depth Zone	*Substrate*			*Prohib*	*Restr*	*NR*	*Prohib*	*NR*	*Prohib*	*Restr*	*NR*	
Shelf[1]	All	NA	5.28	3.96	4.31	NA	4.31	NA	NA	3.50	4.48	2.63
	hard	NA	3.65	NA	3.57	NA	3.57	NA	NA	3.51	3.65	2.30
	mixed	NA	3.61	NA	3.55	NA	3.55	NA	NA	3.46	3.95	2.31
	soft	NA	3.98	NA	3.64	NA	3.64	NA	NA	3.52	3.73	2.40
	undefined	NA	5.32	3.96	4.67	NA	4.67	NA	NA	3.44	4.71	5.03
Upper Slope[2]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.25
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.18
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.29
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.25
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.03
Lower Slope[3]	All	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00
	hard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.03
	mixed	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.99
	soft	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.10
	undefined	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.98
Grand mean	All	NA	5.28	3.96	4.31	NA	4.31	NA	NA	3.50	4.48	1.15

[1] Continental shelf (i.e., coastline to continental shelf break), as defined by regional habitat layers.
[2] Upper continental slope (i.e., shelf break – 700 ftm EFH shoreward boundary). 700 ftm is generally recognized as the seaward extent of the groundfish fishery.
[3] Lower continental slope (i.e., 700 ftm EFH shoreward boundary – EEZ seaward boundary).

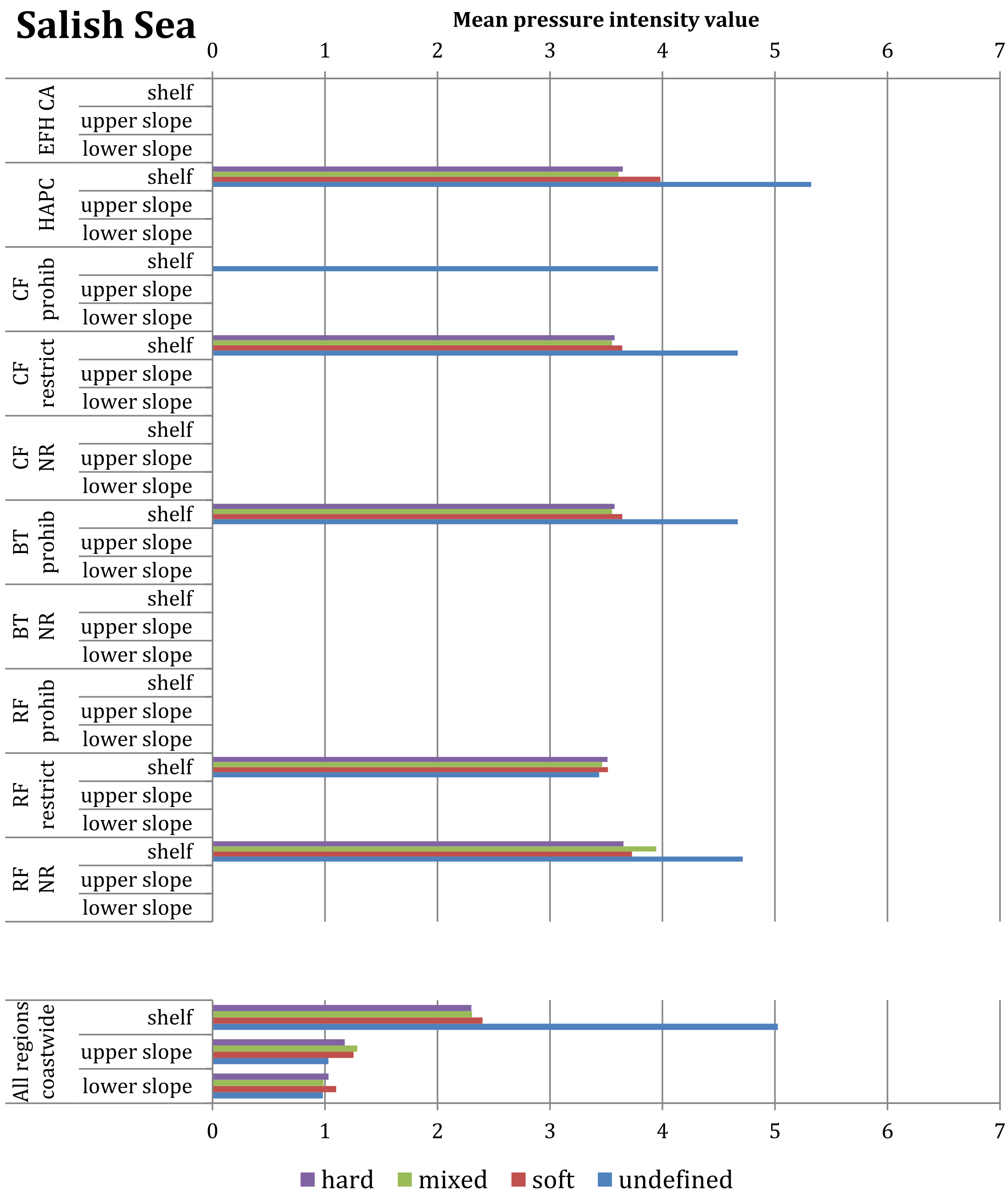


Figure A3b.59. Combined non-fisheries pressures. Mean pressure intensity values among seabed substrate types by depth zones in various management boundaries in the "Salish Sea" biogeographic region (i.e., Straits of Juan de Fuca, Georgia and Puget Sound). EFH CA = essential fish habitat conservation areas, HAPC = habitat areas of particular concern; CF = commercial fishing; BT = bottom trawling; RF = recreational fishing; prohib = type of fishing is prohibited; restrict = type of fishing is restricted; NR = no restrictions on type of fishing.

3.3 EMERGING PRESSURES

There are several pressures that will begin to exert larger influence across groundfish EFH in the near future. Natural gas terminals and associated activities, development of tidal, wave and offshore wind energy production, offshore mining activities, desalination plants, and other hydrokinetic projects will all affect groundfish EFH. There are currently preliminary permits for wave energy projects off the coast of Oregon, tidal energy projects in San Francisco Bay and other hydrokinetic projects in southern California (Fig. A3b.60), but these projects have not been deployed as of the time this report was written, so they were not included in our ‘combined’ pressures calculation.

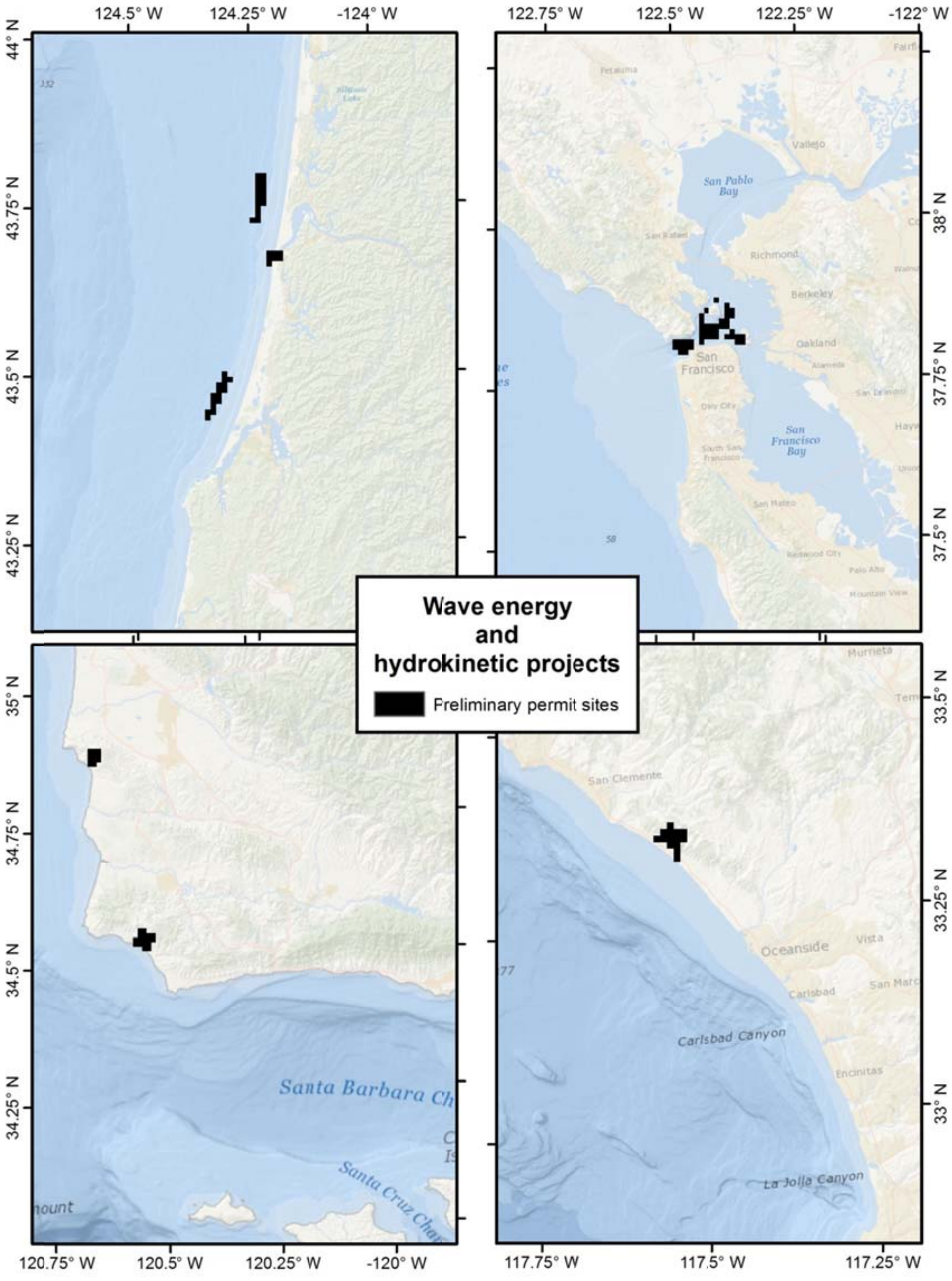


Figure A3b.60. Location of preliminary permits for wave energy and hydrokinetic projects along the U.S. West Coast.

3.4 CLIMATE CHANGE PRESSURES

Fully-developed analyses of the effects of climate change on groundfish essential fish habitat are beyond the scope of the current synthesis. Below, we outline two examples of how environmental pressures related to climate change could be incorporated into the EFH management framework.

3.4.1 Ocean acidification

In general, atmospheric carbon dioxide (CO_2) levels have been increasing at historically high rates since the industrial revolution. Rising atmospheric CO_2 is tempered by oceanic uptake where surface waters exchange gases at equilibrium with the atmosphere which has resulted in greater CO_2 uptake by the oceans (Feely et al. 2004, Doney et al. 2009). Increases in CO_2 uptake by the oceans results in lower pH values for seawater through a series of chemical reactions involving carbonate (CO_3^{2-}) ions. As the pH of seawater decreases (i.e. more acidic), calcifying organisms, such as corals and other shell-forming organisms, have decreased calcification and growth rates (Kleypas et al. 2006, Fine and Tchernov 2007, Fabry et al. 2008). Many of these affected taxa form biogenic habitat (e.g. corals) or are the basis of the food web (pteropods and coccolithophores) for a variety of zooplankton, larvae and fish predators, including groundfish in the North Pacific.

In order to determine what habitats on the U.S. West Coast may be most susceptible to ocean acidification, we used the ocean acidification (OA) data layer from Halpern et al. (Fig. 4b.61; Halpern et al. 2009) and two biogenic habitat layers. First, Guinotte & Davies (2012) have developed predictive models that identify areas with the highest probability of harboring deep-sea corals (Fig. A3b.62). Second, we used the map of direct observations of biogenic habitat described in Chapter 2. For both biogenic habitat data sets, we multiplied the OA intensity value by the corresponding habitat suitability probability value or the number of observations in each cell. This product results in an exposure intensity index that shows where the threat of OA is likely to be of greatest concern to biogenic habitats. For example, areas with high OA values and high habitat suitability values will have the highest exposure intensity values, while areas with low OA values and low habitat suitability values will have the lowest exposure intensity values.

Both data sets (Figs. 4b.63-64) show relatively high exposure intensity values in the northern region off the coast of Washington, particularly in the Olympic National Sanctuary. There also seems to be correspondence between the two data sets showing pockets of high exposure values in southern California. However, there appears to be differences among the two maps in Monterey Bay, CA. The exposure index is mostly in the medium high quintile using the habitat suitability values, while the exposure index is mostly in the two lowest quintiles using the direct observation data. OA values are consistently low across this region (Fig. A3b.61), so the difference arises because the suitability values are relatively high in Monterey Bay compared to the rest of the coast, while the numbers of direct observations in Monterey Bay are lower compared to areas with the highest numbers of direct observations along the coast.

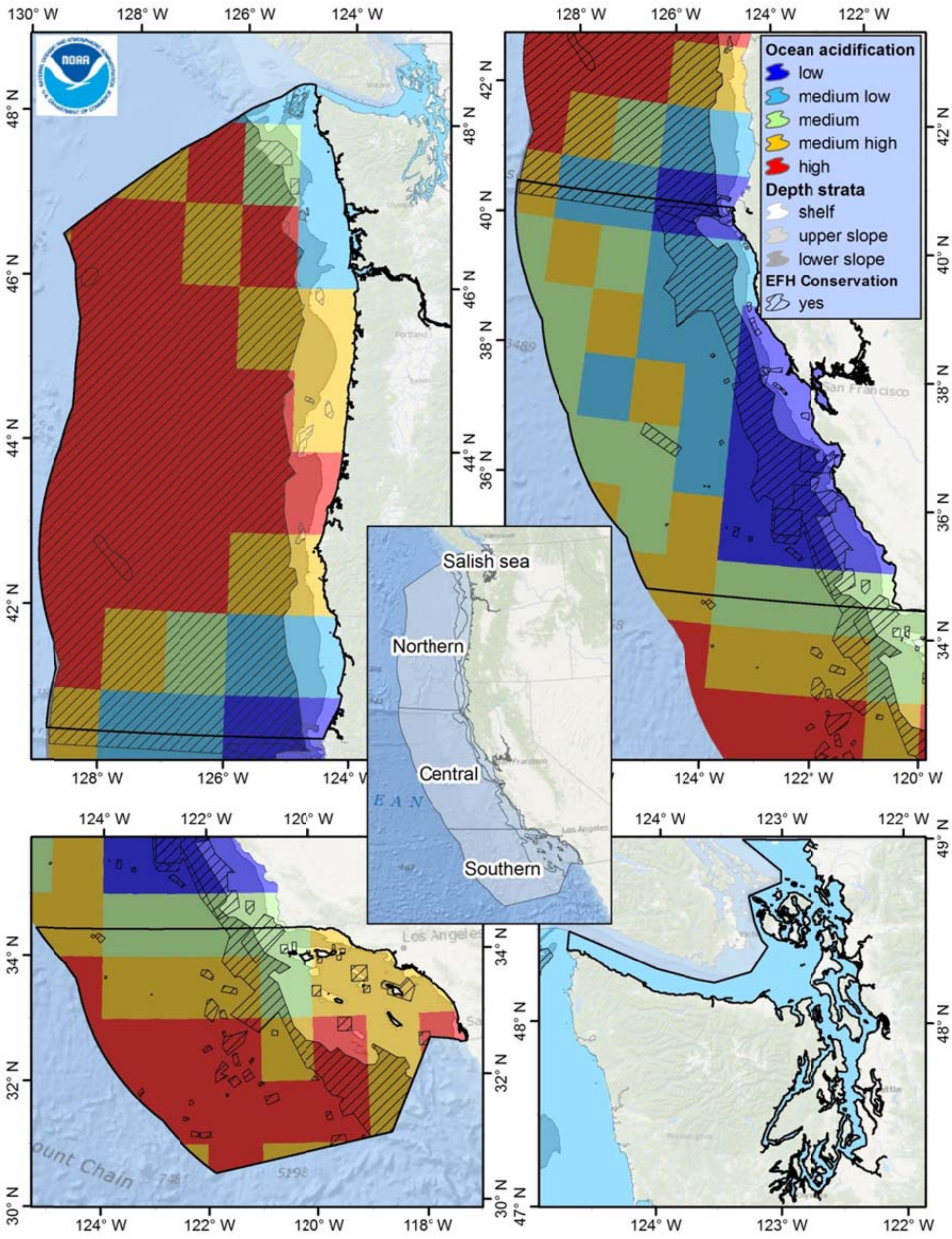


Figure A3b.61. Distribution of ocean acidification pressure intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Data for each pressure is from Halpern et al. 2009.

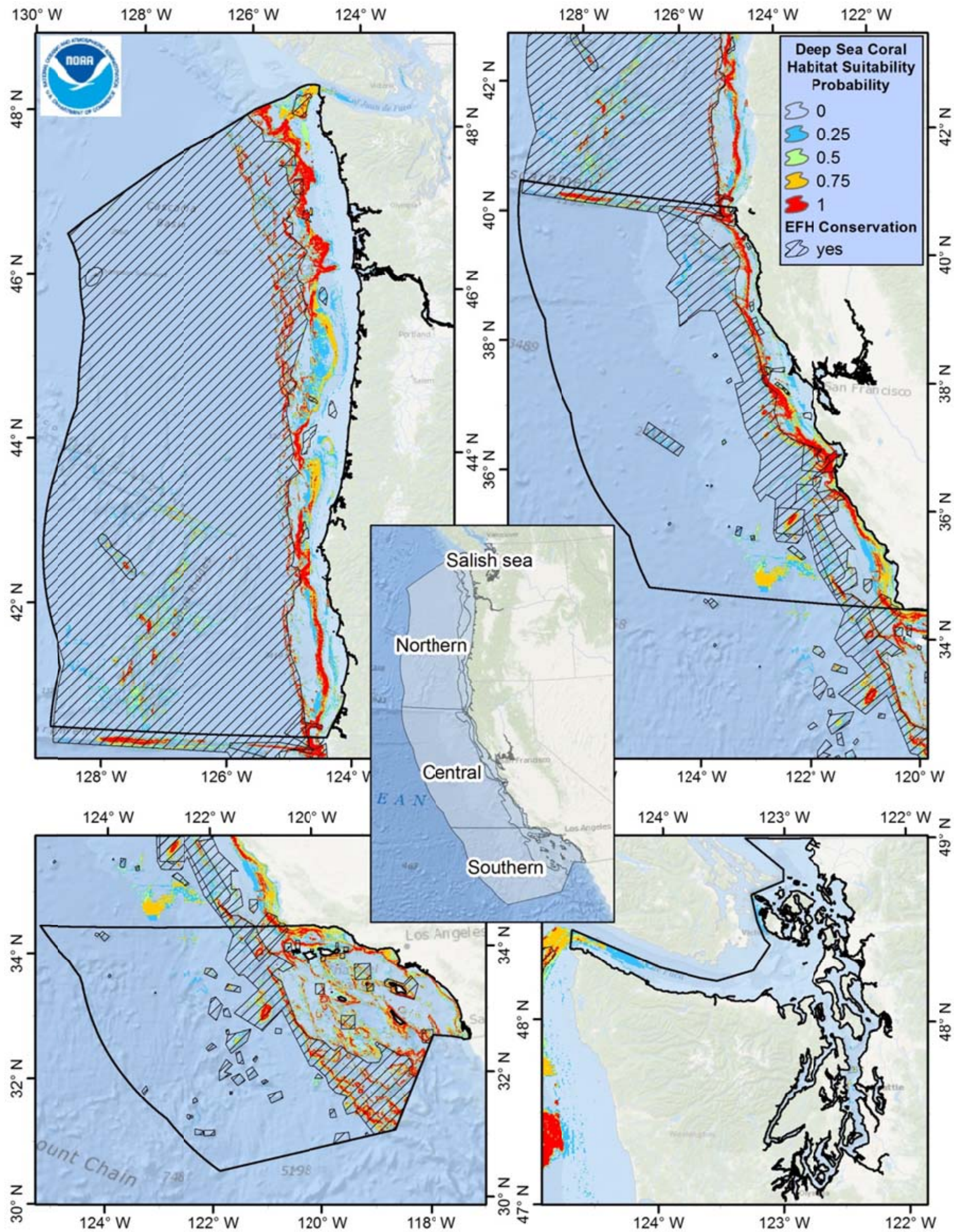


Figure A3b.62. Habitat suitability probabilities for deep sea corals. Data is from Guinotte & Davies (2012).

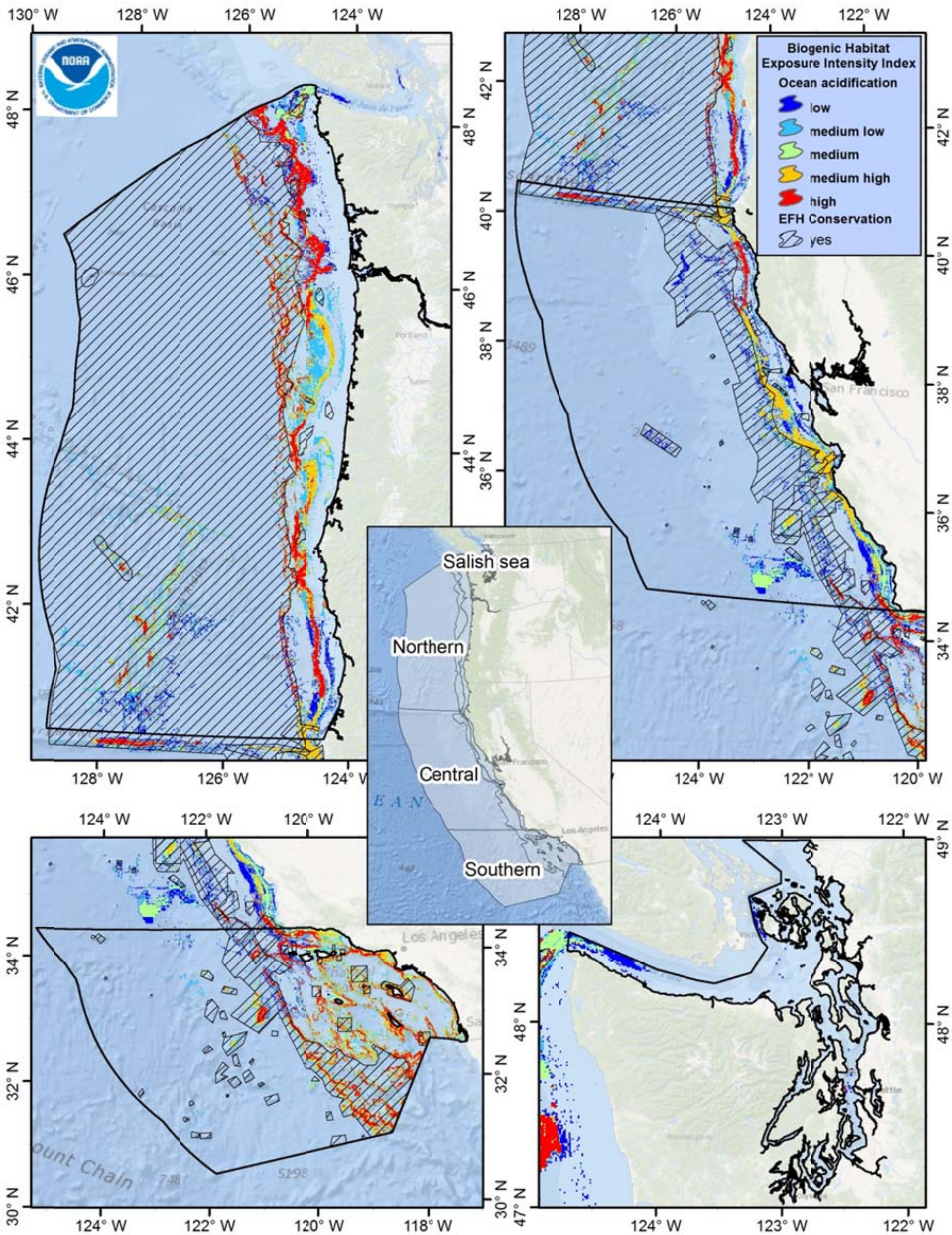


Figure A3b.63. Exposure intensity index of biogenic habitats using the habitat suitability probabilities for coral habitats described in Section 1 of this appendix. Regions with the highest exposure intensities are areas where biogenic habitat is most likely to occur and where ocean acidification is predicted to be highest. Essential Fish Habitat (EFH) conservation areas are overlaid.

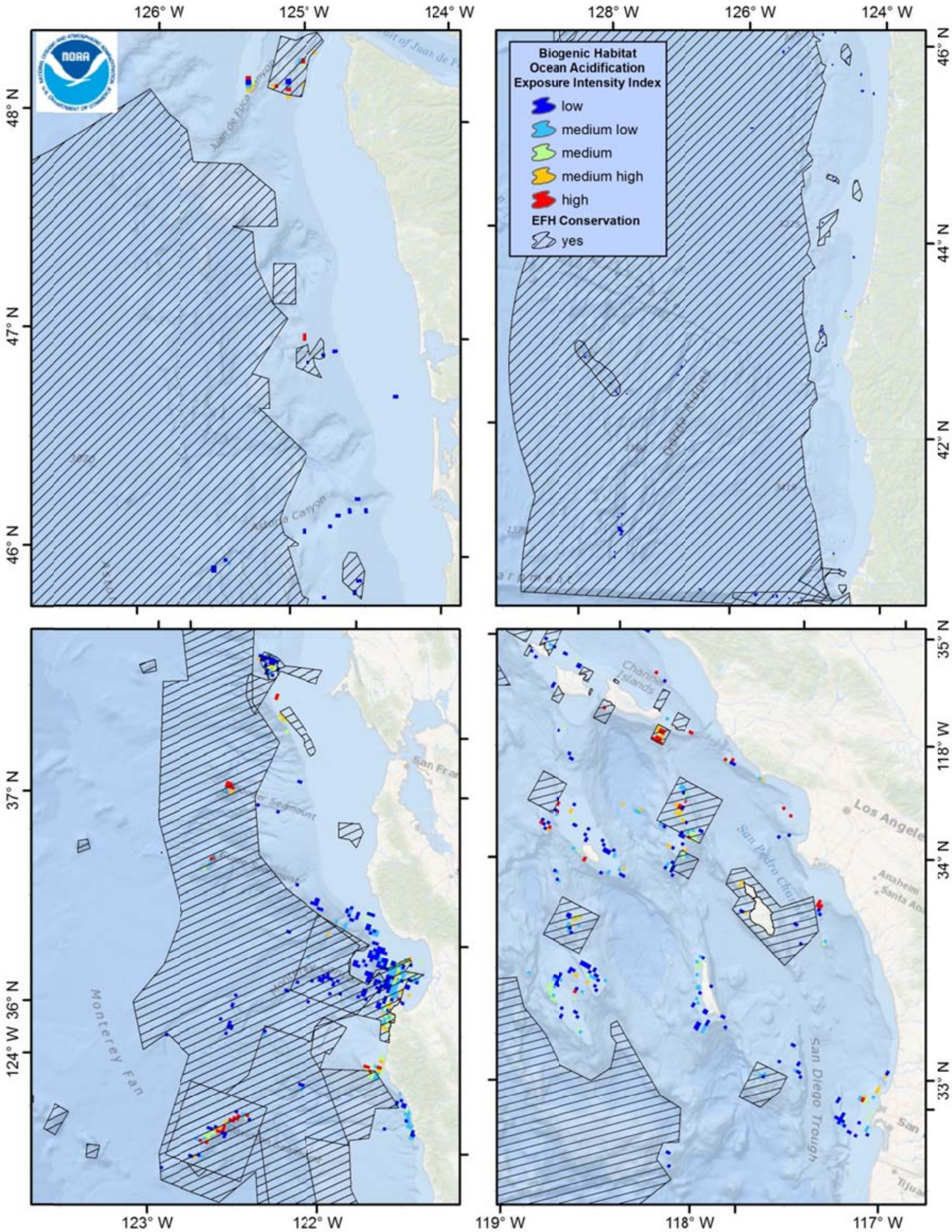


Figure A3b.64. Exposure intensity index of biogenic habitats using the database of coral and sponge occurrences described in Section 1 of this appendix. Locations with the highest exposure intensities are areas where large numbers of corals and sponges have been observed and where ocean acidification is predicted to be greatest. Essential Fish Habitat (EFH) conservation areas are overlaid. Note the entire coast is not shown to focus on areas where coral and sponge have been observed.

3.4.2 Sea-surface Temperature Anomalies

In general, global datasets show a rise in sea-surface temperatures since the 1970's (Hurrell and Trenberth 1999) and an increase in the ocean heat content since the 1950's (Levitus et al. 2005, Domingues et al. 2008). Rises in sea-surface temperature and ocean heat content have been linked with increases of greenhouse gases in the Earth's atmosphere (Levitus et al. 2001). With increasing ocean temperatures, marine species will have to adapt and they may do this in several ways. Some may simply be able to adjust their thermal tolerances (Young and Cech Jr 1996) if the changes occur slowly enough; however, this may come at a cost because energy allocation towards growth and reproduction declines at temperatures near the range extremes (Miller et al. 1988, Sogard and Olla 2002). Other species will likely exhibit behavioral thermoregulation, in that they will move to preferred temperatures or will have to move because their prey sources have moved. For example, the numbers and abundance of tropical species showing up in temperate habitats are slowly increasing because of increases in bottom water temperatures (1 – 6°C) over a 15-year period (Parker Jr and Dixon 1998). Moreover, two-thirds of the North Sea demersal fish assemblage has responded to increases in sea temperature by shifting their mean latitude or depth or both over a 25-year period (Perry et al. 2005).

In order to determine what areas of each species' distribution may be most at risk to temperature changes, we used the sea-surface temperature anomaly (SST) data layer from Halpern et al. (Halpern et al. 2009) and the across-year mean combined probability maps for each of the six groundfish species developed in Chapter 3. Each species distribution data layer was multiplied by the SST data layer. This product results in an exposure intensity index that shows where the threat of SST is likely to be of greatest concern to each species. For example, areas with high SST values and high probability values will have the highest exposure intensity values, while areas with low SST values and low probability values will have the lowest exposure intensity values.

Sea-surface temperature anomaly data shows relatively higher values in the northern biogeographic sub-region (Fig. A3b.65) and as a result, each species shows high exposure intensity values in the northern sub-region where the species is most likely to occur, regardless of whether the species is most likely to be found in offshore (longspine thornyhead: Fig. A3b.68; and sablefish: Fig. A3b.70), mid-depths (darkblotched: Fig. A3b.66; greenstriped: Fig. A3b.67; and yelloweye rockfish: Fig. A3b.71) or nearshore (petrale sole: Fig. A3b.69) waters.

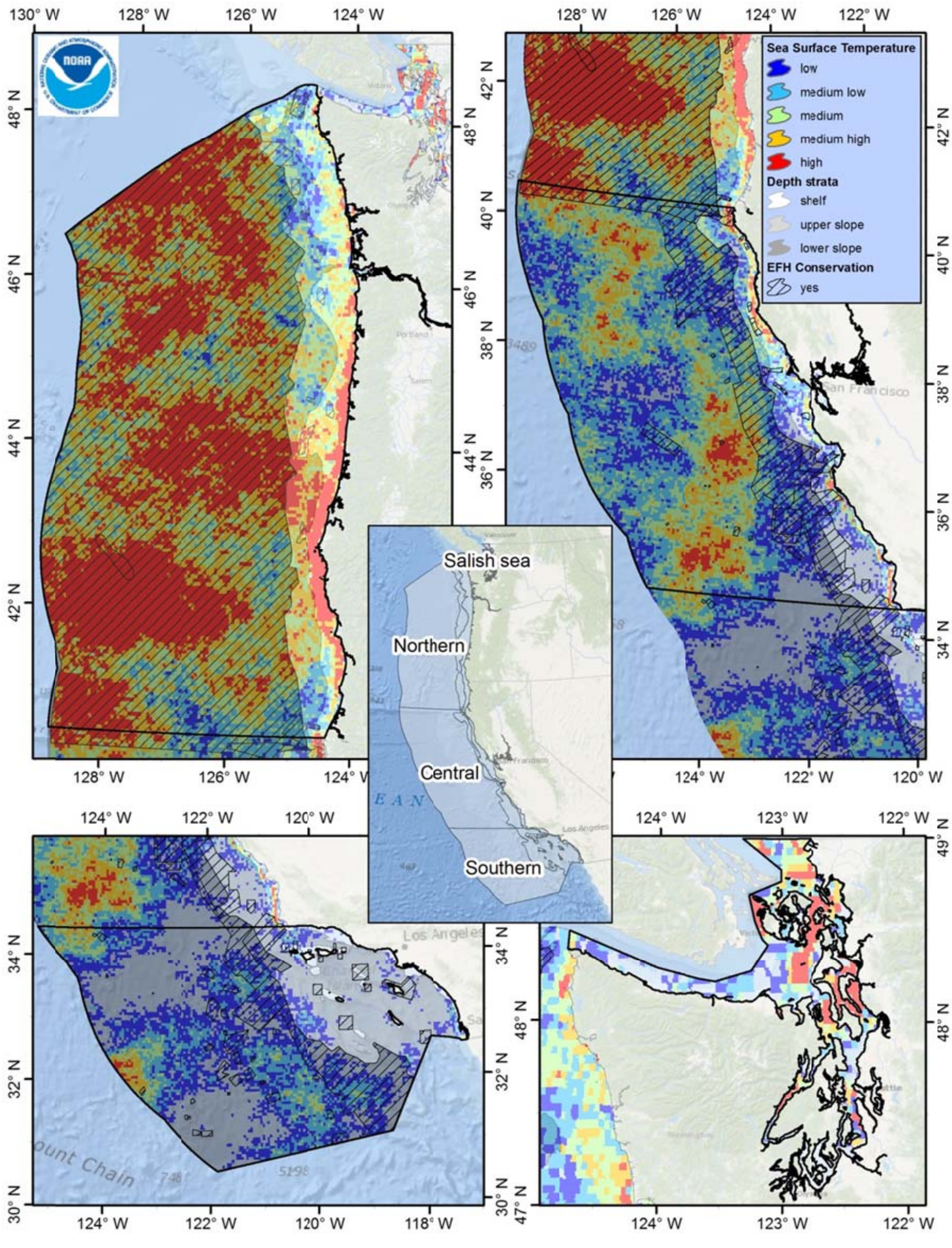


Figure A3b.65. Distribution of sea-surface temperature anomalies pressure intensity values among biogeographic regions, depth strata and essential fish habitat (EFH) conservation areas. Data for each pressure is from Halpern et al. 2009.

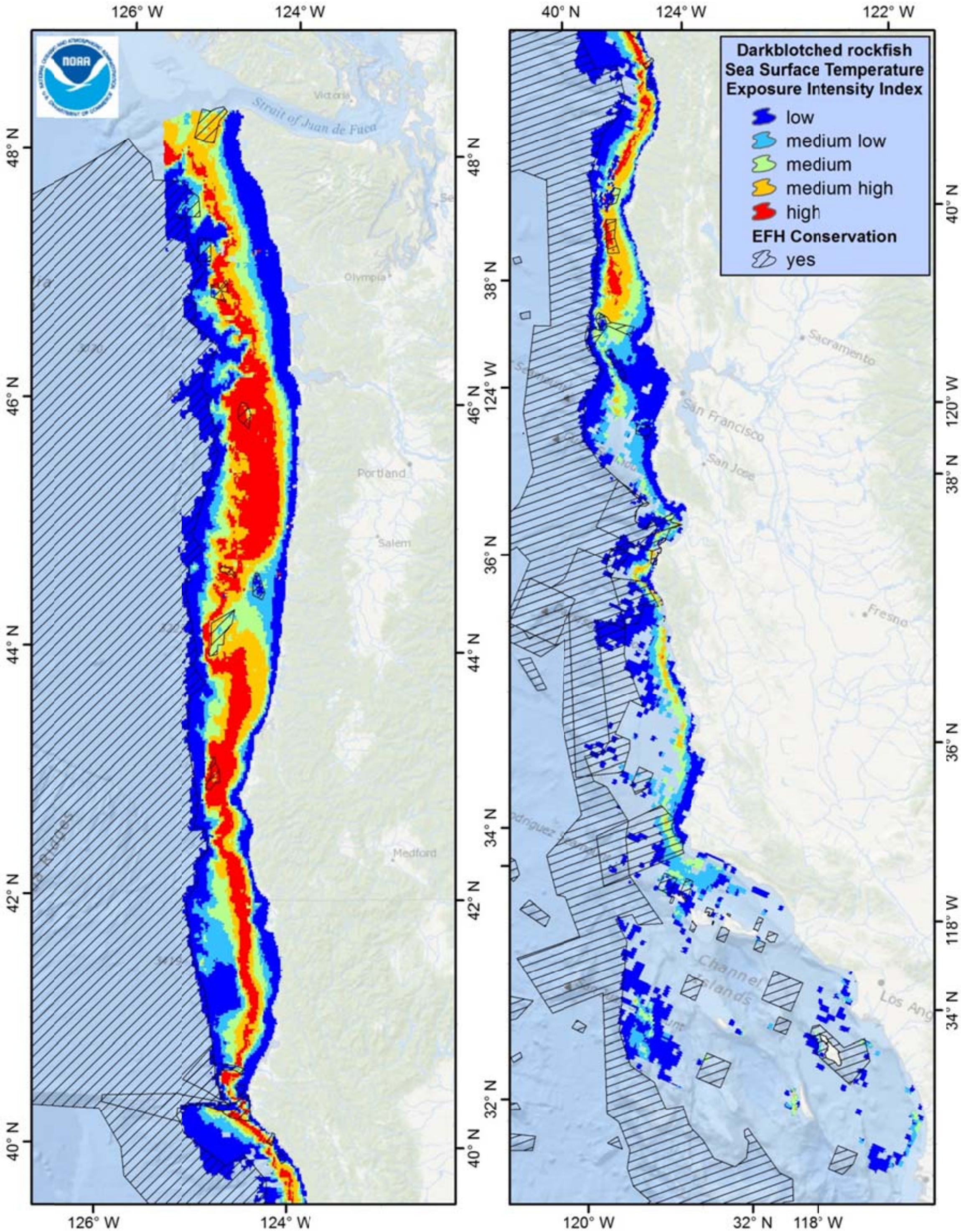


Figure A3b.66. Sea-surface temperature exposure intensity index for darkblotched rockfish *Sebastes crameri*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

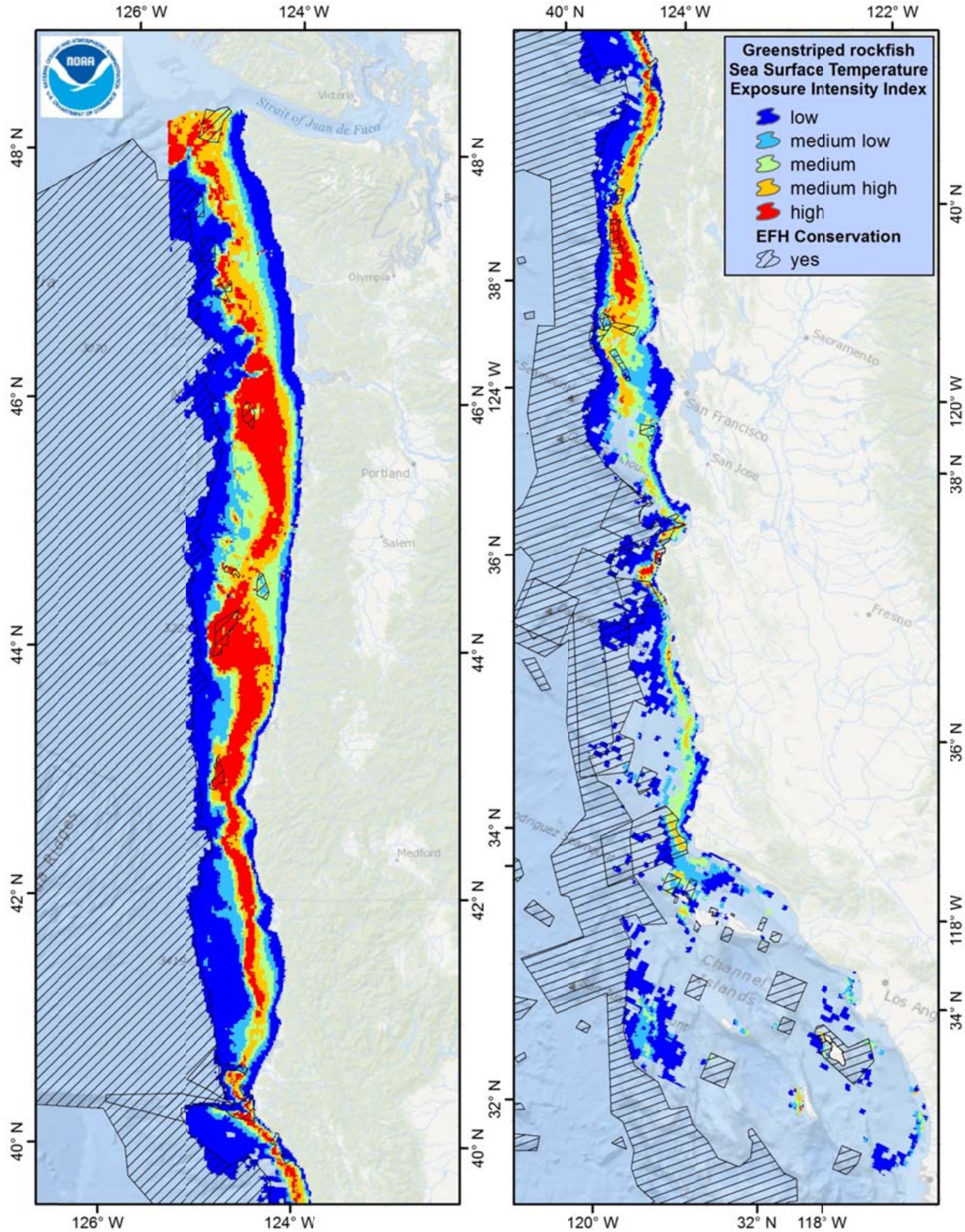


Figure A3b.67. Sea-surface temperature exposure intensity index for greenstriped rockfish *Sebastes elongatus*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

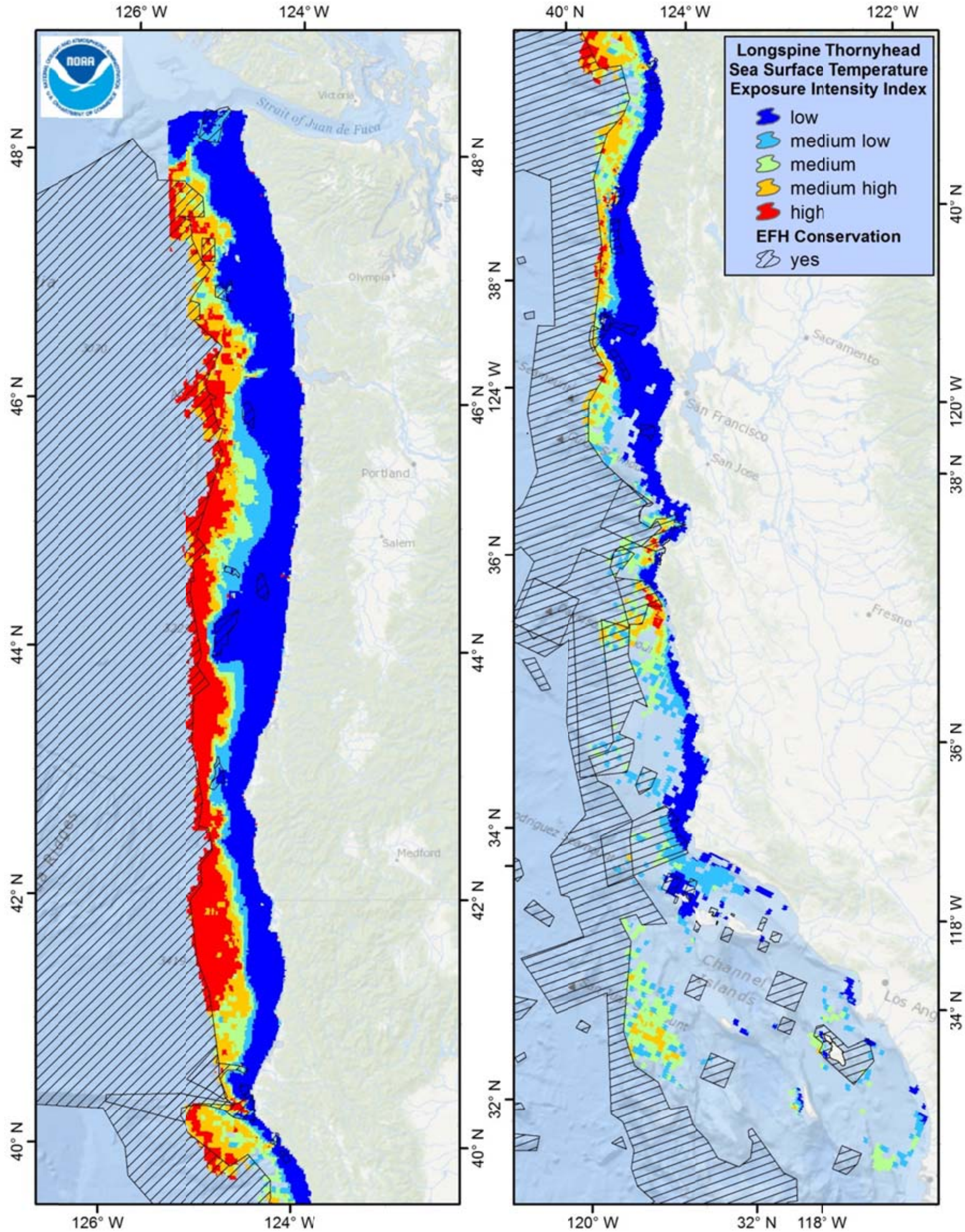


Figure A3b.68. Sea-surface temperature exposure intensity index for longspine thornyhead *Sebastolobus altivelis*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

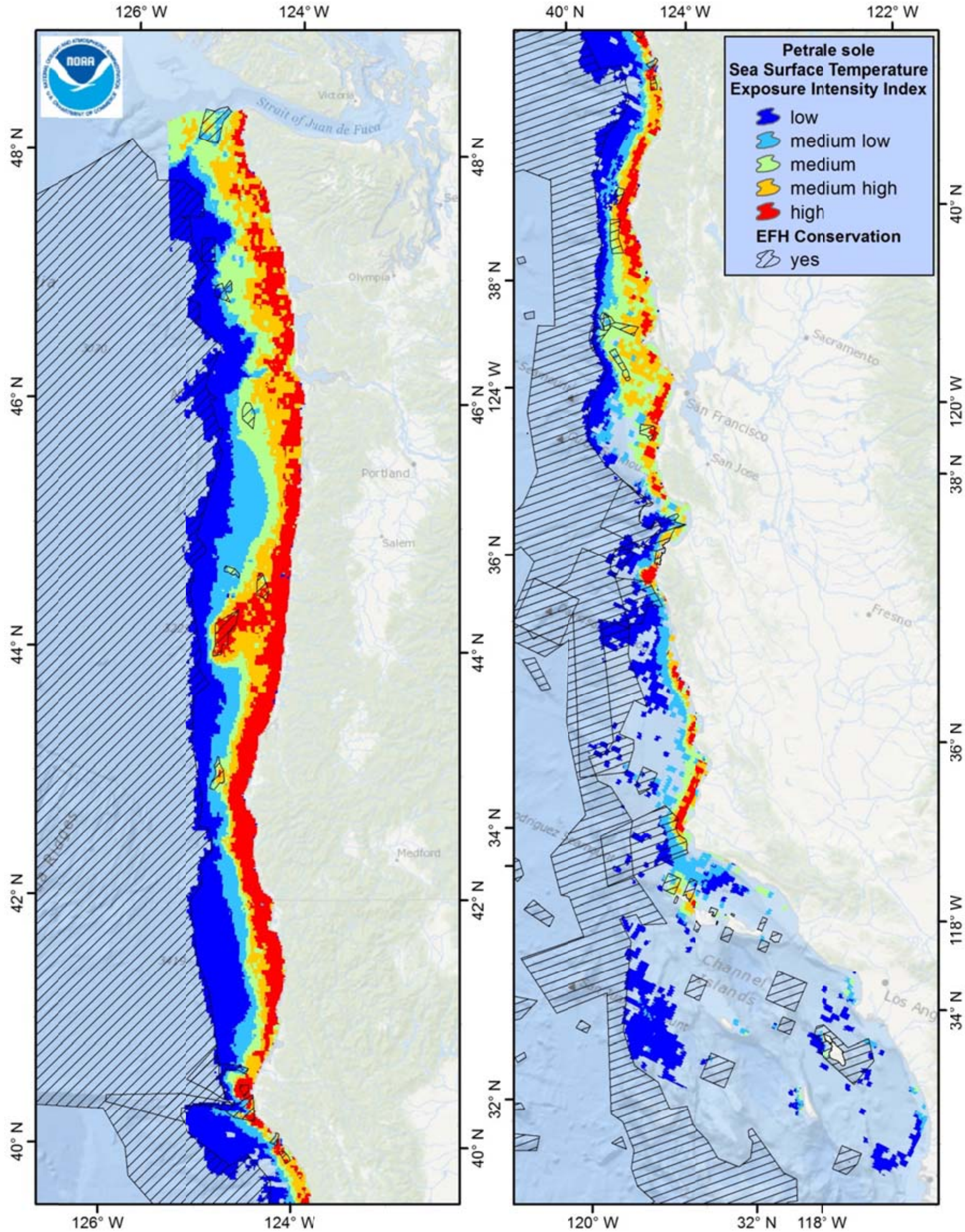


Figure A3b.69. Sea-surface temperature exposure intensity index for petrale sole *Eopsetta jordani*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

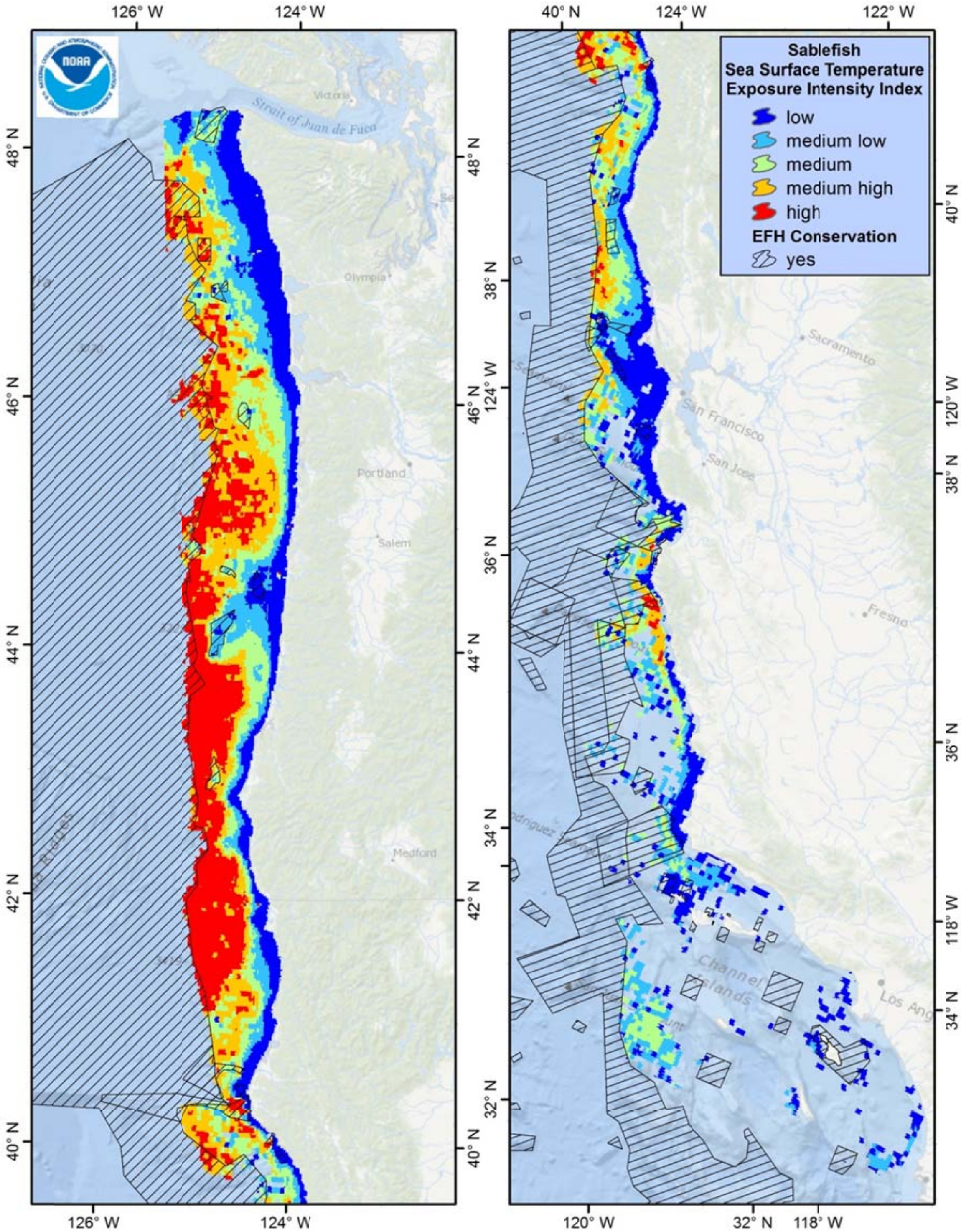


Figure A3b.70. Sea-surface temperature exposure intensity index for sablefish *Anoplopoma fimbria*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

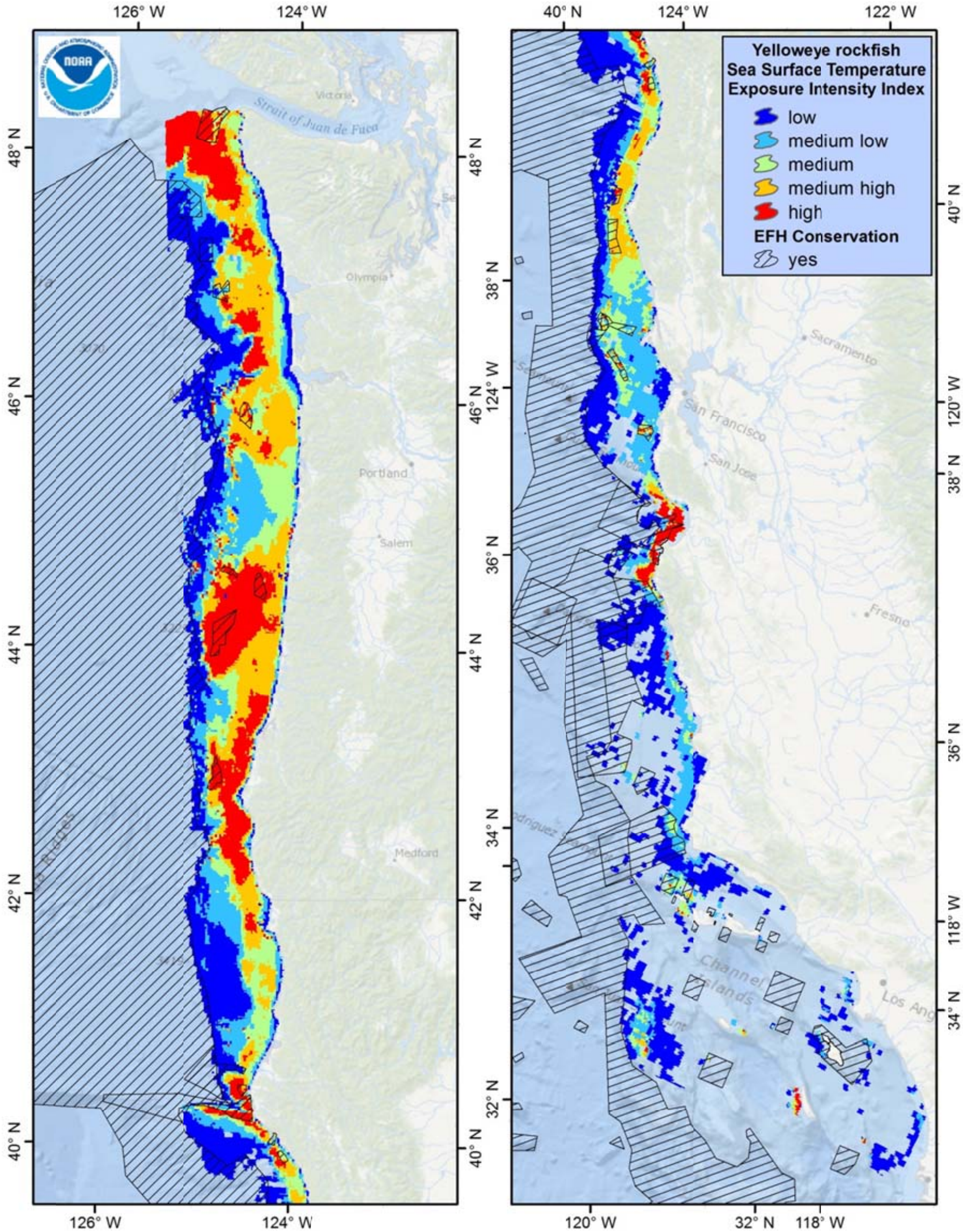


Figure A3b.71. Sea-surface temperature exposure intensity index for yelloweye rockfish *Sebastes ruberrimus*. Exposure intensity values represent the product of the probability of species occurrence (see individual species-habitat maps in Section 2 of this appendix) and the sea-surface temperature anomaly pressure (see Halpern et al. 2008, 2009) data layers. Exposure intensity values were classified and shown by quintiles (20% of the data in each color). Essential Fish Habitat (EFH) conservation areas are overlaid.

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4.0 METHODS FOR EXAMINING PREDATOR/PREY RELATIONSHIPS

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4.1 INFORMATION USED TO EVALUATE DIET COMPOSITION OF SELECT GROUNDFISH SPECIES

PETRALE SOLE. Author(s) and year of publication, number of stomachs with prey (*n*), sampling year, sampling method, study region, size range (SL = standard length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight; %IRI = percent index of relative importance) for petrale sole (*Eopsetta jordani*). U = unknown.

Study	*n*	Year	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Morejohn et al. 1978	10	1978	Trolling, set lines, trawls	Central CA	U	U	37 - 73	%IRI
Morejohn et al. 1978	4	1978	Trolling, set lines, trawls	Southern CA	U	U	55 - 73	%IRI
Wakefield 1984	29	1979	Trawl	OR	10 - 32 SL	Juvenile - Adult	73	%W

DOVER SOLE. Author(s) and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (SL = standard length; FL = fork length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight) for Dover sole *(Microstomus pacificus*). U = unknown.

Study	*n*	Year(s)	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Pearcy and Hancock 1978	326	1968 - 1970	Beam trawl	OR	5 - 45 SL	Juvenile - Adult	74 - 195	%W
Gabriel and Pearcy 1981	202	1976	Beam trawl	OR	11 - 42 SL	Juvenile - Adult	119	%W
Gabriel and Pearcy 1981	202	1976	Beam trawl	OR	11 - 42 SL	Juvenile - Adult	426	%W
Allen 1982	23	1973 - 1977	Trawl	Southern CA	U	U	88 - 182	%W
Manzanilla and Cross 1982	38	1980	Trawl	Santa Monica Bay, CA	U	U	60	%W
Wakefield 1984	24	1979	Trawl	OR	10 - 22 SL	Juvenile - Adult	73	%W
Buckley et al. 1999	262	1989	Trawl	Point Conception, CA - Cape Blanco, OR	15 - 54 FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	261	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	15 - 54 FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	116	1991	Trawl	Point Conception, CA - Cape Blanco, OR	25 - 54 FL	Juvenile - Adult	366 - 1279	%W
Buckley et al. 1999	131	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	20 - 54 FL	Juvenile - Adult	183 - 1279	%W

SABLEFISH. Author(s) and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (FL = fork length; SL = standard length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight; %V = percent volume) for sablefish (*Anoplopoma fimbria*). U = unknown. * = mean length (+ SD).

Study	*n*	Year(s)	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Conway 1967	556	1965 - 1966	Set lines, purse seine	Southern CA - Northern Baja	5 - 75 FL	Juvenile - Adult	Surface waters, 366 - 549	%W
Allen 1982	12	1972 - 1973	Trawl	Southern CA	U	U	30 - 190	%V
Laidig et al. 1997	1868	1987 - 1992	Trawl	OR - CA	25 - 75 FL	Juvenile - Adult	183 - 1280	%V
Cailliet et al. 1988	19	1973 - 1974	Traps, otter trawl, gill nets, angling	Monterey Bay, CA	20 - 30 SL	Juvenile	92 - 915	%V
Cailliet et al. 1988	295	1973 - 1974	Traps, otter trawl, gill nets, angling	Monterey Bay, CA	31 - 91 SL	Juvenile - Adult	92 - 549	%W
Buckley et al. 1999	129	1989	Trawl	Point Conception, CA - Cape Blanco, OR	20 - 59 FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	129	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	20 - > 70 FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	88	1991	Trawl	Point Conception, CA - Cape Blanco, OR	40 - > 70 FL	Juvenile - Adult	366 - 1279	%W
Buckley et al. 1999	76	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	40 - 69 FL	Juvenile - Adult	183 - 1279	%W
Miller and Brodeur 2007	6	2000	Trawl	OR - Northern CA	16 (± 2) FL*	Juvenile	< 18	%W
Miller and Brodeur 2007	15	2002	Trawl	OR - Northern CA	18 (± 9) FL*	Juvenile	< 18	%W

LINGCOD. Author(s) and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (FL = fork length; SL = standard length; TL = total length), maturity (after Miller and Brodeur, 2007; Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight) for lingcod *Ophiodon elongatus*). * = mean length (± SD).

Study	*n*	Year(s)	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Steiner 1978	68	1976 - 1977	Angling	OR	40 - 115 FL	Juvenile - Adult	10 - 50	%W
Wakefield 1984	4	1979	Trawl	OR	22 - 65 SL	Juvenile - Adult	73	%W
Beaudreau and Essington 2007	13	2004 - 2005	Beach seine	San Juan Archipelago, WA	10 - 20 TL	Juvenile	< 5	%W
Beaudreau and Essington 2007	385	2004 - 2005	Angling	San Juan Archipelago, WA	31 - 110 TL	Juvenile - Adult	9 - 55	%W
Miller and Brodeur 2007	10	2000	Trawl	OR - Northern CA	7 (± 4) FL*	Juvenile	< 18	%W
Miller and Brodeur 2007	1	2002	Trawl	OR - Northern CA	6 FL*	Juvenile	< 18	%W

GREEENSTRIPED ROCKFISH. Author and year of publication, number of stomachs with prey (*n*), sampling years, sampling method, study region, size range (TL = total length; FL = fork length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (%V = percent volume; %W = percent weight) for greenstriped rockfish (*Sebastes elongatus*). U = unknown. * = mean length (+ SD).

Study	*n*	Years	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Allen 1982	12	1965-1980	Trawl	Southern CA	4 - 31 TL	Juvenile - Adult	90 - 274	%V
Shaw 1999	47	1986	Trawl	CA to WA	21 - 35 TL	Juvenile - Adult	< 500	%W
York 2005	51	2003-2004	Trawl	Central CA - Canadian Border	27 (+ 5) FL*	Juvenile - Adult	U	%W

ROSETHORN ROCKFISH. Author and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (TL = total length; FL = fork length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (%W = percent weight; %V = percent volume) for rosethorn rockfish (*Sebastes helvomaculatus*). U = unknown. * = mean length (+ SD).

Study	*n*	Years	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Shaw 1999	8	1986	Trawl	CA to WA	20 - 30 TL	Juvenile - Adult	< 500	%W
York 2005	60	2003 - 2004	Trawl	Central CA - Canadian Border	26 (+ 3) FL*	Juvenile - Adult	U	%V

SHARPCHIN ROCKFISH. Author and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (FL = fork length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight) for sharpchin rockfish *(Sebastes zacentrus*). U = unknown. * = mean length (+ SD).

Study	*n*	Year(s)	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Shaw 1999	8	1986	Trawl	OR	U	U	25 - 444	%W
York 2005	36	2003 - 2004	Trawl	Central CA - Canadian Border	27 (+ 4) FL*	Juvenile - Adult	U	%W

DARKBLOTCHED ROCKFISH. Authors and year of publication, number of stomachs with prey (*n*), sampling year, sampling method, study region, size range (TL = total length; FL = fork length), maturity (after Miller and Brodeur 2007), sampling depth, and metric used in diet composition calculations (% W = percent weight) for darkblotched rockfish (*Sebastes crameri*). * = mean length (+ SD).

Study	*n*	Year	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Brodeur and Pearcy 1984	20	1980	Trawl	Northern CA to Vancouver Island, BC	33 (+ 8) TL*	Juvenile - Adult	55 - 366	%W
Miller and Brodeur 2007	7	2000	Trawl	OR to Northern CA	5 (+ 0.4) FL*	Juvenile	< 18 m	%W
Miller and Brodeur 2007	11	2002	Trawl	OR to Northern CA	3 (+ 0.2) FL*	Juvenile	< 18 m	%W

YELLOWEYE ROCKFISH. Author and year of publication, number of stomachs with prey (*n*), sampling years, sampling method, study region, size range (FL = fork length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight) for yelloweye rockfish (*Sebastes ruberrimus*). U= unknown. * = mean length (+ SD).

Study	*n*	Year	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Steiner 1978	28	1976 - 1977	Angling	OR	U	U	10 - 30	%W
York 2005	9	2003 - 2004	Trawl	Central CA - Canadian Border	35 (+ 19) FL*	Juvenile - Adult	U	%W

LONGSPINE THORNYHEAD. Author(s) and year of publication, number of stomachs with prey (*n*), sampling year(s), sampling method, study region, size range (FL = fork length; SL = standard length), maturity (after Love 2011), sampling depth, and metric used in diet composition calculations (% W = percent weight; %V = percent volume) for longspine thornyhead *(Sebastolobus altivelis*).

Study	*n*	Year	Method	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Buckley et al. 1999	168	1991	Trawl	Point Conception, CA - Cape Blanco, OR	5 - 34 FL	Juvenile - Adult	366 - 1279	%W
Buckley et al. 1999	113	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	5 - 34 FL	Juvenile - Adult	366 - 1279	%W
Laidig, unpublished data; Field 2004	959	1988 - 1990	Trawl	OR - CA	6-32 SL	Juvenile - Adult	183 - 1280	%V

PACIFIC HAKE. Author(s) and year of publication, number of stomachs with prey (*n*), sampling years, sampling method, study region, size range (TL = total length; TL* = presumed total length; FL = fork length, SL = standard length), maturity, (after Love 2011, Gustafson et al. 2000), sampling depth, and metric used in diet composition calculations (% V = percent volume; %IRI = percent index of relative importance, %W = perecent weight) for the Pacific hake (*Merluccius productus*). U = unknown. * = mean length.

Study	*n*	Year(s)	Method(s)	Study Region	Size Range (cm)	Maturity	Depth (m)	Diet Metric
Gotshall 1969	449	1964 - 1965	Trawl	Northern CA	10 - 82 TL	Juvenile - Adult	≤ 338	%V
Morejohn et al. 1978	13	1978	Trolling, set lines, trawls	Central CA	U	U	37 - 73	%IRI
Morejohn et al. 1978	4	1978	Trolling, set lines, trawls	Southern CA	U	U	55 - 73	%IRI
Livingston 1983	202	1967	Trawl	OR	49* TL*	U	< 100	%W
Livingston 1983	1,228	1967	Trawl	WA	50* TL*	U	< 100	%W
Livingston 1983	40	1980	Trawl	CA	< 20 TL*	Juvenile	77 - 298	%W
Livingston 1983	16	1980	Trawl	OR	35 - 45 TL*	Juvenile - Adult	77 - 298	%W
Livingston 1983	17	1980	Trawl	OR	45 - 55 TL*	Adult	77 - 298	%W
Livingston 1983	20	1980	Trawl	OR	≥ 55 TL*	Adult	77 - 298	%W
Livingston 1983	70	1980	Trawl	WA - Vancouver Island, BC	45 - 55 TL*	Adult	77 - 298	%W
Livingston 1983	41	1980	Trawl	WA - Vancouver Island, BC	≥ 55 TL*	Adult	77 - 298	%W
Rexstad and Pikitch 1986	4	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	30 - 34 TL*	Juvenile - Adult	< 200	%W
Rexstad and Pikitch 1986	94	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	35 - 39 TL*	Juvenile - Adult	< 200	%W
Rexstad and Pikitch 1986	69	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	40 - 44 TL*	Juvenile - Adult	< 200	%W
Rexstad and Pikitch 1986	77	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	45 - 49 TL*	Adult	< 200	%W
Rexstad and Pikitch 1986	82	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	50 - 54 TL*	Adult	< 200	%W
Rexstad and Pikitch 1986	21	1983	Trawl	Cape Blanco, OR - Cape Flattery, WA	≥ 55 TL*	Adult	< 200	%W
Brodeur et al. 1987	28	1981	Purse Seine	Cape Blanco, OR - Cape Flattery, WA	43 - 60 FL	Adult	15 - 65	%W
Brodeur et al. 1987	58	1982	Purse Seine	Cape Blanco, OR - Cape Flattery, WA	31 - 63 FL	Juvenile - Adult	15 - 65	%W
Brodeur et al. 1987	10	1983	Purse Seine	Cape Blanco, OR - Cape Flattery, WA	46 - 62 FL	Adult	15 - 65	%W
Brodeur et al. 1987	60	1984	Purse Seine	Cape Blanco, OR - Cape Flattery, WA	37 - 59 FL	Juvenile - Adult	15 - 65	%W
Buckley and Livingston 1997	1	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	20 - 29 FL	Juvenile	55 - 366	%W
Buckley and Livingston 1997	3	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	30 - 39 FL	Juvenile - Adult	55 - 366	%W
Buckley and Livingston 1997	495	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	40 - 49 FL	Juvenile - Adult	55 - 366	%W
Buckley and Livingston 1997	180	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	50 - 59 FL	Adult	55 - 366	%W
Buckley and Livingston 1997	15	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	≥ 60 FL	Adult	55 - 366	%W
Buckley and Livingston 1997	58	1989	Trawl	Point Conception, CA - Cape Blanco, OR	10 - 19 FL	Juvenile	55 - 366	%W
Buckley and Livingston 1997	29	1989	Trawl	Point Conception, CA - Cape Blanco, OR	20 - 29 FL	Juvenile	55 - 366	%W
Buckley and Livingston 1997	38	1989	Trawl	Point Conception, CA - Cape Blanco, OR	30 - 39 FL	Juvenile - Adult	55 - 366	%W
Buckley and Livingston 1997	146	1989	Trawl	Point Conception, CA - Cape Blanco, OR	40 - 49 FL	Adult	55 - 366	%W
Buckley and Livingston 1997	30	1989	Trawl	Point Conception, CA - Cape Blanco, OR	50 - 59 FL	Adult	55 - 366	%W
Buckley and Livingston 1997	1	1989	Trawl	Point Conception, CA - Cape Blanco, OR	≥ 60 FL	Adult	55 - 366	%W
Buckley and Livingston 1997	10	1991	Trawl	Point Conception, CA - Cape Blanco, OR	10 - 19 FL	Juvenile	183 - 1280	%W
Buckley and Livingston 1997	58	1991	Trawl	Point Conception, CA - Cape Blanco, OR	20 - 29 FL	Juvenile	183 - 1280	%W
Buckley and Livingston 1997	26	1991	Trawl	Point Conception, CA - Cape Blanco, OR	30 - 39 FL	Juvenile - Adult	183 - 1280	%W
Buckley and Livingston 1997	28	1991	Trawl	Point Conception, CA - Cape Blanco, OR	40 - 49 FL	Adult	183 - 1280	%W
Buckley and Livingston 1997	7	1991	Trawl	Point Conception, CA - Cape Blanco, OR	50 - 59 FL	Adult	183 - 1280	%W
Buckley and Livingston 1997	2	1991	Trawl	Point Conception, CA - Cape Blanco, OR	≥ 60 FL	Adult	183 - 1280	%W
Buckley and Livingston 1997	1	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	30 - 39 FL	Juvenile - Adult	183 - 1280	%W
Buckley and Livingston 1997	70	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	40 - 49 FL	Juvenile - Adult	183 - 1280	%W
Buckley and Livingston 1997	3	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	50 - 59 FL	Adult	183 - 1280	%W
Buckley et al. 1999	62	1987	Trawl	Central CA	3 - 10 FL	Juvenile	U	%W
Buckley et al. 1999	302	1988	Trawl	Central CA	3 - 13 FL	Juvenile	U	%W
Buckley et al. 1999	302	1989	Trawl	Point Conception, CA - Cape Blanco, OR	10 - 60+ FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	694	1989	Trawl	Cape Blanco, OR - Vancouver Island, Canada	20 - 60+ FL	Juvenile - Adult	55 - 364	%W
Buckley et al. 1999	131	1991	Trawl	Point Conception, CA - Cape Blanco, OR	10 - 60+ FL	Juvenile - Adult	183 - 913	%W
Buckley et al. 1999	74	1992	Trawl	Cape Blanco, OR - Vancouver Island, Canada	30 - 59 FL	Juvenile - Adult	183 - 913	%W

Grover et al. 2002	151	1995	Trawl	Central CA	1 - 8 SL	Juvenile	30	%V
Grover et al. 2002	250	1997	Trawl	Central CA	1 - 8 SL	Juvenile	30	%V
Grover et al. 2002	240	1998	Trawl	Central CA	1 - 8 SL	Juvenile	30	%V
Grover et al. 2002	253	1999	Trawl	Central CA	1 - 8 SL	Juvenile	30	%V
Miller and Brodeur 2007	72	2002	Trawl	Northern CA - OR	5* FL	Juvenile	≤ 18	%W

References

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5.0 RELEVANT MARINE PROTECTED AREAS

Various map figures presented here (Figure A5.1 map plates) and elsewhere within the Synthesis Report and its associated appendix depict the spatial distribution of selected federal and state marine protected areas (MPA). The source of these GIS layers is the MPA Inventory (vers. 3, Mar 2012); a collaboration between NOAA's MPA Center and the Department of the Interior. MPAs included in the Pacific Fishery Management Council (PFMC) region were designated between 1909 and 2012, with 150 MPAs designated since implementation of Amendment 19 regulations (Table A5.1). These include Pacific coast groundfish EFH conservations areas (n=51), California State MPAs designated as part of the Marine Life Protection Act (n=94), and non-trawl and recreational Rockfish Conservation Areas (n=5). In addition to those MPAs included in the National MPA Inventory, 3 additional areas were added since all three prohibit the use of bottom trawls. These include the state territorial seas of Washington and California, and the NMFS trawl rockfish conservation area (RCA) between the 100- and 150-ftm RCA boundaries. See Table A5.2 for a complete list of MPAs included in the inventory for the PFMC region.

In order to explore physical and biogenic habitats in the context of various protected areas, MPAs were further categorized by gear prohibitions, if applicable. For example, MPAs designated as "no-take" or where commercial fishing is "prohibited" in fact prohibit the use of any of the three main gear types (bottom trawl, midwater trawl, fixed gears). In contrast, MPAs classified as "restricted" to commercial fishing typically prohibit the use of only one gear type (usually bottom trawl) while allowing the use of fixed gears. Unfortunately, not all MPAs were designated with specific gear prohibitions in mind. For example, state conservations areas off California were often designed to protect selected fish and invertebrate species, while allowing take of a limited set of organisms (e.g., pelagic finfish, lobster). These are often classified as having commercial fishing "restricted." Despite this distinction, most of the state territorial sea of California (including these conservation areas) is closed to bottom trawling.

In addition to MPAs in the inventory where either commercial fishing is prohibited or bottom trawling is prohibited, the trawl rockfish conservation area (RCA) also prohibits the use of bottom trawls within certain depth ranges. The RCA is a type of time-area closure, with the shoreward and seaward boundaries being adjusted, sometimes monthly, as a result of varying levels of bycatch of overfished species. Despite this dynamic type of closure, an area between the 100- and 150-fathom RCA lines has been closed consistently since the inception of the RCA in 2002. Consequently, we incorporated this area into our regional layer of bottom trawl closures.

References

NMPAC (National Marine Protected Areas Center). 2012. Marine Protected Areas Inventory, vers. 3, Mar 2012.

Table A5.1. Summary of federal and state MPAs depicted in map figures, categorized by level of fishing restriction and time period of designation. "Before" means MPA was designated prior to 2006 and "After" between 2006 and 2012. Data Source: National Marine Protected Areas Center, Marine Protected Areas Inventory, vers. 3, Mar 2012.

	# MPAs	
FISHING RESTRICTION	BEFORE	AFTER
Commercial and Recreational Fishing Prohibited	33	48
Commercial Fishing Prohibited	0	1
Commercial Fishing Prohibited and Recreational Fishing Restricted	10	14
Commercial Fishing Restricted	7	54
Commercial and Recreational Fishing Restricted	39	28
Commercial Fishing Restricted and Recreational Fishing Prohibited	3	1
Recreational Fishing Prohibited	0	1
Recreational Fishing Restricted	11	3
Restrictions Unknown	2	0
No Site Restrictions	3	0
Total	**108**	**150**

Table A5.2. List of marine protected areas (MPAs) with relevant attributes including year established, level of government designation, type of fishing restriction, and temporal nature. Values in the "MPA ID" column correspond to labels in the map figures. MPA type and agency abbreviations are listed in Tables 3 and 4, respectively. Data Source: National Marine Protected Areas Center, Marine Protected Areas Inventory, vers. 3, Mar 2012. In addition to those MPAs included in the National MPA Inventory, 3 additional areas were added since all three prohibit or restrict bottom trawling. These include the state territorial seas of Washington and California, and the NMFS trawl rockfish conservation area (RCA) between the 100- and 150-ftm RCA boundaries.

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
CA100	MacKerricher SMCA	1970	CDPR	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA102	Russian Gulch SMCA	1970	CDPR	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA104	Van Damme SMCA	1970	CDPR	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA136	Richardson Rock SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA137	Judith Rock SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA138	Harris Point SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA139	Skunk Point SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA140	Carrington Point SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA141	South Point SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA142	Gull Island SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA143	Scorpion SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA144	Santa Barbara Island SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA145	Anacapa Island SMR	2003	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA146	Anacapa Island SMCA	2003	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA147	Painted Cave SMCA	2003	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA151	Anacapa Island SC (B)	2005	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Seasonal
CA201	A±o Nuevo SMCA	2007	CDFG	State	Commercial Fishing Restricted and Recreational Fishing Prohibited	Permanent	Year-round
CA202	Greyhound Rock SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA203	Natural Bridges SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA204	Elkhorn Slough SMR	1980	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA205	Elkhorn Slough SMCA	2007	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA206	Moro Cojo Slough SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA207	Soquel Canyon SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA208	Portugese Ledge SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA209	Edward F. Ricketts SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA210	Lovers Point SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
CA211	Pacific Grove MG SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA212	Asilomar SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA213	Carmel Pinnacles SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA214	Carmel Bay SMCA	1976	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA215	Point Lobos SMR	1973	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA216	Point Lobos SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA217	Point Sur SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA218	Point Sur SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA219	Big Creek SMR	1994	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA220	Big Creek SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA221	Piedras Blancas SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA222	Piedras Blancas SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA223	Cambria SMCA	2007	CDFG	State	Commercial Fishing Prohibited	Permanent	Year-round
CA224	White Rock SMCA	2007	CDFG	State	Commercial Fishing Restricted	Permanent	Year-round
CA225	Morro Bay SMRMA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA226	Morro Bay SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA227	Point Buchon SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA228	Point Buchon SMCA	2007	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA229	Vandenberg SMR	1994	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA230	Anacapa SC (A)	2005	CDFG	State	Commercial Fishing Restricted	Permanent	Year-round
CA231	Footprint SMR	2007	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA233	Point Arena SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA234	Point Arena SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA235	Sea Lion Cove SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA236	Saunders Reef SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA237	Del Mar Landing SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA238	Stewarts Point SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA239	Salt Point SMCA	2010	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA240	Gerstle Cove SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA241	Russian River SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
CA242	Russian River SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA243	Bodega Head SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA244	Bodega Head SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA245	Estero Americano SMRMA	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA246	Estero de San Antonio SMRMA	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA247	Drakes Estero SMCA	2010	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA248	Estero de Limantour SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA249	Point Reyes SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA250	Point Reyes SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA251	Duxbury SMCA	2010	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA252	Southeast Farallon Island SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA253	Southeast Farallon Island SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA254	Montara SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA255	Pillar Point SMCA	2010	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA256	Point Reyes Headlands SC	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA257	Point Resistance SC	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA258	Double Point/Stormy Stack SC	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA259	Egg Rock (Devils Slide) SC	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA260	North Farallon Islands SC	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA261	Southeast Farallon SC (A)	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA262	North Farallon Islands SMR	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA263	Southeast Farallon SC (B)	2010	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Seasonal
CA264	Stewarts Point SMCA	2010	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA265	Point Conception SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA266	Kashtayit SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA267	Naples SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA268	Campus Point SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA269	Goleta Slough SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA270	Begg Rock (San Nicolas Island Quad) SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
CA271	Point Dume SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA272	Point Dume SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA273	Point Vicente SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA274	Abalone Cove SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA275	Bolsa Bay SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA276	Bolsa Chica Basin SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA277	Arrow Point to Lion Head Point (Catalina Island) SMCA	2012	CDFG	State	Recreational Fishing Prohibited	Permanent	Year-round
CA278	Blue Cavern (Catalina Island) SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA279	Bird Rock (Catalina Island) SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA280	Long Point (Catalina Island) SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA281	Casino Point (Catalina Island) SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA282	Lover's Cove (Catalina Island) SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA283	Farnsworth Onshore (Catalina Island) SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA284	Farnsworth Offshore (Catalina Island) SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA285	Cat Harbor (Catalina Island) SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA286	Upper Newport Bay SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA287	Crystal Cove SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA288	Laguna Beach SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA289	Laguna Beach SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA290	Dana Point SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA291	Batiquitos Lagoon SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA292	Swami's SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA293	San Elijo Lagoon SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA294	San Diego-Scripps Coastal SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
CA295	Matlahuayl SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA296	South La Jolla SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA297	South La Jolla SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA298	Famosa Slough SMCA	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA299	Cabrillo SMR	2012	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA300	Tijuana River Mouth SMCA	2012	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA301	San Dieguito Lagoon SMCA	2012	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA38	Albany Mudflats SMP	1986	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA40	Bair Island SMP	1986	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA45	Corte Madera Marsh SMP	1976	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA48	Fagan Marsh SMP	1979	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA49	Farnsworth Bank SMCA	1972	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
CA52	Marin Islands SMP	1993	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA53	Peytonia Slough SMP	1976	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA54	Redwood Shores SMP	1976	CDFG	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
CA67	Punta Gorda SMR	1994	CDFG	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
CA90	Lover's Cove SMCA	1974	CDFG	State	Commercial Fishing Restricted and Recreational Fishing Prohibited	Permanent	Year-round
CA92	Point Cabrillo SMCA	1975	CDFG	State	Commercial Fishing Restricted and Recreational Fishing Prohibited	Permanent	Year-round
CA94	Robert W. Crown SMCA	1980	CDFG	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NER21	South Slough NERR	1974	ODSL & NOAA	Partnership	Commercial Fishing Restricted	Permanent	Year-round
NER22	Tijuana River NERR	1982	CDPR & NOAA	Partnership	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NMF235	North Coast Commercial YRCA	2007	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF236	Salmon Troll YRCA	2007	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF237	South Coast Recreational YRCA	2007	NMFS	Federal	Recreational Fishing Restricted	Permanent	Year-round
NMF238	Westport Offshore Recreational YRCA	2009	NMFS	Federal	Recreational Fishing Restricted	Permanent	Year-round
NMF239	Stonewall Bank YRCA	2007	NMFS	Federal	Recreational Fishing Restricted	Permanent	Year-round
NMF35	Columbia River Salmon CZ	1992	NMFS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NMF36	Klamath River Salmon CZ	1992	NMFS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
NMF74	North Coast Recreational Yelloweye RCA	2003	NMFS	Federal	Recreational Fishing Restricted	Permanent	Year-round
NMF80	Western and Eastern CCAs	2001	NMFS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NMF900	Biogenic 1 EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF901	Biogenic 2 EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF902	Biogenic 3 EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF903	Gray's Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF904	Olympic 2 EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF905	Astoria Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF906	Bandon High Spot EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF907	Daisy Bank/Nelson Island EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF908	Deepwater off Coos Bay EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF909	Heceta Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF910	Nahelem Bank/Shale Pile EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF911	Newport Rockpile/Stonewall Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF912	Rogue Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF913	Siletz Deepwater EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF914	Big Sur/Port San Luis EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF915	Blunt's Reef EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF916	Catalina Island EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF917	Cherry Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF918	Cordell Bank/Biogenic Area EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF919	CCA East EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF920	Delgada Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF921	East San Lucia Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF922	Eel River Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF923	Farallon Islands/Fanny Shoal EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF924	Half Moon Bay EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
NMF925	Hidden Reef/Kidney Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF926	Mendocino Ridge EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF927	Monterey Bay/Canyon EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF928	Point Arena North EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF929	Point Arena South EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF930	Point Conception EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF931	Point Sur Deep EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF932	Potato Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF933	Tolo Bank EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF934	President Jackson Seamount EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF935	Thompson Seamount EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF936	Anacapa Island EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF938	Carrington Point EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF939	Cordell Bank (50 fm (91m) isobath) EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF940	Davidson Seamount EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF941	Footprint EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF942	Gull Island EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF943	Harris Point EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF944	Judith Rock EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF945	Painted Cave EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF946	Richardson Rock EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF947	Santa Barbara Island EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF948	Scorpion EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF949	Skunk Point EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF950	South Point EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMF951	Seaward of the 700 fm - EFH CA	2006	NMFS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMS1	Channel Islands NMS	1980	NMS	Federal	Commercial Fishing Restricted	Permanent	Year-round
NMS11	Monterey Bay NMS	1992	NMS	Federal	No Site Restrictions	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
NMS13	Olympic Coast NMS	1994	NMS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NMS2	Cordell Bank NMS	1989	NMS	Federal	No Site Restrictions	Permanent	Year-round
NMS8	Gulf of the Farallones NMS	1981	NMS	Federal	No Site Restrictions	Permanent	Year-round
NPS12	Channel Islands NP	1938	NPS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NPS19	Golden Gate NRA	1972	NPS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NPS27	Olympic NP	1909	NPS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NPS30	Point Reyes NS	1962	NPS	Federal	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NPS31	Redwood NP	1968	NPS	Partnership	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NPS54	Ebey's Landing NHR	1978	NPS	Federal	Commercial Fishing Restricted	Permanent	Year-round
OR25	Haystack Rock MG	1990	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR26	Cape Kiwanda MG	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR27	Otter Rock MG	1962	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR28	Yaquina Head MG	1988	OBLM	Partnership	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR30	Cape Perpetua MG	1977	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR31	Harris Beach MG	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR32	Netarts Bay Shellfish Pres.	1960	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR33	Yaquina Bay Shellfish Pres.	1970	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR35	Pirate Cove RR	1996	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR36	Gregory Point RR	1996	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR37	Boiler Bay RR	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR38	Neptune SP RR	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR39	Cape Arago RR	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR40	Brookings RR	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
OR41	Whale Cove Habitat Refuge	1978	ODFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
OR515	Yachats MG	1997	ODFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA102	Brackett's Landing Shoreline Sanct. Cons. Area	1970	WDFW	Partnership	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA19	Dabob Bay NAP	1987	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA33	Zella M. Schultz/Protection Island Seabird Sanct.	1975	WDFW	Partnership	Commercial and Recreational Fishing Prohibited	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
WA34	Argyle Lagoon SJI Marine Pres.	1990	WDFW	State	Commercial Fishing Restricted and Recreational Fishing Prohibited	Permanent	Year-round
WA44	False Bay SJI Marine Pres.	1990	WDFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA47	Friday Harbor SJI Marine Pres.	1990	WDFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA50	Haro Strait SMFA	1972	WDFW	State	Restrictions Unknown	Permanent	Year-round
WA506	Woodard Bay NRCA	1987	WDNR	State	Recreational Fishing Restricted	Permanent	Year-round
WA507	Sund Rock Cons. Area	1994	WDFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA508	Titlow Beach Marine Pres.	1994	WMPDT	Partnership	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA509	Octopus Hole Cons. Area	1998	WDFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA510	Orchard Rocks Cons. Area	1998	WDFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA511	South 239th Street Park Cons. Area	1998	WDFW	Partnership	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA512	City of Des Moines Park Cons. Area	1998	WDFW	Partnership	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA513	Waketickeh Creek Cons. Area	2000	WDFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA514	Saltar's Point Beach Cons. Area	2000	WDFW	Partnership	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA515	Zee's Reef Marine Pres.	2002	WDFW	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
WA516	Admiralty Head Marine Pres.	2002	WDFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA517	Keystone Cons. Area	2002	WDFW	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA518	Colvos Passage Marine Pres.	2000	WDFW	State	Commercial Fishing Prohibited and Recreational Fishing Restricted	Permanent	Year-round
WA522	Blake Island Underwater Park	1970	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA524	Fort Worden Underwater Park	1977	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA525	Deception Pass Underwater Park	1970	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA526	Fort Casey Underwater Park	1970	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA527	Fort Ward Underwater Park	1970	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA528	Kopachuck Underwater Park	1971	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA529	Saltwater Underwater Park	1970	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA530	Tolmie Underwater Park	1971	WSPRC	State	Recreational Fishing Restricted	Permanent	Year-round
WA531	Kennedy Creek NAP	1990	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA532	Skookum Inlet NAP	1986	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA533	San Juan County/Cypress Island MBP	1923	UW-FHL	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round

MPA ID	MPA Name	Year Est.	Agency ABBR	Govt. Level	Fishing Restriction	Permanence	Constancy
WA534	Elk River NRCA		WDNR	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA536	Chehalis River Surge Plain NAP	1989	WDNR	State	Recreational Fishing Restricted	Permanent	Year-round
WA537	North Bay NAP	1988	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA540	Bone River NAP	1987	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA541	Niawiakum River NAP	1987	WDNR	State	Commercial and Recreational Fishing Prohibited	Permanent	Year-round
WA69	San Juan Channel and Upright Channel SMFA	1972	WDFW	State	Restrictions Unknown	Permanent	Year-round
WA72	Shaw Island SJI Marine Pres.	1990	WDFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
WA87	Yellow and Low Islands SJI Marine Pres.	1990	WDFW	State	Commercial and Recreational Fishing Restricted	Permanent	Year-round
NA	Washington State Territorial Sea		WDFW & NMFS	Partnership	Commercial Fishing Restricted	Unknown	Year-round
NA	California State Territorial Sea		CDFG & NMFS	Partnership	Commercial Fishing Restricted	Unknown	Year-round
NA	Trawl RCA - 100-150 ftm closure*	2002	NMFS	Federal	Commercial Fishing Restricted	Unknown	Year-round

*Trawl Rockfish Conservation Area boundaries defined in 50 CFR 660.130 (2012).

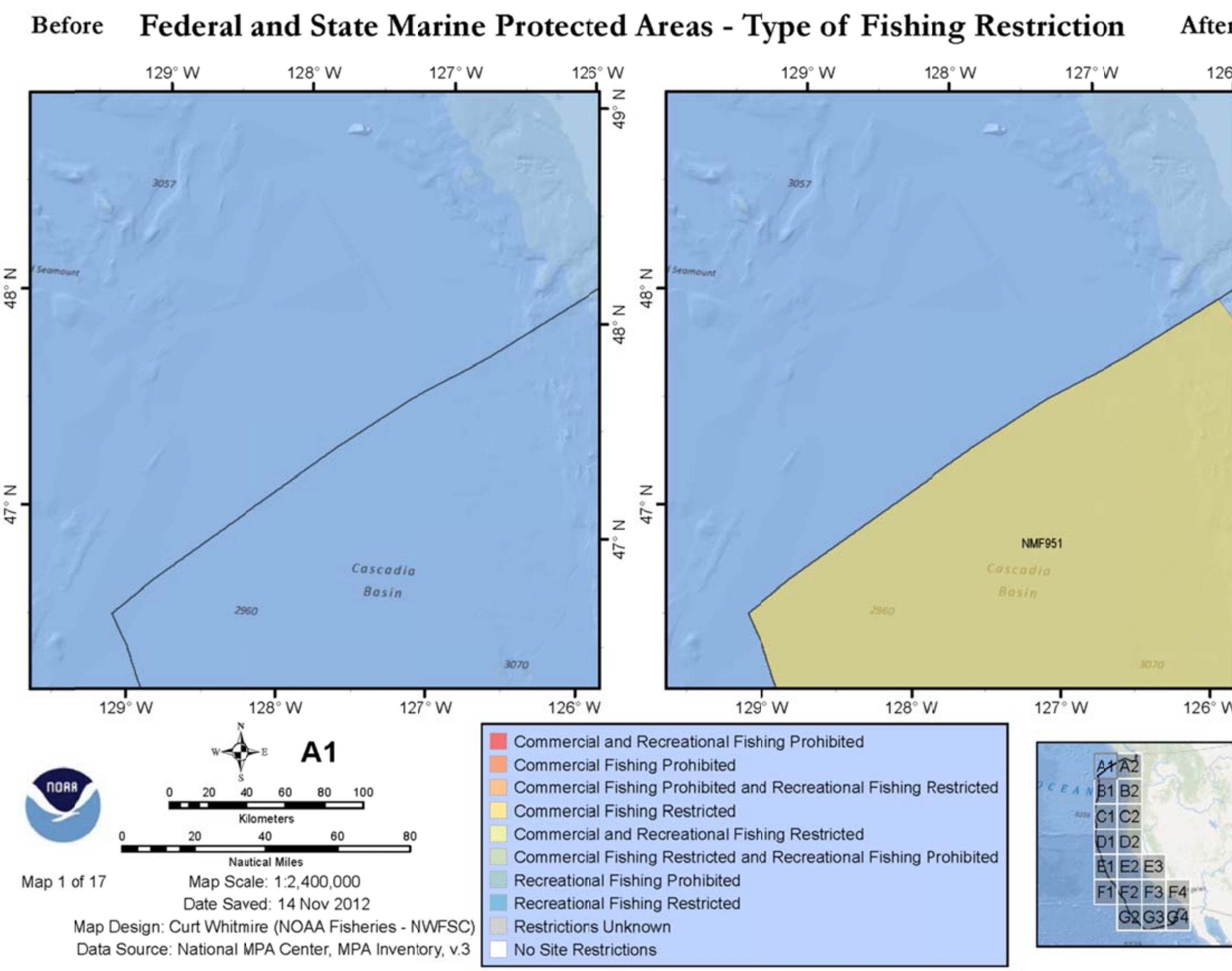
Table A5.3. Acronyms for MPA types listed as part of the "MPA Name" column in Table 2.

Acronym	MPA Type	# MPAs
CCAs	Cowcod Conservation Areas	1
Cons. Area	Conservation Area	8
CZ	Conservation Zone	2
EFH CA	Essential Fish Habitat Conservation Area	51
	Habitat Refuge	1
MBP	Marine Biological Preserve	1
MG	Marine Garden	7
Marine Pres.	Marine Preserve	4
NAP	Natural Area Preserve	7
NERR	National Estuarine Research Reserve	2
NHR	National Historical Reserve	1
NMS	National Marine Sanctuary	5
NP	National Park	3
NRA	National Recreation Area	1
NRCA	Natural Resources Conservation Area	2
NS	National Seashore	1
Shellfish Pres.	Shellfish Preserve	2
RCA	Rockfish Conservation Area	2
RR	Research Reserve	6
Sanct.	Sanctuary	1
Sanct. Cons. Area	Sanctuary Conservation Area	1
SC	Special Closure	9
SJI Marine Pres.	San Juan Islands Marine Preserve	5
SMCA	State Marine Conservation Area	65
SMFA	Special Management Fishery Area	2
SMP	State Marine Park	7
SMR	State Marine Reserve	44
SMRMA	State Marine Recreational Management Area	3
	State Territorial Sea	2
	Underwater Park	8
YRCA	Yelloweye Rockfish Conservation Area	5
	Total	259

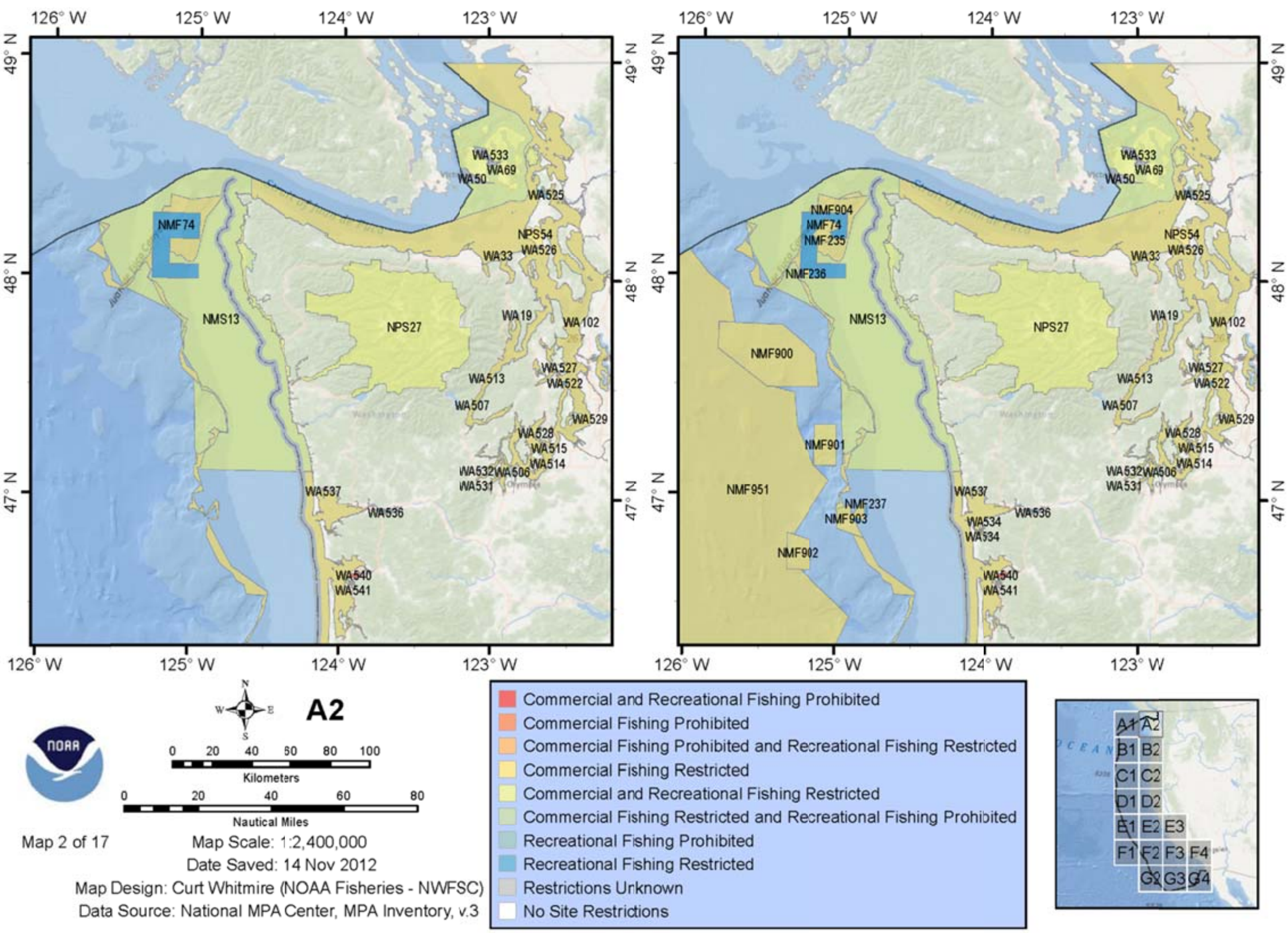
Table A5.4. Abbreviations for federal and state management agencies responsible for designation of MPAs, and listed under the "Agency ABBR" column in Table 2.

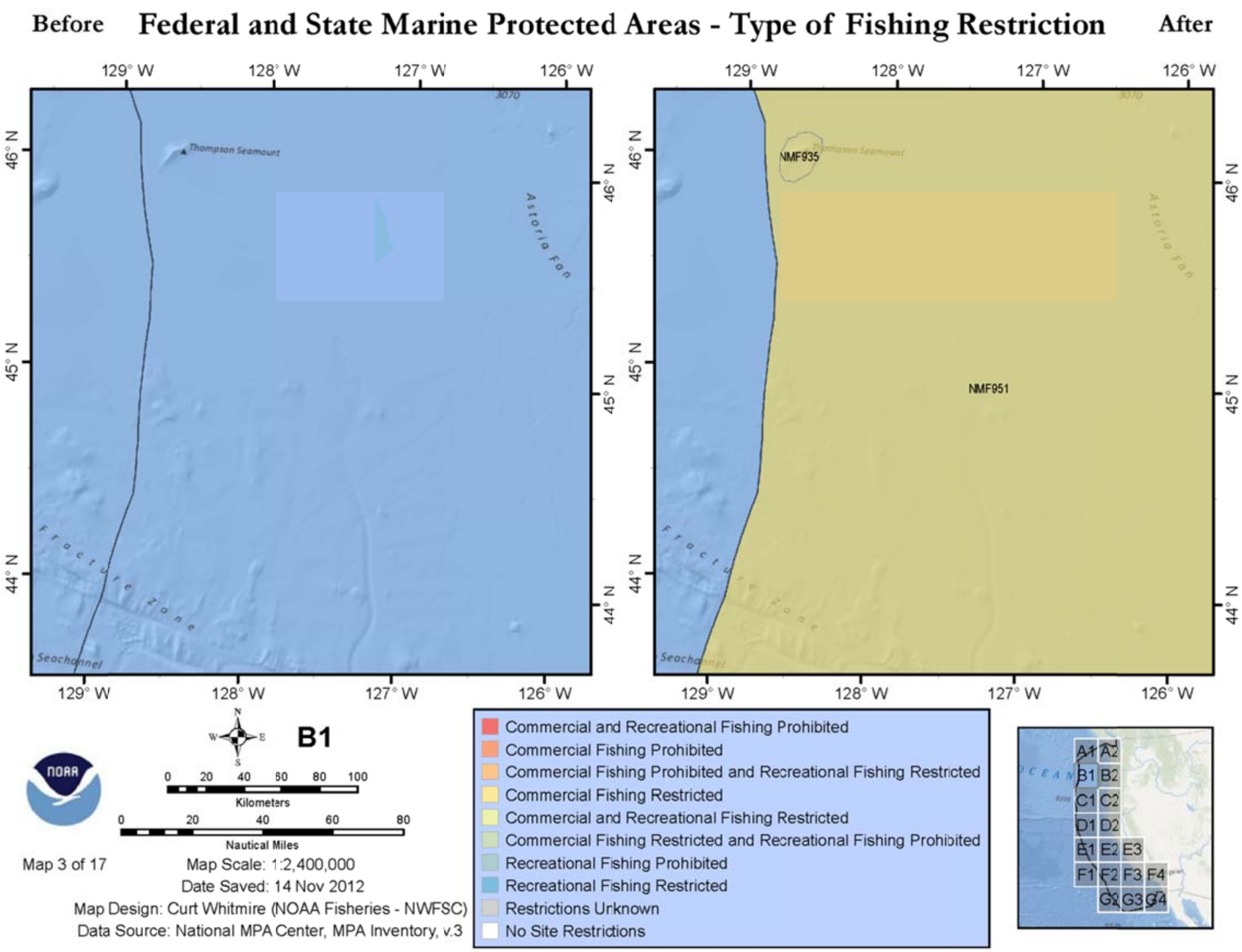
Agency ABBR	Management Agency	# MPAs
CDFG	California Department of Fish and Game	125
CDFG & NMFS	California Department of Fish and Game & National Marine Fisheries Service	1
CDPR	California Department of Parks and Recreation	3
CDPR & NOAA	California Department of Parks and Recreation & National Oceanic and Atmospheric Administration	1
NMFS	National Marine Fisheries Service	61
NMS	National Marine Sanctuaries	5
NPS	National Park Service	6
OBLM	Oregon Bureau of Land Management	1
ODFW	Oregon Department of Fish and Wildlife	15
ODSL & NOAA	Oregon Department of State Lands & National Oceanic and Atmospheric Administration	1
UW-FHL	University of Washington Friday Harbor Laboratories	1
WDFW	Washington Department of Fish and Wildlife	20
WDFW & NMFS	Washington Department of Fish and Wildlife & National Marine Fisheries Service	1
WDNR	Washington Department of Natural Resources	9
WMPDT	Washington Metropolitan Park District of Tacoma	1
WSPRC	Washington State Parks & Recreation Commission	8
	Total	259

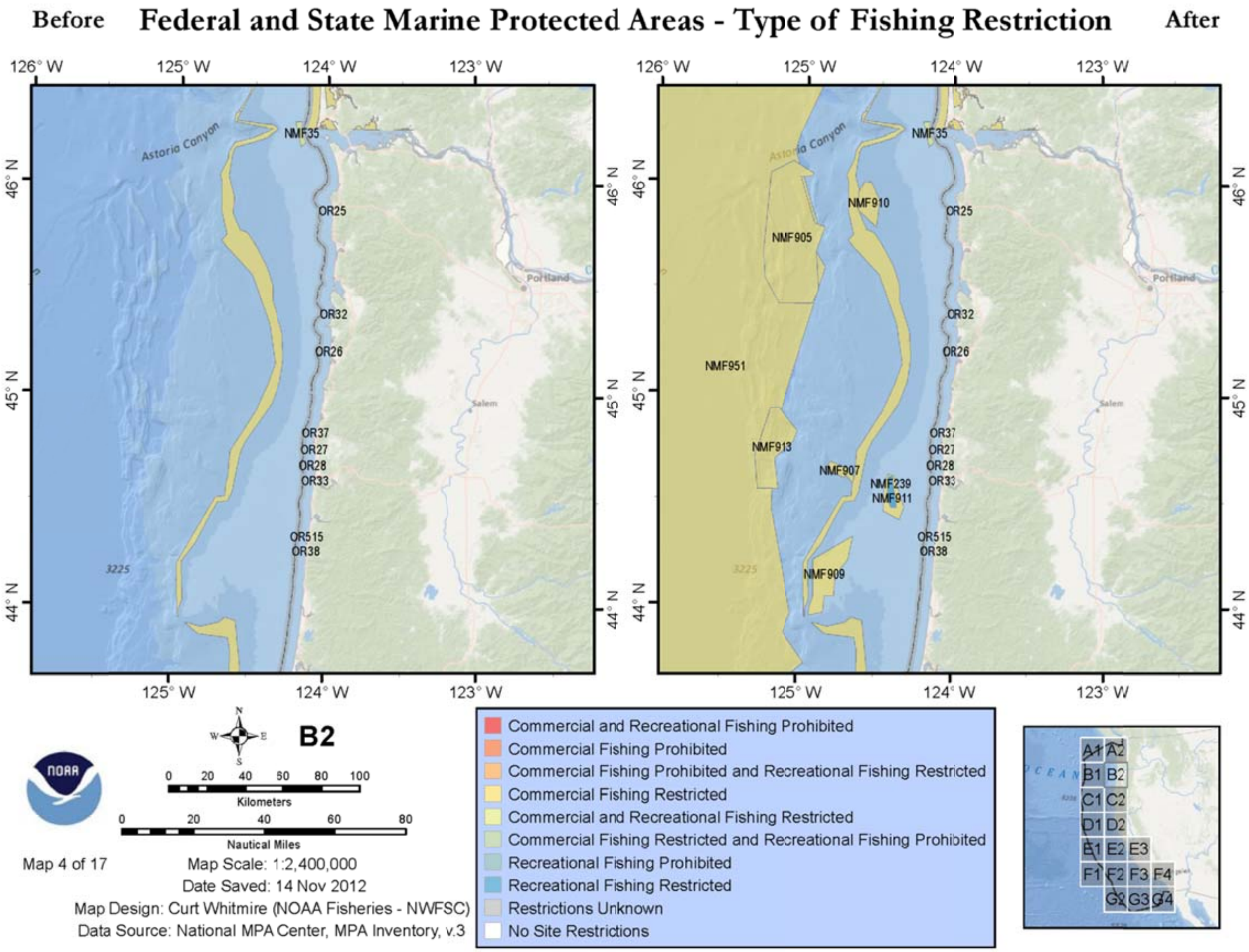
Figure A5.1. Map views (A1-G4) showing the spatial distribution of various federal and state marine protected areas. Data Source: NMPAC, 2012 and 50 CFR 660.130 (2012).

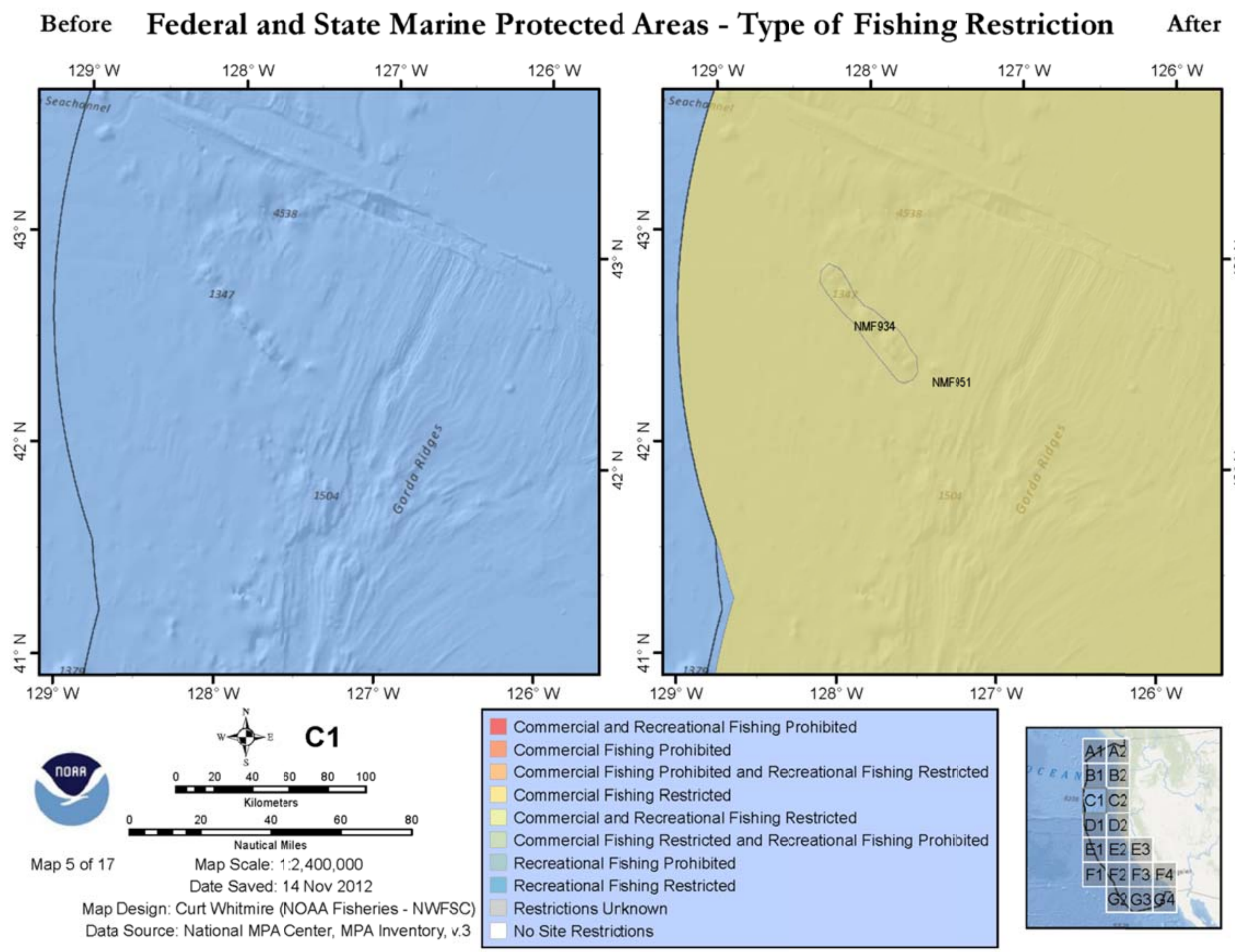


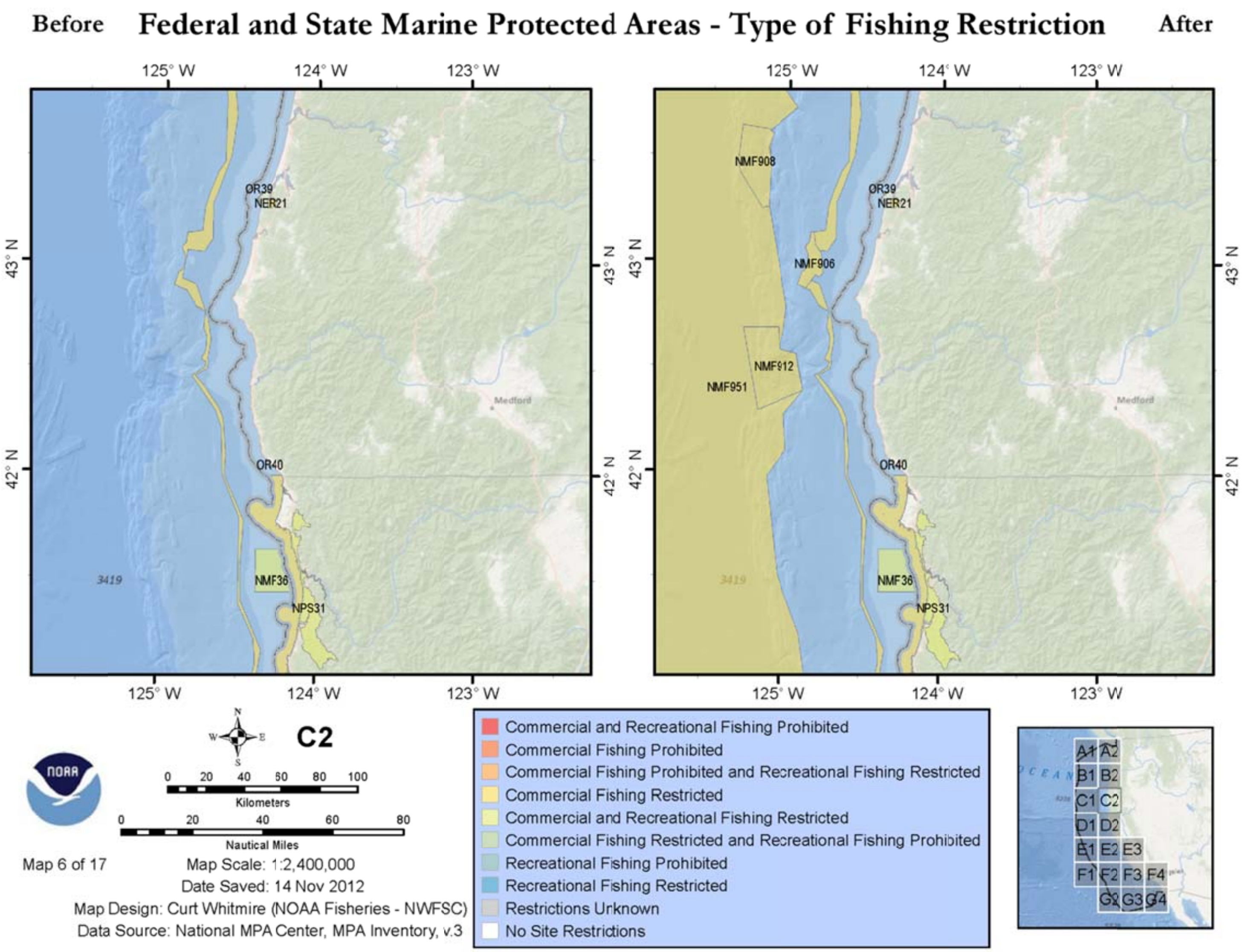
Before **Federal and State Marine Protected Areas - Type of Fishing Restriction** **After**

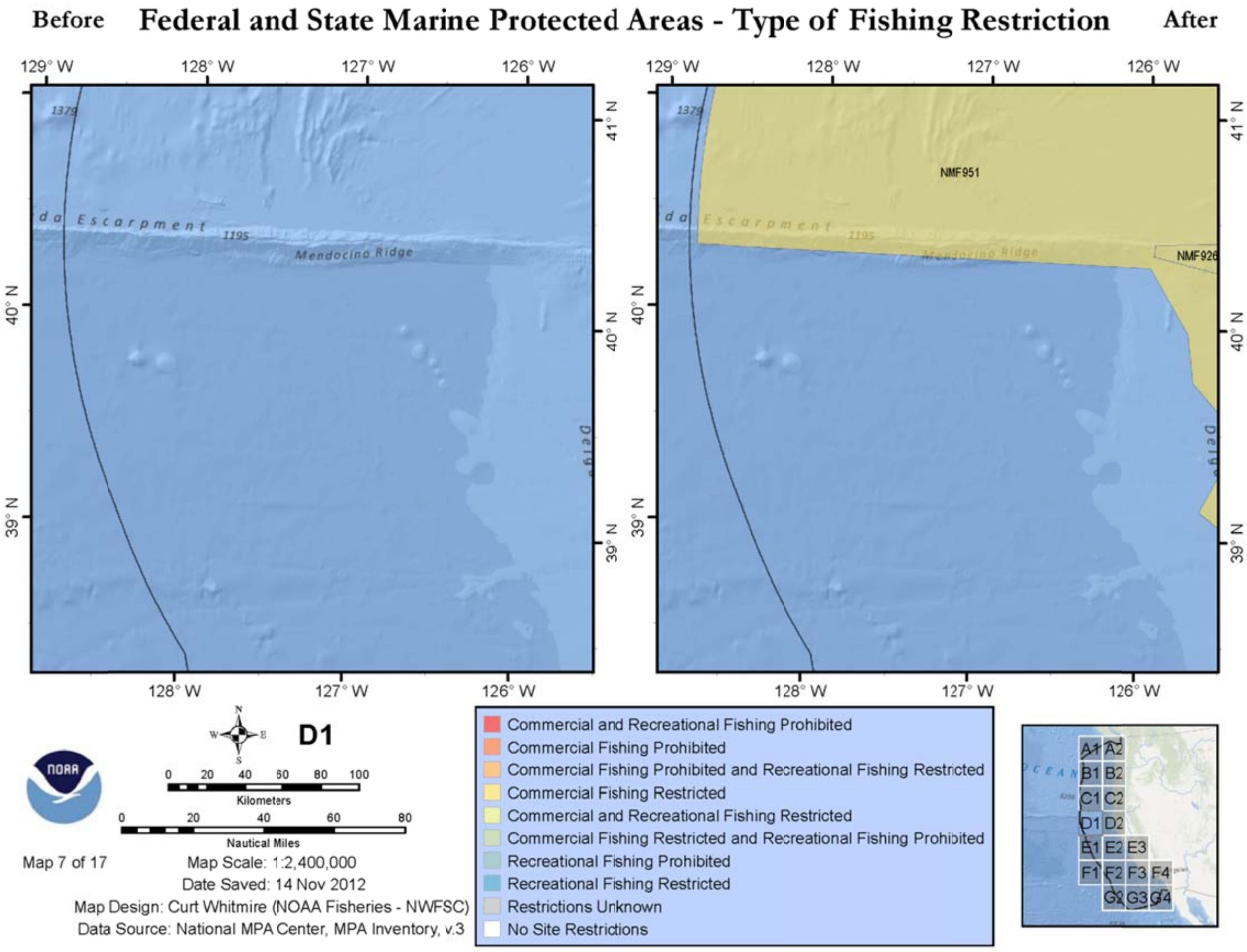



Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
129° W
128° W
127° W
126° W
46° N
45° N
44° N
Thompson Seamount
Astoria Fan
Fracture Zone
Seachannel
NMF935
NMF951
B1
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map 3 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

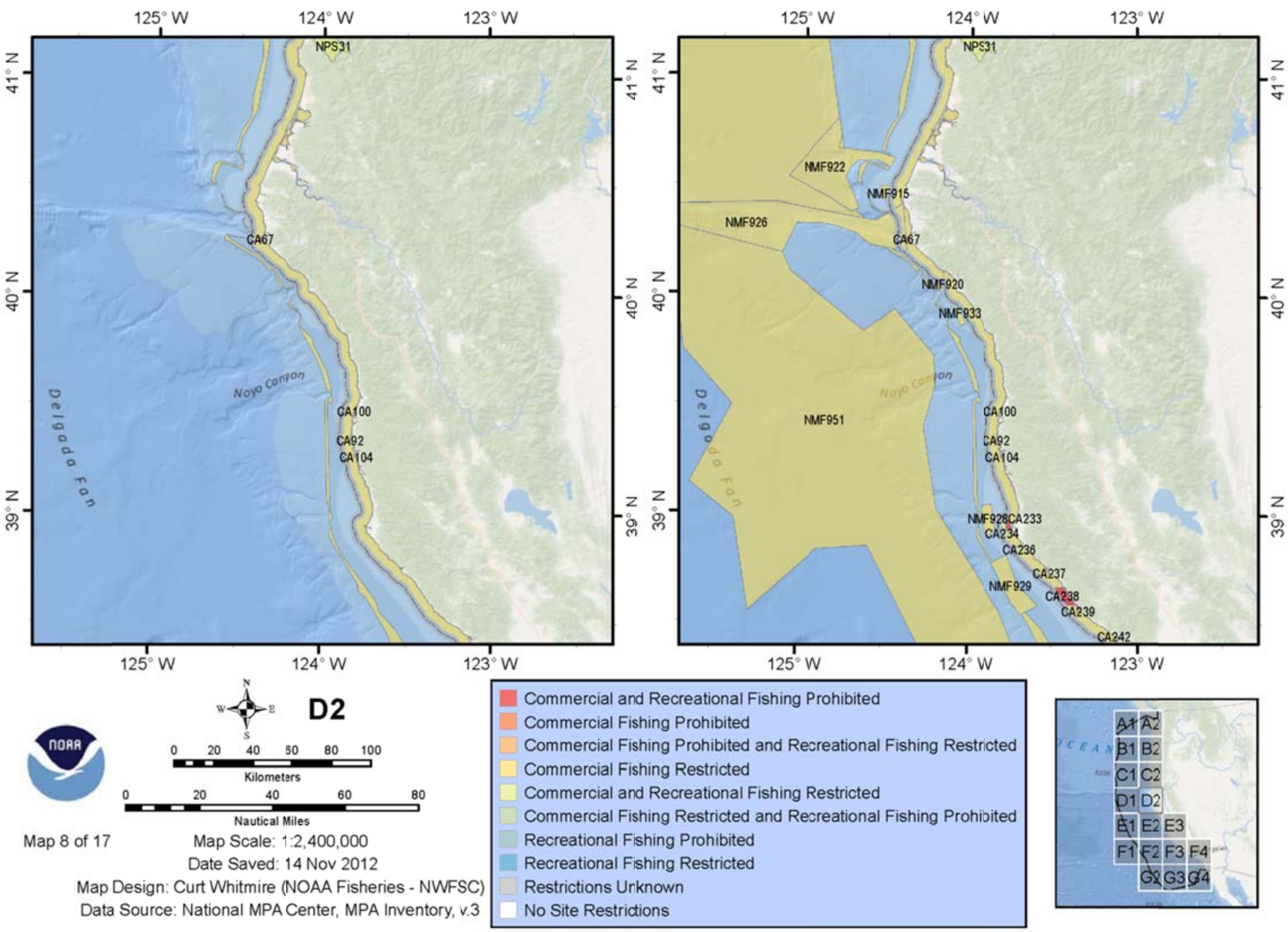

Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
126° W
125° W
124° W
123° W
46° N
45° N
44° N
Astoria Canyon
NMF35
OR25
OR32
OR26
OR37
OR27
OR28
OR33
OR515
OR38
NMF910
NMF905
NMF951
NMF913
NMF907
NMF239
NMF911
NMF909
B2
Kilometers
Nautical Miles
Map 4 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

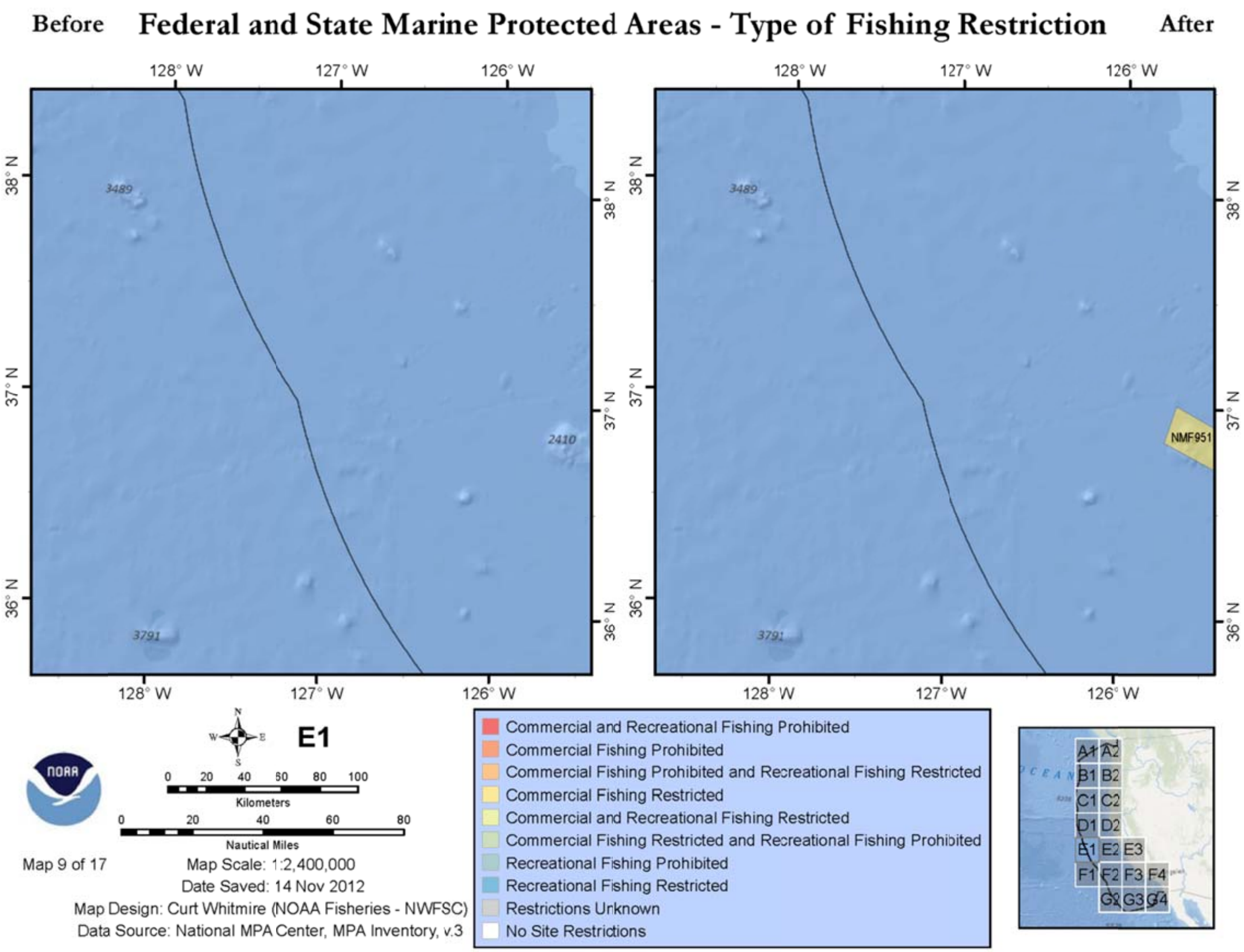

Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
129° W
128° W
127° W
126° W
43° N
42° N
41° N
Seachannel
4538
1347
1504
1379
Gorda Ridges
NMF934
NMF951
C1
Kilometers
0 20 40 60 80 100
Nautical Miles
0 20 40 60 80
Map 5 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4


Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
125° W
124° W
123° W
43° N
42° N
OR39
NER21
OR40
NMF36
NPS31
3419
Medford
NMF908
NMF906
NMF912
NMF951
C2
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map 6 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

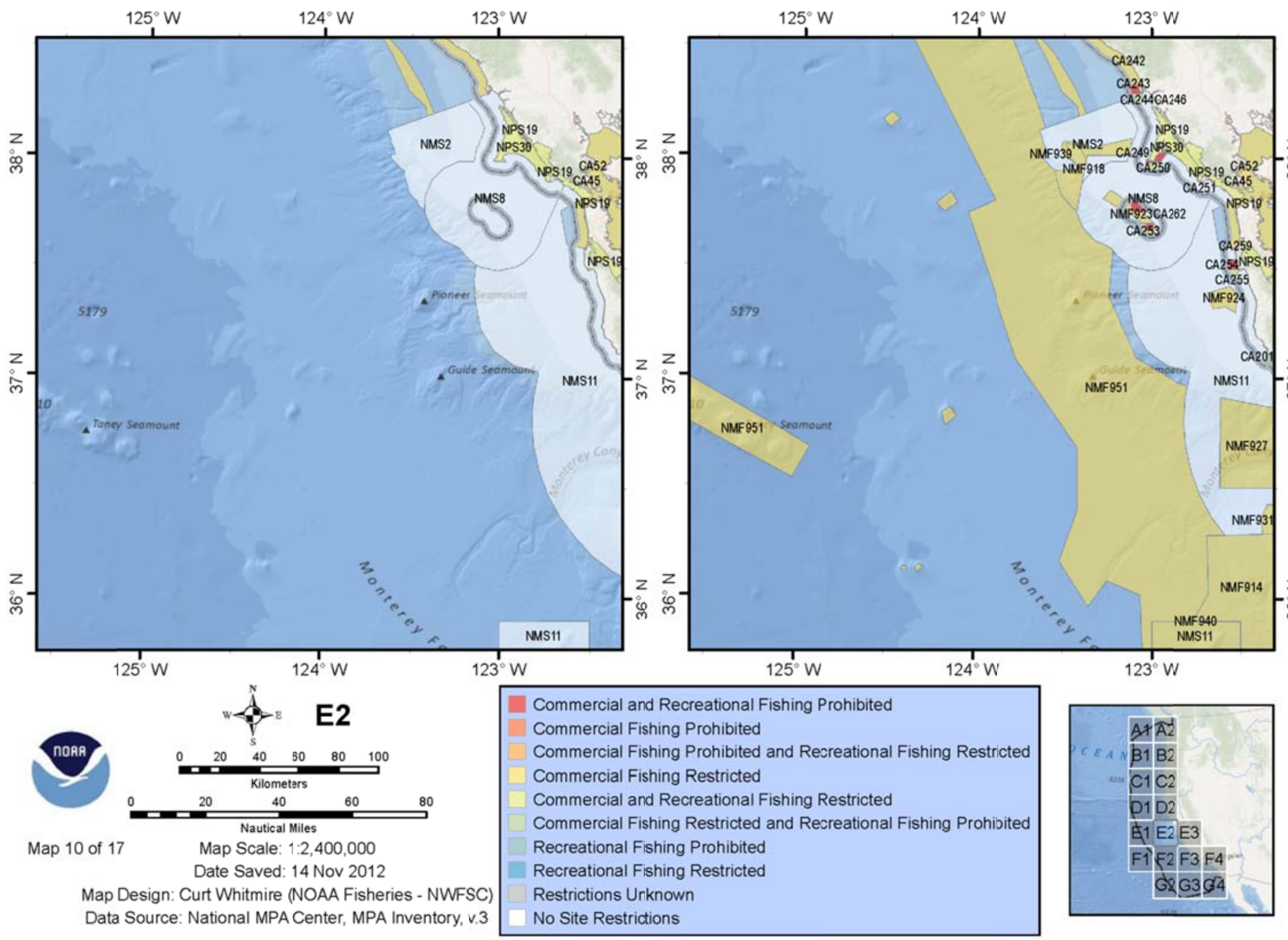

Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
129° W
128° W
127° W
126° W
41° N
40° N
39° N
Escarpment
Mendocino Ridge
1379
1195
NMF951
NMF926
D1
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map 7 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

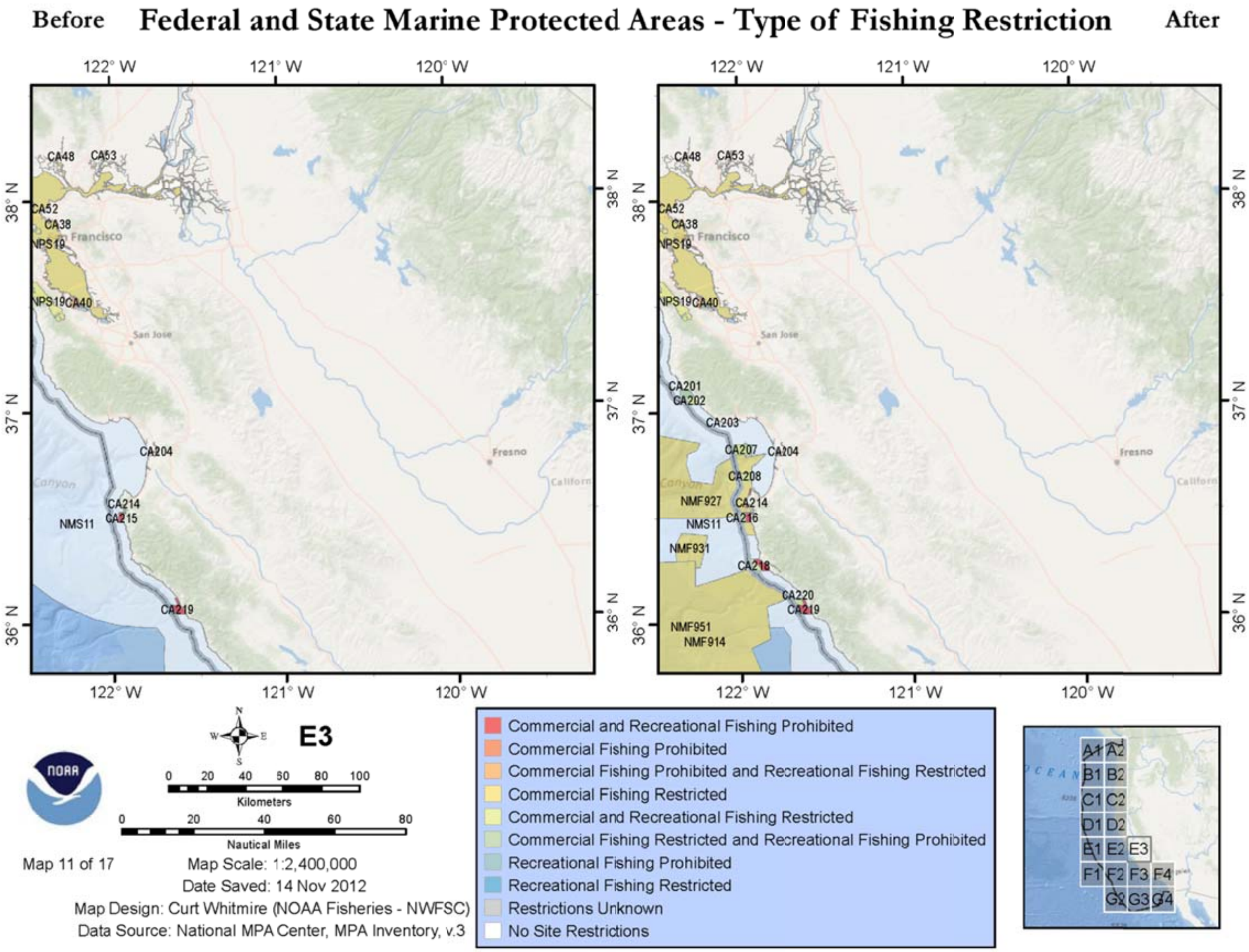
Before **Federal and State Marine Protected Areas - Type of Fishing Restriction** After



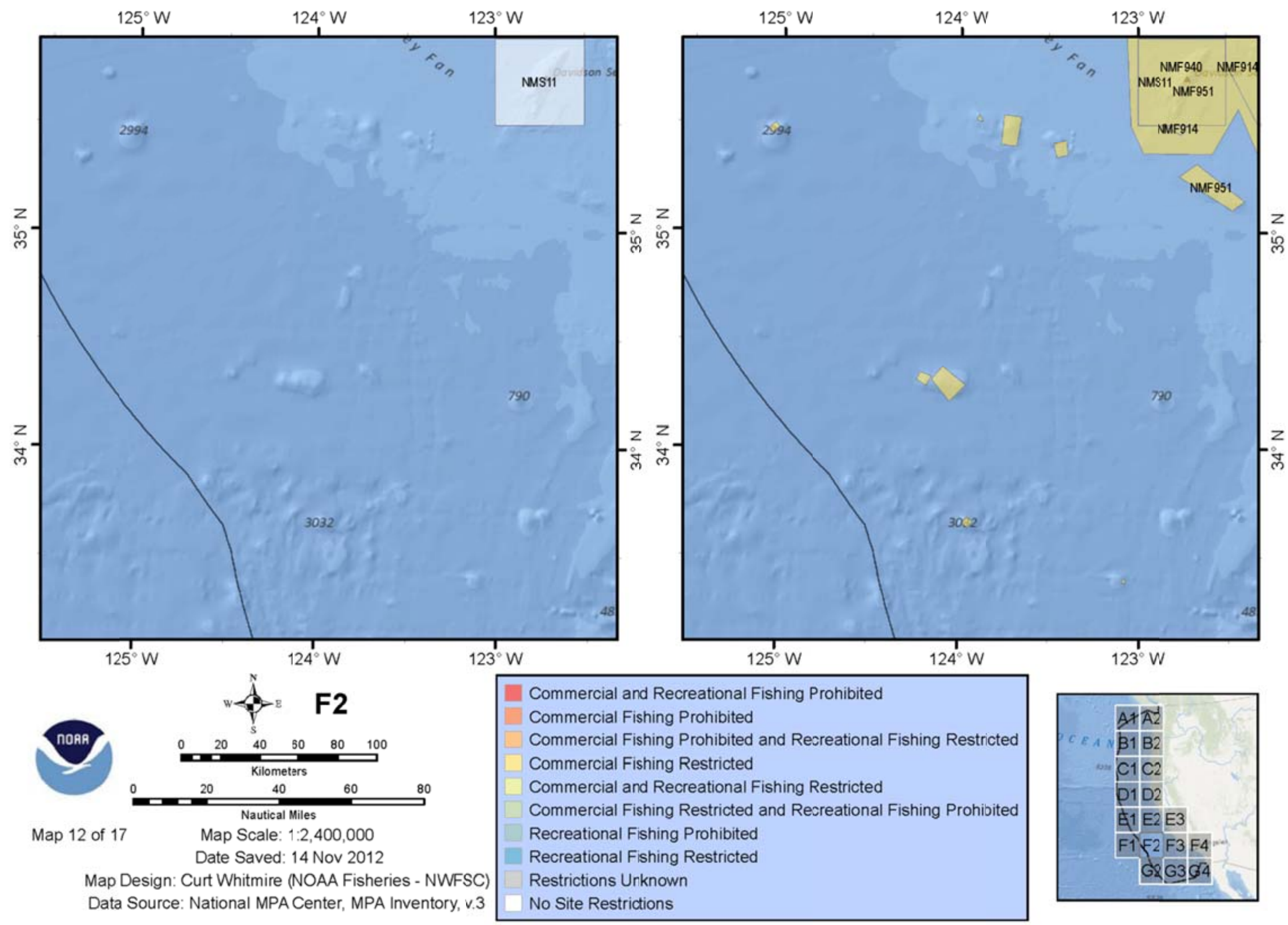

Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
128° W
127° W
126° W
38° N
37° N
36° N
3489
2410
3791
NMF951
E1
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map 9 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

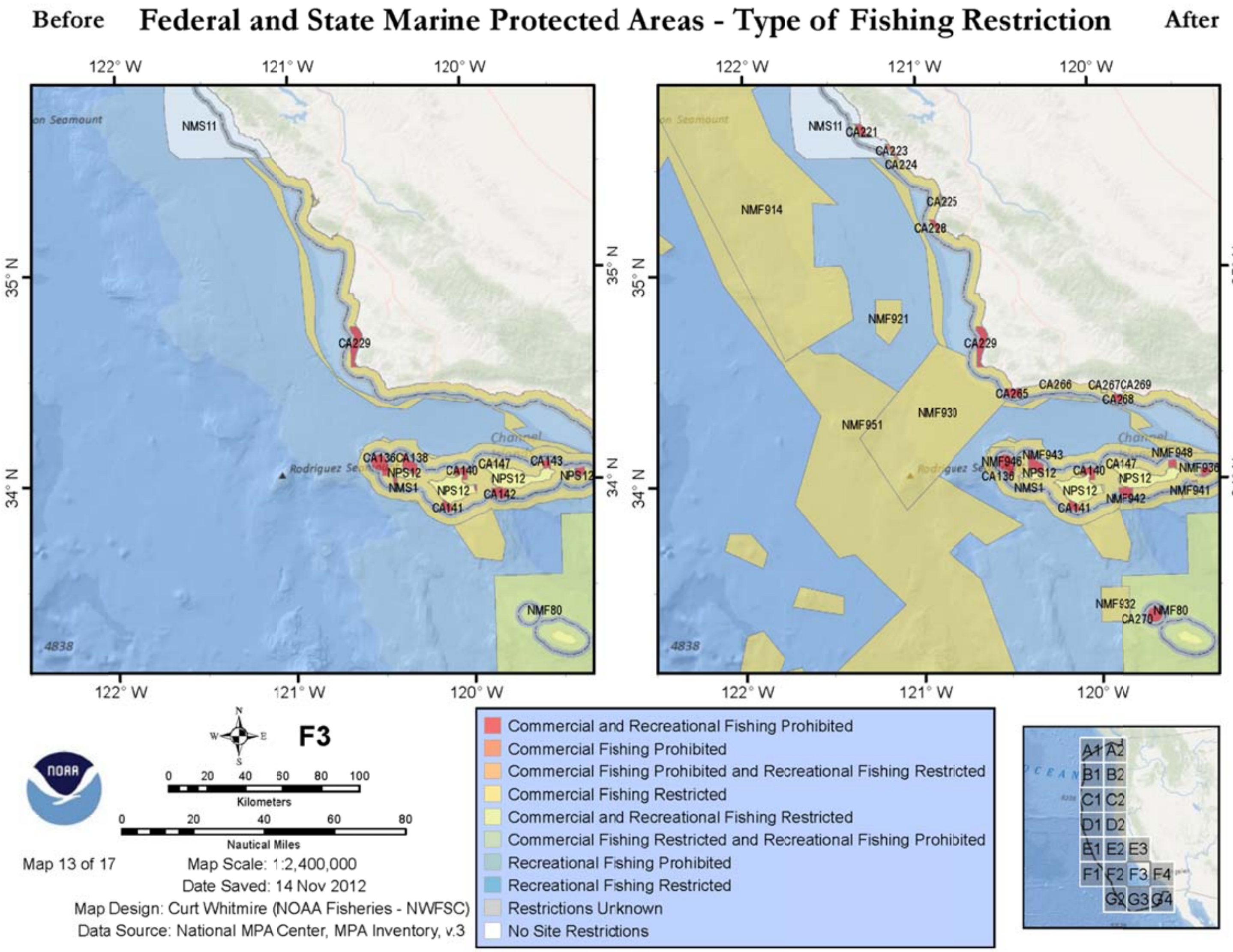
Before **Federal and State Marine Protected Areas - Type of Fishing Restriction** After

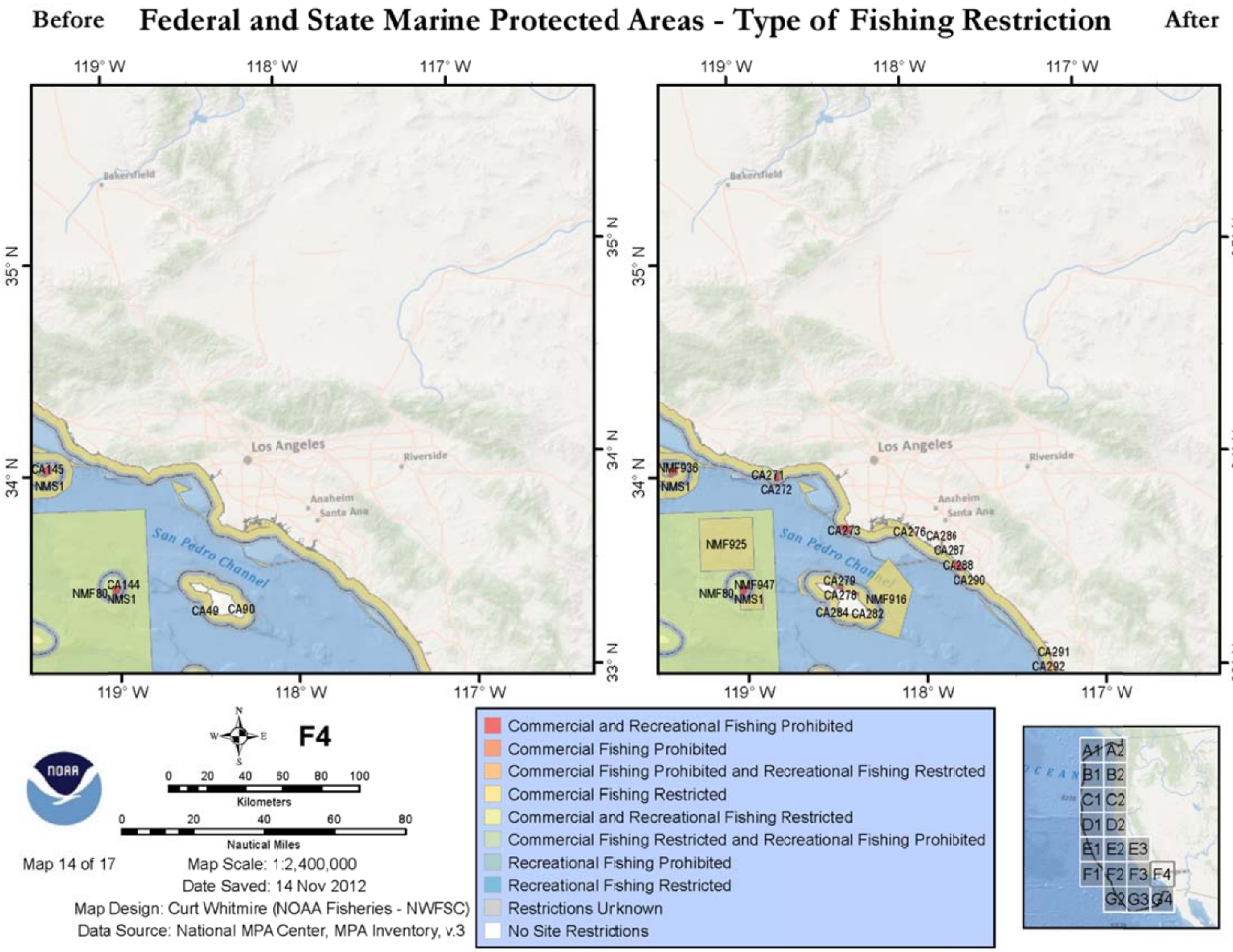


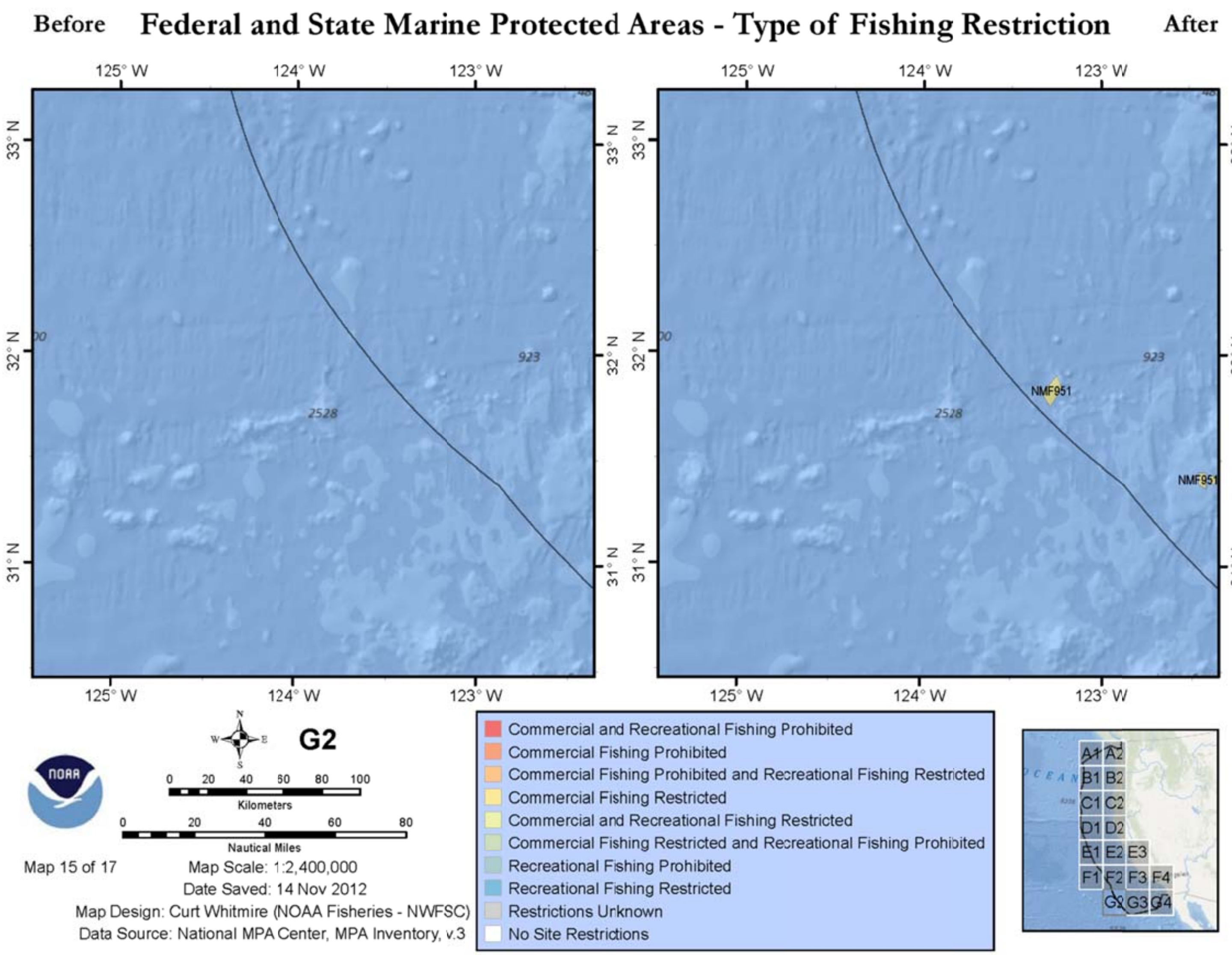

Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
122° W
121° W
120° W
38° N
37° N
36° N
CA48
CA53
CA52
CA38
NPS19
NPS19
CA40
CA204
CA214
CA215
NMS11
CA219
CA201
CA202
CA203
CA207
CA208
NMF927
CA216
NMF931
CA218
CA220
NMF951
NMF914
Fresno
E3
Kilometers
0 20 40 60 80 100
Nautical Miles
0 20 40 60 80
Map 11 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

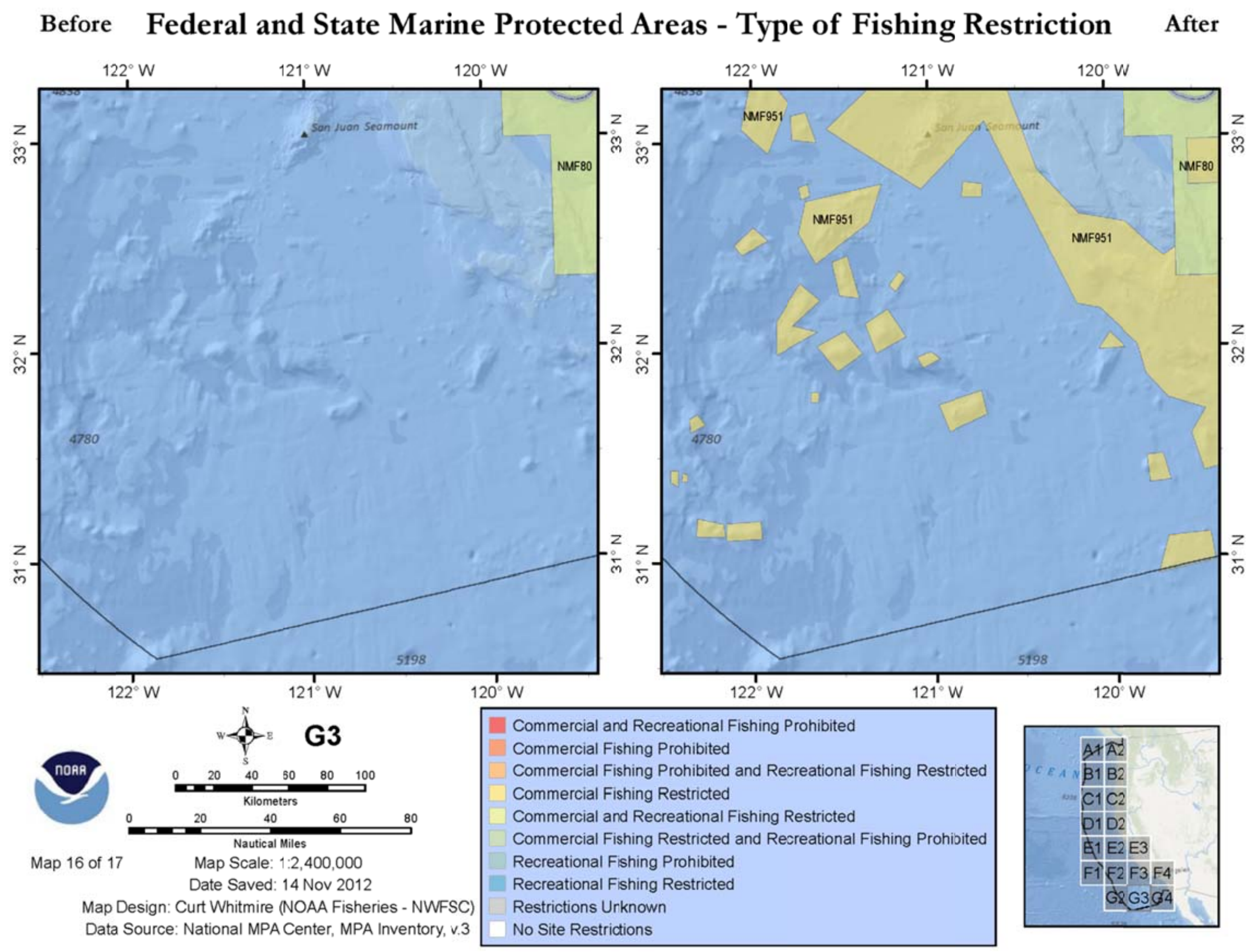
Before Federal and State Marine Protected Areas - Type of Fishing Restriction After




Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
122° W
121° W
120° W
35° N
34° N
NMS11
CA229
CA136
CA138
NPS12
NMS1
CA140
CA141
CA147
CA142
CA143
NMF80
NMF914
NMF921
NMF951
NMF930
CA221
CA223
CA224
CA225
CA228
CA265
CA266
CA267
CA269
CA268
NMF943
NMF946
NMF948
NMF941
NMF942
NMF932
CA270
F3
Kilometers
0 20 40 60 80 100
Nautical Miles
0 20 40 60 80
Map 13 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4


Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
119° W
118° W
117° W
35° N
34° N
33° N
Bakersfield
Los Angeles
Riverside
Anaheim
Santa Ana
San Pedro Channel
CA145
NMS1
NMF80
CA144
CA49
CA90
NMF936
CA271
CA272
NMF925
CA273
CA276
CA286
CA287
CA288
CA290
NMF947
CA279
CA278
NMF916
CA284
CA282
CA291
CA292
F4
0 20 40 60 80 100
Kilometers
0 20 40 60 80
Nautical Miles
Map 14 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4


Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
125° W
124° W
123° W
33° N
32° N
31° N
2528
923
NMF951
NMF951
G2
Kilometers
Nautical Miles
Map 15 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4


Before
Federal and State Marine Protected Areas - Type of Fishing Restriction
After
122° W
121° W
120° W
33° N
32° N
31° N
San Juan Seamount
NMF80
NMF951
4780
5198
G3
Kilometers
0 20 40 60 80 100
Nautical Miles
0 20 40 60 80
Map 16 of 17
Map Scale: 1:2,400,000
Date Saved: 14 Nov 2012
Map Design: Curt Whitmire (NOAA Fisheries - NWFSC)
Data Source: National MPA Center, MPA Inventory, v.3
Commercial and Recreational Fishing Prohibited
Commercial Fishing Prohibited
Commercial Fishing Prohibited and Recreational Fishing Restricted
Commercial Fishing Restricted
Commercial and Recreational Fishing Restricted
Commercial Fishing Restricted and Recreational Fishing Prohibited
Recreational Fishing Prohibited
Recreational Fishing Restricted
Restrictions Unknown
No Site Restrictions
A1 A2
B1 B2
C1 C2
D1 D2
E1 E2 E3
F1 F2 F3 F4
G2 G3 G4

Before **Federal and State Marine Protected Areas - Type of Fishing Restriction** **After**