PACIFIC COAST GROUNDFISH FISHERY MANAGEMENT PLAN

FOR THE CALIFORNIA, OREGON, AND WASHINGTON GROUNDFISH FISHERY

APPENDIX C
PART 1

THE EFFECTS OF FISHING ON GROUNDFISH HABITAT: WEST COAST PERSPECTIVE

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June 2019

The Effects of Fishing on Groundfish Habitat: West Coast Perspective

Revised for Amendment 28

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June 2019

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1 INTRODUCTION

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires fishery management councils for each fishery management plan (FMP) to identify fishing activities that may adversely affect essential fish habitat (EFH) and to minimize adverse effects of those activities to the extent practicable. Fishing activities should include those regulated under the Pacific Coast Groundfish FMP that affect EFH identified under any FMPs, as well as those fishing activities regulated under other FMPs that affect EFH designated under the Pacific Coast Groundfish FMP. In addition, FMPs must describe each fishing activity and provide conclusions as to whether and how each activity, and cumulative effects of multiple activities, adversely affects EFH (see 50 CFR 600.815).

This appendix describes the fishing activities that may adversely affect EFH, and evaluates the nature and extent of any adverse effects based on the types of habitats and related functions that may be disturbed. In evaluating the adverse effects of fishing activities, we reviewed the comprehensive risk assessment that was completed for Amendment 19 (NMFS 2005, Appendix A), considered information presented in various reports to the Council as part of the development of Amendment 28 (PFMC 2012, PFMC 2014, NMFS 2013a and b), and reviewed the recent literature on the impacts of fishing on various habitats. This appendix does not include descriptions of the management measures employed by Pacific Fishery Management Council (PFMC or "the Council") to minimize adverse effects on EFH, as those are already detailed in the FMP body.

2 INFORMATION ON HABITAT EFFECTS OF FISHING GEAR

2.1 2005 Findings Summary

Acting on advice from the National Research Council's Committee on the Ecosystem Effects of Fishing (NRC 2002, Chapter 7), National Marine Fisheries Service (NMFS) and the Council developed a comprehensive risk assessment to consider EFH-related issues through the Council and National Environmental Policy Act (NEPA) processes for Amendment 19. A significant portion of this risk assessment focused on fishing impacts, including the following products:

- **Description of fishing gears used on the U.S. Pacific Coast** (Recht 2003), with attention to components of gear that could impact structural features of habitat.
- **The Effects of Fishing on Habitat: A West Coast Perspective** (MRAG 2004; Appendix A-10), in which adverse impacts were indexed for each gear type and recovery times were estimated for each habitat type.
- **Impacts Model for Groundfish Essential Fish Habitat (**MRAG 2004), in which cumulative anthropogenic impacts to habitat (from fishing and non-fishing sources) were considered using limited data.
- **Other relevant data products** (e.g., groundfish life history information, substratum data, etc.).

Significant data gaps (FMP Appendix B) prevented a definitive determination of adverse impacts at a functional scale (e.g., quantifying population and ecosystem effects resulting from fishing impacts to habitat). However, the risk assessment focused attention on sensitive habitats with slow recovery times as the scientific basis for Council action (NMFS 2006, sections 3.3 and 5.3).

In 2005, there were several literature reviews on the effects of fishing gears on habitat, containing some studies specific to the West Coast. Only two studies from the Pacific were found that had useful information for the analysis. In order to develop a more complete picture of potential impacts, and following the recommendations of the NRC 2002 report on the Effects of Trawling and Dredging on Seafloor Habitat, the review relied on studies from the global literature. It was determined reasonable to infer impacts from studies in other areas so long as they are based on similar gear x habitat combinations, so the analysis was limited to only studies that involved gear types used on the West Coast and the major habitat types that occur there. Hence, research from areas other than the Pacific coast provided most of the information on which the analysis was based.

In an effort to provide a quantitative measure of the degree of habitat modification resulting from a unit of fishing effort, two theoretical indices were developed: the Sensitivity Index and the Recovery Index. The Sensitivity Index provided a relative measure of the sensitivity of habitats to the action of fishing gears. The Recovery Index provided a measure of the time taken for a habitat to recover to a pre-impacted state.

The analysis suggested the following relative rankings of gear from highest to lowest impact: dredges > bottom trawls > pots & traps (no empirical data available for nets and hook & line gears). Although relatively less research existed on fixed gears, the various types of nets (gillnets, seines) were generally considered to have much less impact on the seabed than dredges and trawls, and hook & line methods had the least impact. Hence, the derived values reflect this relative ranking of impacts: dredges > trawls > nets > pots and traps > hook and line. These relative rankings corroborated those provided in Chuenpagdee et al.'s (2003) evaluation of U.S. fishing gears on seafloor habitat.

In addition to the relative gear rankings, the analysis of empirical research also showed a nearly consistent sensitivity ranking by substrate/macrohabitat type almost regardless of gear type from most adversely impacted to least: biogenic > hard bottom > soft sediment.

The 2005 analysis emphasized they only had a preliminary understanding of how fishing gear impacts biogenic habitats. Recovery times ranged mainly from zero to five years, although these were thought to be much longer for slow growing biogenic habitat such as corals and sponges, and the overall trends by gear and habitat types were similar to the trends indicated by sensitivity levels.

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

There was very little research useful for the analysis on gear impacts in water depths exceeding 200 m. It should be noted, however, that there are theoretical bases for adjusting values from these deeper habitats. Benthic communities in deeper waters where wind and waves do not disturb the seabed were found to be probably less adapted to resisting and recovering from physical disturbances generally (Watling and Norse 1998). No such adjustments, however, were attempted for the analysis. Hence, the analysis should not be interpreted as a direct quantification of gear impacts that can be used to infer, for example, functional habitat characteristics related to EFH.

A related topic that was not considered in the analysis was the issue of fishing intensity, or frequency of disturbance of the bottom by fishing gear. In particular, if the period between successive trawl tows in a specific habitat is less than the recovery time, the habitat will remain in a chronically impacted state.

There was very little quantitative information describing the relationship between habitat type, structure, and function and the productivity of managed fish species. In particular, the level of information for most species x habitat associations remained at Level 1 as defined in the NMFS EFH Final Rule Guidance (i.e., presence-absence only), requiring a precautionary approach to the determination of potential adverse impacts.

2.2 Summary of Changes since the 2005 Findings

Several new publications (including peer-reviewed literature, white papers, and technical memorandums) on the effects of fishing gear on benthic habitats, fish associations with biogenic habitats, and predictive modeling of biogenic habitats have been identified in the EFH Review Committee (EFHRC) Phase 1 (PFMC 2012) and Northwest Fisheries Science Center (NWFSC) Synthesis reports (NWFSC 2013a, 2013b). In addition, the spatial distribution of fishing effort using bottom trawl, midwater trawl, and fixed gears was compared before and after implementation of Amendment 19 regulations. From the Phase 1 report, (1) effects of fishing with mobile, bottom-contact fishing gear on benthic habitats are increasingly well-established worldwide; (2) there is little new information on recovery of seafloor habitats from the effects of fishing and, therefore, an improved evaluation of fishing impacts is hindered; (3) long estimates of recovery time, on the order of hundreds of years, should be used for hard corals; and (4) with regard to impacts from recreational fishing gear, biogenic habitats are most at-risk followed by hard substrata and soft sediments.

Data useful to the development of public proposals to change EFH and/or regulatory measures to minimize adverse effects to EFH were summarized in the NMFS Synthesis report (NMFS 2013a, 2013b). Recognizing that a scientific peer review has yet to be conducted, some findings in the Synthesis report are: (1) approximately 10% of upper slope and shelf habitats (0-700 ftm) along the West Coast are closed to bottom trawling, and the bottom trawl closure seaward of 700 ftm accounts for the majority of all EFH conservation areas; (2) effort 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; (3) patterns of fishing effort have remained moderately stable over the previous decade, but have likely varied over longer periods; there has been some displacement of trawling activity seaward from conservation areas; (4) EFH conservation areas protect some groundfish species from fishing more than others; and (5) EFH conservation areas protect many deep-sea coral and sponge (DSCS) habitats, but additional areas remain open to some or all bottom contact gears.

Several recent studies of DSCS, including a regional initiative funded by the National Oceanic and Atmospheric Administration (NOAA) Deep Sea Coral Research and Technology Program and a geo-referenced database, have increased our understanding of diversity, habitat associations, distribution and abundance of DSCS on the continental shelf and slope of the West Coast (see Clarke et al. 2017). DSCS, as well as other relatively large invertebrate taxa, add complexity and structure to seafloor habitat (which also is referred to as biogenic habitat). Many fishes associate with various types of structure, such as rocks, depressions in soft sediment, kelp, thermal gradients, man-made debris, and DSCS. DSCS mostly occur on rocky substrata (e.g., boulders, pinnacles, rock outcrops), although sea pens in particular are found in mud and sand sediments. Many FMP groundfish species, especially the rockfishes, co-occur with DSCS in the same rocky areas. DSCS taxa are slow growing and vulnerable to disturbance by bottom-tending fishing gears that target North Pacific groundfish species. Adverse impacts of such disturbance can be long lasting and recovery of DSCS likely can be slow.

In response to a Council request for more information, NMFS, in March 2015, held a summit with experts on the role of DSCS as habitat for managed species off the West Coast and Alaska. A preliminary summit report was presented to the Council in April 2015, detailing outcomes in four categories: 1) associations between groundfishes and DSCS; 2) evidence of functional roles of DSCS as habitat for groundfishes; 3) data analysis and interpretation points; and 4) considerations when communicating research results on DSCS as habitat. Several important findings pertain to the effects of fishing on groundfish populations and habitats.

- Compared to Alaska, the level of sustained pressure from both recreational and commercial fishing has been greater and over a longer time period off the West Coast. The removal of large fishes has resulted in altered ecosystems, with demersal fish assemblages in rocky areas now dominated by dwarf species of rockfishes. The connection between DSCS and rockfishes may not be as important when large predators are not present in the community. With almost no information on intact fish assemblages prior to fishing, it is impossible to fully understand the function of DSCS as habitat for groundfishes off the West Coast.
- Restoration of community structure (both species and size compositions) of groundfishes and their habitats to pre-fishing conditions off the West Coast is central to the evaluation of the function of DSCS as habitat in any role (nursery, shelter, prey enhancement, etc.).
- Long-term restriction on the use of the most damaging bottom-contact fishing gears is an appropriate management measure to protect DSCS from physical damage. Restoring community structure and potentially the functional role of DSCS to particular areas off the West Coast may require no-take fishery closures.
- Protection of DSCS (particularly on the West Coast) is not likely to result in increased production of groundfishes unless this protection is coupled with measures to restore the entire demersal community.

2.2.1 Recent Literature on the Effects of Fishing Gear on Benthic Habitats

The recent studies on the effects of fishing gear on benthic habitats are primarily focused on the effects of trawling. However, there is at least one publication that discusses the effects of bottom longlines. Of these new studies, there have been several conducted along the West Coast of the contiguous U.S., Canada and Alaska that have focused on otter trawls in unconsolidated substrate including sand and mud that contain biogenic habitat on the seafloor. Additionally since 2005, general effects of fishing with mobile, bottom-contact fishing gear (such as otter trawls) are increasingly well established through studies worldwide. Relative to the information available in 2005, the new studies including those performed on the U.S. West Coast, found significant impacts of trawling on soft sediment habitats. The following are summaries of the most recent and relevant findings that highlight new information to be considered when evaluating potential adverse effects to EFH:

- Kaiser et al. (2006) conducted a meta-analysis of 101 different fishing impact manipulations and found that the direct effects of different types of fishing gear were strongly habitat-specific. The biota of soft-sediment habitats, in particular muddy sands, were surprisingly vulnerable, with predicted recovery times measured in years. Slow-growing large-biomass biota such as sponges and soft corals took much longer to recover (up to 8 yr.) than biota with shorter life-spans such as polychaetes (<1 yr.). Otter trawls had a significant initial effect on muddy-sand and mud habitats and this could reflect the great depth to which otter doors penetrate this soft sediment habitat, but on the latter these effects were short-lived with an apparent long-term, positive, post-trawl, disturbance response (there were no recovery data for muddy-sand). This positive response may represent an increase in the abundance of smaller-bodied fauna, but a possible overall decrease in biomass in response to trawling. In muddy sand, crustaceans appear more strongly impacted by otter trawls than annelids and mollusks. The effect of otter trawls in biogenic habitats was less severe than for scallop dredges, but there was insufficient data to deduce an accurate recovery time based on published experimental manipulations.
- Baer et al. (2010) found that bottom longlines can cause significant damage to sensitive habitats through entanglement and concluded that management of areas to be fished appear to be the main mitigative strategy for this problem.
- Brown et al. (2005) studied the effects of commercial otter trawling on benthic communities in the southeastern Bering Sea and documented that mobile invertebrate scavengers were more abundant in chronically trawled areas.
- De Marignac et al. (2008) conducted an analysis of videographic data on unconsolidated substrates in areas opened and closed to trawling on the central California coast and found that significant differences existed between an actively trawled area and an area that had been recovering from trawling impacts for three years at the time of sampling. Findings indicated that biogenic mound and biogenic depression microhabitats were significantly less abundant at trawled sites. Epifaunal macro-invertebrates were sparsely distributed and occurred in low numbers in both treatments. However, their total abundance was significantly different between treatments, which was attributable to lower densities at trawled sites. These differences were manifest in the micro-topographic structure that fish utilize for protection from predation and as refugia from currents, as well as in invertebrate epifaunal and infaunal communities. Each of the differences was found to be consistent

with the literature dealing with gear impacts to seafloor communities.

- Lindholm et al. (2008) studied patterns in the distribution of the sea whip in an area impacted by mobile fishing gear off the central California coast and found that the marked difference in the occurrence of upright sea whips among video transects was un-anticipated and may be attributable to two primary factors: water depth and/or impacts from otter trawling.
- Hannah et al. (2010) studied the effects of trawling for ocean shrimp on macroinvertebrate abundance and diversity near Nehalem Bank, Oregon depths and found that densities of a sea whip, the flat mud star, an unidentified sea star, and squat lobsters were lower at heavily trawled sites, as was invertebrate diversity based on the Shannon-Wiener index. Sea cucumbers and unidentified corals were observed at lightly trawled sites but not at heavily trawled sites. Observed differences in invertebrate density and seafloor complexity between sites were likely a mixture of physical and long-term ecological effects, and were either comparable or lower in general than other studies on the effects of bottom trawling. The authors point out that trawling effects are dependent on local factors such as gear type, fishing distribution and intensity, and the types of habitats and organisms present. They suggest, with evidence from an earlier study (Hannah and Jones 2003), that the semi pelagic nature of the shrimp trawl gear results in lower capture efficiency for macroinvertebrates and demersal fishes.
- Hannah et al. (2013) examined the disturbance rates of benthic macroinvertebrates from four different ocean shrimp trawl footrope configurations, and concluded that simple modifications to groundlines in order to reduce pinch points and to elevate portions of the groundline above the seafloor could significantly reduce benthic impacts, particularly to sea pens and sea whips.
- Hixon and Tissot (2007) compared trawled versus untrawled mud seafloor assemblages of fishes and macroinvertebrates at Coquille Bank, Oregon and concluded that the observed differences between trawled and untrawled demersal fish and epibenthic macroinvertebrate communities on deep mud seafloors adjacent to Coquille Bank were the result of gear impacts of groundfishing activities, particularly trawling, rather than local environmental differences. These differences suggest that the effects of bottom trawling along the West Coast of North America are similar to those documented on deep soft-sediment seafloors elsewhere in the world. Furthermore, they point out that it seems prudent to consider the adverse impacts of bottom trawling on mud-seafloor ecosystems of the continental shelf and slope and that their results are best examined in the context of the many rigorous studies worldwide demonstrating that bottom trawling clearly alters communities of seafloor species. However, Hannah et al. (2010) pointed out that interpretation of the Hixon and Tissot study is complicated by the fact that the sites they compared had nonoverlapping depth ranges, confounding depth, and trawling-related effects on the biota.
- Yoklavich et al. (2018) summarized damage to DSCS in areas of high trawl bycatch off southern Oregon and northern California. They reported damage to 20-53% of bamboo corals observed while all other taxa showed relatively low (<=5%) levels of disturbance. Damage to bamboo corals included overturned and dead colonies, and stumps still attached to rocks. They state that the pattern of disturbance to bamboo corals suggests bottom trawling as the source, either from commercial or research trawls, though the exact source and timing of disturbance was unknown. The patterns reported were similar to

those in other studies in Alaska (Heifetz et al. 2009, Krieger 2001) and British Columbia (Du Preez and Tunnicliffe 2011).

Several papers have underscored the fact that little has been written about recovery of seafloor habitat from the effects of fishing and that there is a lack of long-term studies, control sites or research closures, which hinder the ability to fully evaluate impacts. ODFW Marine Resources Program Staff also highlighted this issue during a technical review and discussion of the Hixon and Tissot paper where concerns were raised about the designated 'untrawled' area as an area that was part of historical shrimp and groundfish trawling grounds, which could hinder an accurate evaluation of impacts and recovery. They stated: "This is an analysis of data collected during a 1990 survey in response to proposals for oil drilling off of the west coast. The result was a comparison that was not adequately controlled for differences between sites. In addition, MRP data shows that both sites had been trawled by bottom trawl gear." In response to this critique and other concerns raised, the authors responded that these critiques did not affect the general result of documented trawl impacts to soft sediment.

2.2.2 Predictive Modeling of Biogenic Habitats and Fishing Effects

Subsequent to the EFH Final Action in 2005, Fujioka (2006) documented the impacts model used in the Alaska EFH process. This model offered several advantages over the impacts model used in the West Coast EFH process. In particular the model addressed:

- Spatial heterogeneity in trawl effort and habitat types;
- Trawl intensity, using empirical trawl effort data from the region;
- More realistic estimates of recovery time for hard corals on the order of 100 years;
- Development of a Long-term Effect Index (LEI), which calculated an estimate of the proportion of each habitat type in each cell impacted over the long-term under current levels of effort.

Key outcomes of the analysis were that the LEI results for hard corals were typically greater than 50% even under low levels of trawl effort and that substantial long-term impacts could occur to soft sediment habitats depending on trawl intensity. While this approach employs a model with several underlying assumptions, it provides for quantitative estimates of fishing impacts in a spatially explicit manner, which is a significant improvement over the qualitative nature of the impacts model used in the West Coast Pacific EFH process that concluded in 2005.

Guinotte and Davies (2014) modelled the habitat suitability of several higher taxonomic levels of deep-sea corals off the U.S. West Coast. Their models used a very earlier version of NOAA's National Deep-Sea Corals and Sponge Database, where taxonomic resolution for many presence records was limiting.

Partly to improve upon previous models of coral habitat suitability, the Bureau of Ocean Energy Management (BOEM) in 2018 contracted NOAA National Centers for Coastal and Ocean Science (NCCOS) to develop region wide models of DSCS and benthic macrofaunal. NCCOS is currently finalizing habitat suitability models for several taxa of DSCS, primarily at the genus and species level. Although the performance of the models has yet to be determined, perhaps the suitability predictions can be integrated into some new overall habitat impacts model in the future.

2.2.3 The Effects of Marine Debris on Benthic Habitats

Watters et al. (2010) provided the first quantitative assessment of marine debris and its impacts to the seafloor in deep submarine canyons and continental shelf locations off California and the U.S. They discerned only a few negative impacts to benthic organisms. Two incidents of ghost fishing by derelict gear were observed over 189 km of surveyed seafloor and a variety of habitats; however, several gear items could not be evaluated for ghost fishing due to limited viewing from the videotape. Entanglement of fishes in other types of debris was not witnessed. Some physical disturbance to habitats (including common structure-forming macroinvertebrates) was observed, which was caused by debris. It is possible that there was limited ability to see disturbance from the videotape, especially when caused by monofilament line. However, from scuba surveys conducted in shallow reefs (which provide direct viewing of marine debris), Chiappone et al. (2005) found that less than 0.2% of the available invertebrates were affected by lost hook-and-line fishing gear, even though this gear caused 84% of the documented impacts (primarily tissue abrasion) to sponges and cnidarians. Debris was found to alter the seafloor, by providing artificial habitat to demersal organisms. The majority of the debris was colonized, sometimes quite heavily, by encrusting invertebrates. Lastly, Keller et al. (2010) documented the distribution and frequency of marine debris for two years of the annual NWFSC West Coast groundfish bottom trawl survey. Debris was distributed throughout the West Coast and increased with depth and proximity to major populations centers (e.g., southern California). Also in southern California, the weight of marine debris showed a significant negative impact on the catch of demersal fishes and benthic invertebrates. Across the entire study region, plastics and metals were mostly frequently recorded while fishing gear represented the largest category collected by weight.

3 FISHING EFFECTS ON EFH BY HABITAT TYPE

The degree of impact that affects a habitat is dependent upon several conditions including the inherent dynamics (dynamic vs. static), history of disturbances (disturbed vs. non-disturbed), and recovery of fished habitats and the relationships of adjoining habitats.

3.1 Dynamic Habitats

Dynamic seafloor conditions generally consist of soft, unconsolidated sediment that migrates across the seafloor and is mobilized by bottom currents. Submarine bedforms such as dunes, mobile sand sheets, sediment waves and ripples are the common habitat types that represent dynamic bottom conditions. These features may be foraging habitats for groundfish and long-term disturbances may disrupt habitation of prey species. Chronic or severe impacts may reduce the abundance of some prey species, such as Pacific sand lance (*Ammodytes hexapterus*), whereas they may make others more available to groundfishes through suspension (e.g., epifauna) or exposure (e.g., infauna). Some soft, unconsolidated habitats, especially those that have resulted from rising sea level during the early Holocene, may be relict (static) at deeper depths (>30 m). By contrast, others in shallow water (<30 m) may seasonally cover or expose hard bedrock outcrops (dynamic). Hard gravel/pebble/cobble pavements, ridges, boulder fields, and pinnacles are generally considered to be static habitats that only typically vary as a result of punctuated, high energy events (e.g., geologic activity, tsunamis).

3.2 Disturbed Habitats

Historic and, to a lesser degree, contemporary fishing activities have been concentrated at specific areas on the continental shelf and slope. This repetitive fishing activity disturbs the seafloor to various degrees depending on gear types used. Most of the current trawling activities occur on soft, unconsolidated sand and mud seafloor and adjacent to hard bedrock outcrops, whereas longlines, fish traps (or pots) and other gear types are often also fished on hard-bottom regions.

3.3 Recovery of Habitats

Recovery of benthic habitats after disturbances occur is critical to the sustainability of a fishery. Many habitats such as soft, unconsolidated, dynamic, sedimentary bedforms can recover rapidly (within days or months) after disturbance, but it may take longer for the reoccupation of interstitial and other benthic organisms that make the seafloor a good foraging habitat. If a habitat is static then recovery after disturbance may be long-term (years to decades). Attached and sessile biogenic habitats associated with hard bedrock exposures may require considerable time to recover after fishing disturbance. Recovery times of these organisms depend upon the extent of removal and damage, as well as growth and recolonization rates.

3.4 Habitat Relationships

The degree of adverse impacts by fishing activities upon a benthic habitat is associated with the concentration and abundances of diverse habitats at fishing grounds. In regions where a fishing ground is homogenous and fairly extensive the impact may be low, while in regions of highly diverse benthic habitats consisting of foraging and various bottom fish life stage habitats disturbances may be acute, as it may interrupt feeding, predation avoidance, and reproduction activities of certain species.

3.5 Effects by Vessels

A variety of fishing and other vessels can be found in estuaries and the marine environment of the Pacific Coast. Vessel size ranges from small single-person vessels used in streams and estuaries, to mid-size commercial or recreational vessels, to large-scale vessels limited to deep-draft harbors and marine waters. Fishing vessels can adversely affect EFH by affecting physical, chemical, or biological components. Physical effects can include physical contact with propeller wash in eelgrass beds (estuaries). Derelict, sunk, or abandoned vessels can cause physical damage to any bottom habitat. Chemical effects from fishing activities could derive from anti-fouling paint, oil or gas spills, bilge waste, or other potential contaminants associated with commercial or recreational vessels operating in freshwater, estuaries, or the marine environment. Biological effects include introducing invasive species from bilge waters in fishing vessels that can disrupt communities upon which managed fish species rely.

4 FISHING EFFECTS ON EFH BY GEAR TYPE

The most common and direct effect of fishing on groundfish EFH results from fishing gear coming in contact with bottom habitats. Several review papers have been published on the effects of fishing gears on benthic habitats, including Auster and Langton (1999), Hamilton (2000), Barnette (2001), Johnson (2002), and NRC (2002), and more recently Kaiser et al. (2006). Though many of these reviews are somewhat dated, they still provide relevant information on the general effects of fishing on benthic habitats. Johnson (2002) classified fishing gear effects into five broad categories: 1) alteration of physical structure; 2) sediment suspension; 3) chemical modifications; 4) changes to benthic communities; and 5) changes to ecosystems. Fishing gears can cause physical harm to corals, sponges and other structure-forming invertebrates, rocky reefs, sandy ocean floor, eelgrass beds, and other components of seafloor habitats. Mobile bottom contact gears can resuspend sediments, with effects ranging from reduced feeding and metabolic rates to burial and associated mortality of benthic biota (Johnson 2002). These effects tend to be reduced in coastal areas where benthic communities are more adapted to persistent disturbance from tides and storms (Kaiser et al. 2000, Schoellhamer 1996, Floderus and Pihl 1990). Trawling and dredging call also alter the chemistry of sediments and porewater, especially in deeper and more stable waters (Rumohr 1998), which have implications to global biogeochemistry. Changes to benthic communuties depend on the life history characteristics of the biota (Bergman and Van Santbrink 2000), but can include a shift in community structure of the impacted area (Rijnsdorp and Van Leeuwen 1996).

Fishing gear types used in groundfish fisheries are listed in Federal regulations at 50 CFR 660.302, and are shown in Table 1. Detailed descriptions of these gear types can be found in the Risk Assessment for Amendment 19 of the FMP (NMFS 2005, Appendix 8; Recht 2003). In addition to authorized gears for the groundfish fishery, gear types used in other fisheries, including both MSA and non-MSA regulated fisheries are also evaluated in this document.

Table 1. Gear Types Used in the West Coast Groundfish Fisheries.

	Trawl and Other Net	**Longline, Pot, Hook and Line**	**Other**
Limited Entry Fishery (commercial)	Bottom trawl Mid-water trawl Whiting trawl Scottish seine	Pot Bottom longline	
Open Access Fishery Directed Fishery (commercial)	Set gillnet Sculpin trawl	Pot Bottom longline Vertical hook/line Rod/reel Troll/dinglebar Jig Drifted (fly gear) Stick	

Open Access Fishery Incidental Fishery (commercial)	Exempted trawl (ocean shrimp, spot and ridgeback prawn, CA halibut, sea cucumber) Setnet Driftnet Purse seine (round haul net)	Pot (Dungeness crab, CA sheephead, spot prawn) Bottom longline Rod/reel Troll	Dive (spear) Dive (with hook and line) Poke pole
Tribal	As above	As above	As above
Recreational	Dip net Throw net (within 3 miles)	Hook and line methods Pots (within 3 miles from shore) Private boat Commercial passenger vessel	Dive (spear)

Adapted from Goen and Hastie (2002). Most fishing gear used to target non-groundfish species (such as salmon, shrimp, prawns, scallops, crabs, sea urchins, sea cucumbers, California and Pacific Halibut, herring, market squid, tunas, and other coastal pelagic and highly migratory species) are similar to those used to target groundfish. These gears include trawls, trolls, traps or pots, longlines, hook and line, jig, set net, and trammel nets. Other gear that may be used includes seine nets, brush weirs, and mechanical collecting methods used to harvest kelp and sea urchins.

4.1 Bottom Trawling

Bottom trawling activity is conducted primarily by the West Coast groundfish fishery, harvesting many of the 90+ species listed in the FMP. Bottom trawling is managed under biennial specifications and includes a complicated matrix of sectors, seasons, and spatial limitations. There are many areas closed to bottom contact gear, including bottom trawling, many based on the designated HAPCs in the groundfish FMP EFH designations. (PFMC 2016). Impacts of bottom trawling to physical and biogenic habitats include removal, upending, or burial of vegetation, corals, and sponges that may provide structure for prey species; disturbance of sediments and associated biogeochemical cycling (van de Velde et al. 2018); and possible alteration of physical formations such as boulders and rocky reef formations (NRC 2002, Puig et al. 2012, Oberle et al. 2016, Hiddink et al. 2017, Sciberras et al. 2018).

Over the last two decades, significant effort has been devoted to the development of trawl gear designs that minimize disturbance to the seafloor and benthic organisms. Gear modifications that have been tested include doors that fish off the bottom (He et al. 2002; He and Winger 2010), elevated sweeps (Rose et al. 2010; Ryer et al.,2010; Sistiaga et al. 2015, Lomeli et al. 2019), floating bridles (He et al. 2015), and lighter groundgear (He 2007; He and Winger 2010; Hannah et al. 2013). Some of these studies showed significant reduction in mortality of infaunal (polychaetes), lower-profile epifaunal (crabs, urchins), and some higher-profile epifaunal (sea pens, sponges) organisms while maintaining comparable catch efficiency (Lomeli et al. 2019).

In addition to the Federal fishery, bottom trawls are used to harvest California halibut, ridgeback prawns, and urchins off California. Specific types of bottom trawls, known as double-rigged shrimp trawls, are used in state-managed fisheries to harvest ocean shrimp, primarily over sedimentary shelf habitats north or Fort Bragg, California. The footrope of shrimp trawls is designed to run 12-18 in. above the seafloor, though a groundline made of discs or bobbins and sometimes tickler or ladder chains, do contact the seafloor. That being said, the components of shrimp trawls that do contact the bottom are much lighter than similar components used on bottom trawls. Hannah et al. (2010) suggest alternate groundline designs that have minimal effects on shrimp catch rates, but minimize pinch points that uproot sessile invertebrates like sea pens and sea whips.

4.2 Midwater Trawling

Midwater or pelagic trawls are used to harvest Pacific whiting and some rockfish species off Washington and Oregon. Effects are generally limited to (1) removal of prey species, (2) direct removal of adult and juvenile groundfish, (3) occasional contact with the bottom, and (4) effects resulting from loss of trawl gear, potentially resulting in impacts to bottom habitats and ghost fishing.

In regards to bottom contact with midwater trawls, both NMFS and industry groups (Midwater Trawlers Cooperative, Pacific Whiting Conservation Cooperative, United Catcher Boats) examined the incidence of potential bottom contact in the non-tribal, at-sea hake fishery and reported their findings to the Council in April 2015. Although those reports have not been peer-reviewed, NMFS found that 19% of tows coastwide included highly benthic species, though the frequency reduced to 6% when considering catch of at least 10 kg of any benthic species. Of those tows with at least 10 kg of highly benthic species, <1% had a majority of the tow within EFH conservations areas. Furthermore, bottom contact with midwater trawls occurred rarely (<1% of tow lengths [b]) over hard seafloor and slightly more frequently (<9% of tow lengths [b]) over mixed habitats, most likely due to the increased risk of gear damage when fishing over complex rocky habitats. The NMFS report was considerably improved by feedback from industry groups to refine the basis for determining probable bottom contact.

The analysis of potential bottom contact described above was based on the presence of benthic species in the catch and recorded by fishery observers. There is also potential for components of midwater trawl gear (e.g., groundweights, net, footrope, bridles) to interact with the seafloor and result in no catch of benthic species; however, information to quantify these effects is limited. According to testimony by industry groups and analysis by NMFS, most hauls occurred over soft sediments. Thus the effects might be similar to what is described for bottom trawls over similar habitats, though the geographic extent and frequency of impacts would be much smaller.

4.3 Bottom Longline

Pelagic and bottom longline fishing in the marine environment is prevalent on the Pacific Coast. Pelagic longlining targets chiefly tuna and swordfish, while bottom longlining targets halibut, sablefish, and other species and can be fished on both soft and hard bottom seafloors. Both types of longlining can incidentally harvest managed species as well as prey species. Components of the gear that are in contact with the seafloor include anchors or weights, hooks, and the mainline. During retrieval, bottom longlines can sweep laterally several meters and overturn or undercut emergent organisms such as corals and sponges (Baer et al. 2010, Heifetz et al. 2009, Stone 2006).

4.4 Pot and Trap Gear

This gear type is dominated by commercial and recreational crab fisheries prevalent in estuaries and the marine environment along the entire West Coast. Lobster traps are used in

California, but not typically north of the central California coast, and pot gear is used in the sablefish fishery (NMFS 2009), often deployed as a string of pots.

Pot and trap gear can adversely affect EFH by smothering estuarine eelgrass beds and other marine/estuarine benthic habitats such as cobble and vegetated surfaces utilized by groundfish and can disturb biogenic habitat. Although typically placed in areas of sandy bottom, gear can also be deployed in areas of rocky habitat and may be dragged across the benthos by strong tidal or ocean currents. Lost trap and pot gear also can affect EFH and is discussed below under derelict gear.

4.5 Other Gears

4.5.1 Setnet Gear

Setnets, such as gillnets or trammel nets, are utilized more in fisheries for highly migratory species than in targeting groundfish. Few studies exist on the effects of these gears on benthic habitat, though some point out that gillnets can snag and/or dislodge corals and other emergent organisms upon retrieval (ICES 2000). Despite these risks, global reviews by ICES (1991, 1995) concluded effects on habitat to be minimal.

4.5.2 Roundhaul Gear

Fisheries for coastal pelagic and highly migratory species use purse seines, lampara nets, dip nets, and drum seines to target Pacific sardine, northern anchovy, Pacific mackerel, jack mackerel, market squid, and tuna. Most tuna fishing occurs in the western and central Pacific, and tropical eastern Pacific. However, tuna are highly migratory and are present off the U.S. West Coast. They are therefore included in this consideration of habitat impacts from fishing activities.

Roundhaul gear can affect EFH through managed harvest of species that are prey for Pacific groundfish, as well as for other managed species. It can also affect EFH if nets are allowed to contact the benthos (e.g., in squid spawning areas).

4.5.3 Derelict Gear

When gear associated with commercial or recreational fishing breaks free, is abandoned, or becomes otherwise lost in the aquatic environment, it becomes derelict gear. This phenomenon occurs in fishing activities managed under all four Pacific Coast FMPs, as well as recreational fishing and fishing activities not managed by the Council. In commercial fisheries, trawl nets, long lines, purse seines, crab and lobster pots, and other material, are occasionally lost to the aquatic environment. Recreational fisheries also contribute to the problem, mostly from lost crab pots and other fishing gear.

Derelict fishing gear, as with other types of marine debris, can directly affect groundfish habitat and can directly affect managed species via "ghost fishing." Ghost fishing is included here as an impact to EFH because the presence of marine debris affects the physical, chemical, or biological properties of EFH. For example, once plastics enter the water column, they contribute to the properties of the water. If debris is ingested by fish, it would likely cause harm to the individual. Another example is in the case of a lost net that becomes not only a potential barrier to fish passage, but also a more immediate entanglement threat to individual fish.

Along the Pacific Coast, Dungeness crab pots are especially prevalent as derelict gear (NWSI 2010). Commercial pots are required to use degradable cord that allows the trap lid to open after some time. This is thought to significantly reduce the effects of ghost fishing. There was no reliable information regarding the numbers or impacts of lost recreational derelict crab pots. For longlines, if the gear breaks loose and is lost, it can continue ghost fishing and potentially harm bottom habitat and structure-forming invertebrates.

Derelict gear can adversely affect groundfish EFH directly by such means as physical harm to eelgrass beds or other estuarine benthic habitats; harm to coral and sponge habitats or rocky reefs in the marine environment; and by simply occupying space that would otherwise be available to support managed species. Derelict gear also causes direct harm to groundfish (and potentially prey species) by entanglement. Once derelict gear becomes a part of the aquatic environment, it affects the utility of the habitat in terms of passive use and passage to adjacent habitats. More specifically, if a derelict net is in the path of a migrating fish, that net can entangle and kill the individual fish.

In Puget Sound, derelict fishing nets (primarily gillnets) as well as lost crab traps constitute a significant problem. And estimated 2,493 lost nets were removed recently during 18 months of a project funded under the American Recovery and Reinvestment Act. The Northwest Straits Initiative estimates that these nets were entangling 1.5 million animals annually. The nets are typically made from non-degradable nylon or plastic monofilament and persist in the aquatic environment for years (NWSI 2010). Hundreds of crab pots have also been removed (NWSI 2010).

5 MAGNUSON ACT FISHERIES

The following sections describe the geographic extent and intensity of fishing activities managed under MSA. Data for each gear sector varies in degree of availability, spatial detail, and overall utility to any analysis of potential adverse impacts to habitat. For instance, information on the distribution of bottom trawling is the most detailed spatially and temporally, while information on recreational fishing activities is more difficult to find. Nonetheless, the following sections will describe the available information for major gear categories listed in Table 1. Methodology used for reviewing fishing impacts is described in the EFH 5-year review Phase 1 report (PFMC 2012) and the NWFSC Groundfish EFH Synthesis Report (NWFSC 2013a) and Appendices (NWFSC 2013b). Map views of fishing effort for various gear types and time periods are available on the FRAM Data Warehouse at https://www.nwfsc.noaa.gov/data/map.

5.1 Commercial Fishing

5.1.1 Gear-Type Specific Distribution

Groundfish fishing effort 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 (NWFSC 2013a, 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.

Midwater trawl fishing is conducted off the Washington and Oregon coasts in the northern biogeographic region (NWFSC 2013b, 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, Washington. 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 (NWFSC 2013b, Figure A4a.2.). A decrease 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 scientific information available 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 (NWFSC 2013a, 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 (NWFSC 2013b, Table A4a.7.). The highest effort relative to hard habitat occurred over the central shelf (23.7%).

5.1.2 Fishing Effort Changes Since Amendment 19

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, bottom trawl effort decreased mostly off the northern Washington coast (NWFSC 2013b, 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, California (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 Washington coast (NWFSC 2013b, 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 (NWFSC 2013b, 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.

5.1.3 Fishing Effort Changes Since Amendment 20

Changes to the distribution of fishing effort after the implementation of catch shares in the commercial groundfish fishery are detailed in a report by NMFS (Somers et al. 2017) and submitted to the Council as part of the Biological Opinion on Continuation of Pacific Coast Groundfish Fisheries. The 2017 report, and an update that will be published later in 2019, describes changes in the amount, timing, location and depth of fishing for several gear sectors within the Federal groundfish fishery.

For the bottom trawl sectors, spatial patterns remained consistent despite median and fleet-wide tow durations slightly decreasing from 2011-2015. Effort for the Federal fishery continued to decrease south of San Francisco (Figure 5).

For midwater trawling, fleet wide tow duration in the at-sea hake fishery correlated with changes in quota from year to year (Table 1, Figure 9). In 2015, cumulative tow duration in the catcher-processor (CP) sector was the highest it's been since at least 2002. Since 2011, fishing seemed to move further south and concentrate in 150-200 fm (Table 4, Figure 24). For the mother ship catch vessels (MSCV), trends in effort were often similar to those for the CP sector. Fleet-wide tow duration increased between 2011-2014, but then decreased in 2015, with median tow durations per haul generally lower than that in the CP sector (Table 1, Figure 8 and 19). Fishing effort was focused off central Oregon and moved further offshore in southern Oregon (Figure 22), with at least 80% of the effort between 100 and 200 fm (Table 4, Figure 24). For the shoreside sector, landings and tow duration increased between 2011 and 2015 for tows targeting rockfish, but no clear pattern was evident for tows targeting hake. Hauls for rockfish were more constrained by depth (80% of hauls in waters 50-100 fm) compared to those for hake (90% in waters 50-250 fm). The shoreside hake fishery extends from Eureka, California to the Cape Flattery, Washington while the rockfish fishery has a much smaller and patchy distribution between Florence, Oregon (44° N. latitude) and Cape

Alava, Washington (48° N. latitude).

Fixed gear effort was reported separately in Somers et al. (2017) for pots vs. hook and line (longline), and catch shares vs. non-catch shares sectors. From 2011-2015, effort largely stabilized ~35 pots / set in the NCS sector compared to ~30 in the CS sector (Table 7, Figure 27). The distribution of NCS pot fishing showed little overall change after implementation of catch shares, with ~80% of landings made between 39° N. latitude and 46° N. latitude (Table 9, Figures 28, 29). Depth of hauls showed a bimodal distribution with peaks at 0-250 fm and 500-600 fm (Table 11, Figure 31). For hook and line sectors, the median number of NCS hooks per set increased from ~2000 prior to 2012 to about ~2500 from 2012-2015. The number of CS hooks per set has been more variable both within and across years, but median values are on par with those in the NCS sector (Table 8, Figure 33). More than 70% of sablefish landings in the CS hook and line sector occurred in the 46° N. latitude bin, while landings in the NCS fleet were more evenly distributed along the coast (Figure 34). The overall depth range of fishing was generally similar between hook and line sector, but a higher proportion of sets occurred shallower than 250 fm in the CS sector (Table 11, Figure 37).

5.2 Recreational Fishing

Hook and line gear and pots are the most widely used and most likely sources of potential recreational fishing gear impacts to EFH. Hook and line gear often involves use of large (usually lead) weights when trolling for salmon or fishing groundfish such as halibut, lingcod, and rockfish species. Metal recreational weights can impact biogenic habitat and soft and hard substrate when lost or when contacting the bottom. Hooks, lines, and smaller weights can be lost and become entangled in rocky and biogenic habitat. Recreational pot gear can damage habitat when making initial bottom contact while fishing, or drag across the bottom causing more widespread damage when lost.

Biogenic habitats are most at-risk from recreational fishing gear impacts followed by hard substrate and lastly, soft sediments. Impacts would proportionally be larger in areas of high recreational activity. Many areas of vulnerable biogenic habitat are located far offshore lessening chance of recreational gear and vessel impacts such as anchoring.

Lost gear may remain in-place and adversely affect organism growth while continuing to fish. Ghost fishing can occur but is limited for hook and line gear by number of hooks. Recreational pots can continue to fish until required biodegradable cord opens escape hatches disabling the fishing ability of the gear.

Cumulative impacts from recreational fishing gear are thought to be most pronounced in heavily fished areas but little is known since minimal visual monitoring or inspections have been conducted; research is needed in this area. Due to the relatively small gear and spatial footprint of recreational fisheries overall, impacts are minimal compared to commercial fisheries. Though dive fishing with spears and spear-guns are additional forms of recreational gear, their impacts are minimal to EFH.

6 NON-MAGNUSON ACT FISHERIES

Several state-managed fisheries on the West Coast use bottom contact gears to target non-groundfish species. These fisheries are managed by their respective states (Washington, Oregon, and California), and they operate in both state and Federal waters. They target ocean shrimp (coastwide), California halibut, ridgeback and spot prawns, and sea cucumber (all in California) with bottom trawls, and Dungeness crab (coastwide) and hagfish (Washington and Oregon) with pots. These fisheries are prohibited from fishing inside EFHCAs. The ocean shrimp fishery may fish in the trawl and non-groundfish trawl RCAs.

The following sections describe the geographic extent of fishing activities of those state-managed fisheries. Similar to Federal fisheries, data for each gear sector varies in degree of availability, spatial detail, and overall utility to any analysis of potential adverse impacts to habitat.

6.1 Fisheries Managed by the State of Washington

Logbook data for state managed fisheries were aggregated into 10-minute blocks and indicate where fishing occurred by a minimum of three vessels (i.e., “rule of three”), consistent with other requests from non-fishery management agencies for commercial logbook data. As such, areas or blocks that are not shaded do not necessarily represent areas where fishing did not occur, but rather may not have met the “rule of three” standard.

For the Dungeness crab fishery, logbook data collection began in the 2009-2010 season and specific fishing location data prior then was unavailable. Data for each fishing season is presented separately (PFMC 2012, Figures 19a and 19b).

For the spot prawn fishery, prior to 2003, both trawl and pot gear could be used; however, beginning in 2003, trawl gear was prohibited. Therefore, trawl fishing location data were excluded because inclusion could give a false impression of where the fishery occurs. There are very few participants in this fishery, so applying the “rule of three” resulted in a display of only a few discrete areas; as such, data were aggregated across all years (2003-2011) to better display the extent of the spot prawn fishing footprint (PFMC 2012, Figure 20).

The Washington hagfish fishery, which fishes with strings of baited traps, has such few participants that it was difficult to meet the “rule of three” minimum standard to display informative data, so no maps were included.

6.2 Fisheries Managed by the State of Oregon

Oregon Department of Fish and Wildlife provided fishery footprints created from state fishery logbook information for Dungeness crab (PFMC 2012, Figure 21), hagfish (PFMC 2012, Figure 22) and ocean shrimp (PFMC 2012, Figures 23a-d) fisheries. Three crab seasons are represented in this footprint – 2007-08, 2009-10 and 2010-11. Catches from Oregon hagfish fisheries are presented for 1993-1998, 1999, part of 2001, 2002-2011 (limited catch reported in 2006). Prior to 2002 catch was reported sporadically, but reporting improved from 2002 onward. Ocean shrimp bottom trawl footprint was based on logbook data from five large stock size years, 1987, 1989, 1992, 2005, and 2011.

Each data product represents a multiple year aggregate view of the extent of effort (or footprint) for each fishery. These were developed by taking a series of steps using ArcGIS, based on the methods used by NWFSC analysts to develop the trawl fishery footprint for the EFH process. Each fishery's logbook data was spatially joined to a 0.5° latitude X 0.5° longitude grid. Polygons were then created using the 'Minimum Bounding Geometry' tool with the convex hull bounding type selected for each grid cell. The polygons were then buffered by 1 nm for Dungeness crab and ocean shrimp, and by 3 nm for hagfish, then the boundaries between each polygon were dissolved. The resulting polygons enclose >99% of all set string locations for each fishery. To maintain confidentiality, polygons with locations from fewer than three vessels were eliminated, as were arms on polygons that contained a single sample. These products are only intended to represent the general "footprint" of each fishery for the different time periods specified.

6.3 Fisheries Managed by the State of California

The California Department of Fish and Game (CDFG) issued a report in 2008 that described the nature and extent of the California halibut fishery and to a lesser extent, the California sea cucumber trawl fishery (CDFG 2008). This was concurrent with the closure of California Halibut Trawl Grounds (CHTG), which have certain performance criteria associated with them, to be met prior to re-opening the CHTG. The criteria relate to bycatch, damage to seafloor habitat, ecosystem health, and restoration of biogenic habitats. While the report does not draw specific conclusions, it makes clear that there was a conservation concern.

All citations in the report are from 2007 and before, and the EFHRC did not receive any subsequent information in response to its request to the CDFG before publication of the Phase 1 report. While this report may not represent the most up to date information, it nonetheless provides an indicator of the location and intensity (PFMC 2012, Figures 24 and 25) of California halibut trawling; as well an insight into the potential adverse effects to marine habitat (PFMC 2012, Figure 26).

7 CUMULATIVE FISHING EFFECTS

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. (Table 2) The sensitivity scale consisted of four levels (0, 1, 2, and 3) representing relative sensitivity to gear impacts. 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. Because few studies focused on the recovery times of habitats from various types of fishing, those values were not integrated into the analysis of cumulative impacts.

Table 2. Descriptions of sensitivity levels and recovery time (years) for gear impacts from PSMFC 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.

Indices of sensitivity were prepared by extracting the relevant values 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 3). Sensitivity levels and recovery times 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 4. The impacts shown in Table 4 were derived from two sources: 1) a workshop where expert 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 5. This overview is drawn from a recent analysis of swept area seabed impact (Sasi) 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.

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

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 3. Part B. Recovery time (years) for four major gear types and three bottom types adapted from PSMFC 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 4. 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 5. Impact levels (scale of 0-3) for three major gear types represented as vulnerability of geological 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**

Figures 1-3 show the distribution of cumulative impacts for four major gear types, based on impact levels included in Table 3, Part A. Add more detail.

Figure 1. Distribution of cumulative fishing pressure before implementation of Amendment 19 EFH conservation areas (2002-2005). Fishing pressure is weighted for three main gear types and sensitivity levels reported in Table 3A.

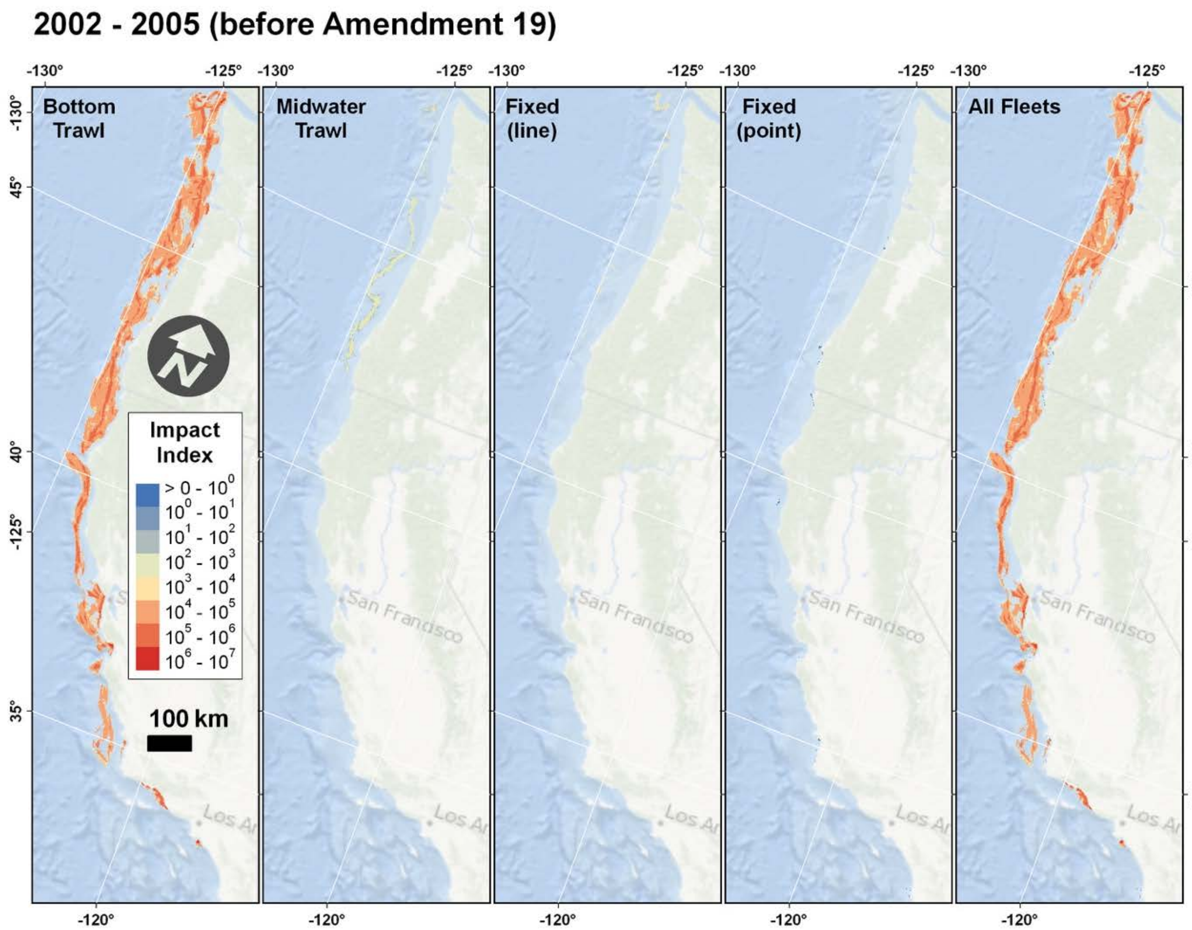


Figure 2. Distribution of cumulative fishing pressure <u>after</u> implementation of Amendment 19 EFH conservation areas (2007-2010). Fishing pressure is weighted for three main gear types and sensitivity levels reported in Table 3A.

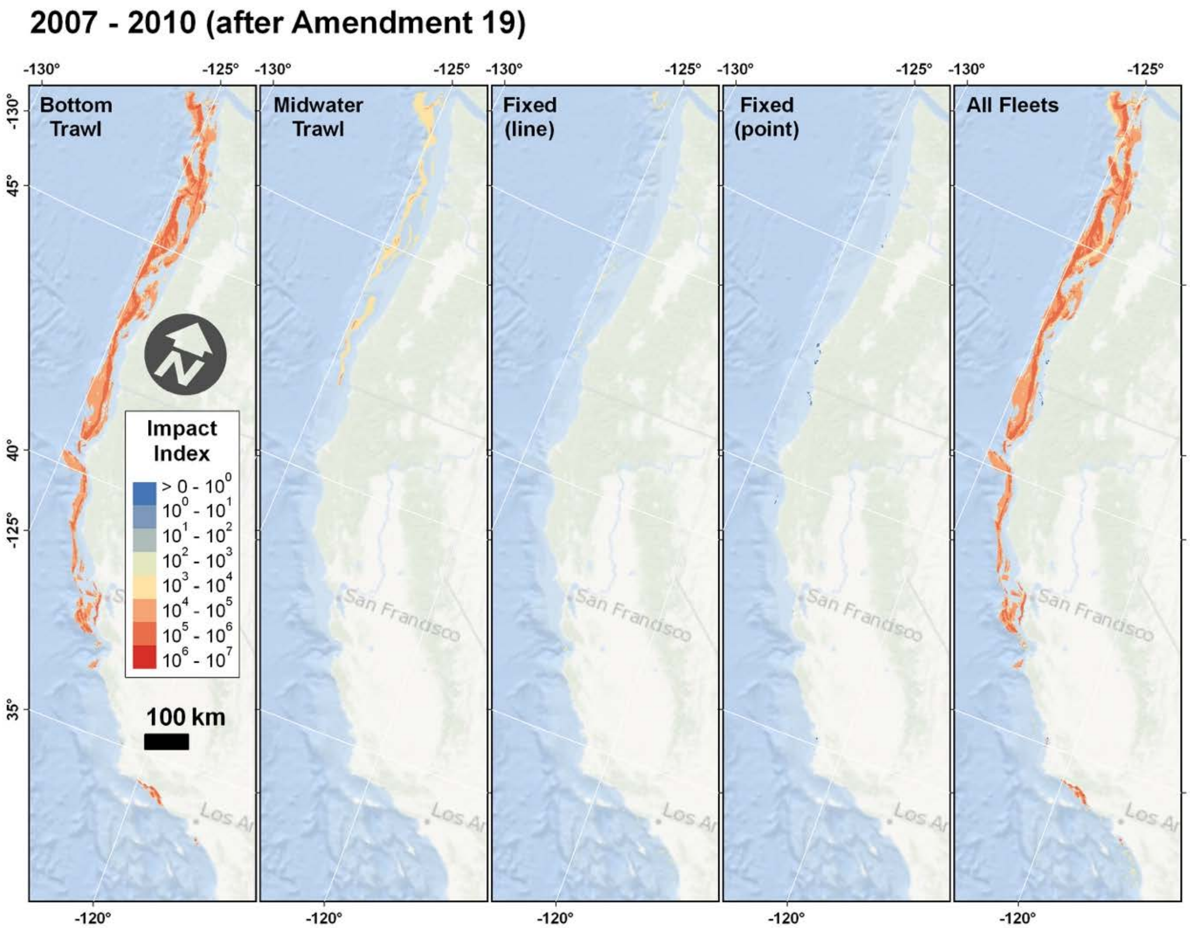
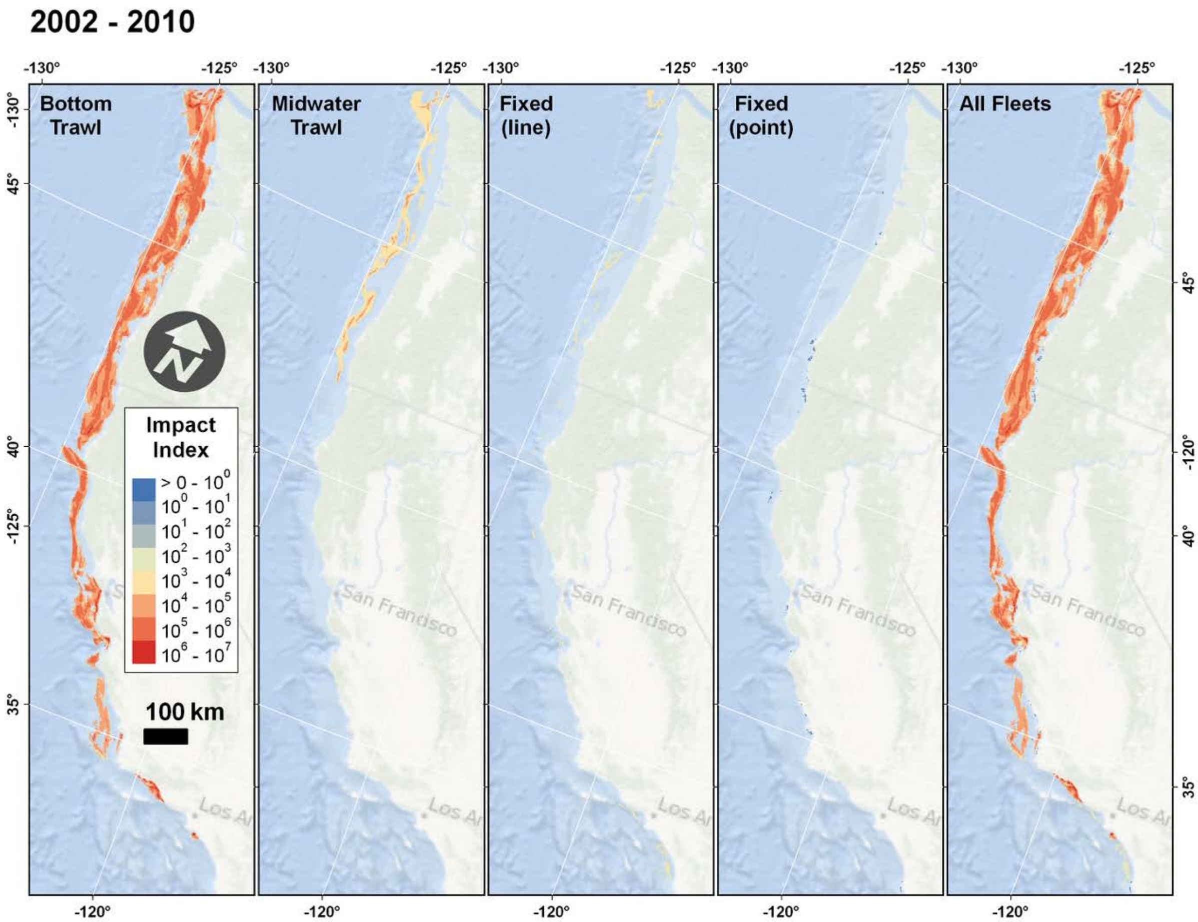


Figure 3. Distribution of cumulative fishing pressure (2002-2010). Fishing pressure is weighted for three main gear types and sensitivity levels reported in Table 3A.



8 DISCUSSION

Since the last review of groundfish EFH that culminated with the publication of the final EIS (NMFS 2005) and implementation of Amendment 19 regulations, a significant amount of new information has been compiled to evaluate the potential adverse effects of fishing on EFH. This new information was detailed in the Phase 1 report (PFMC 2012), synthesized to provide context for development of public proposals to modify EFH and associated regulations (NMFS 2013a, 2013b), and ultimately used to develop eight original proposals, and subsequently refine and evaluate the final preferred alternative adopted by the Council.

Despite greatly improved understanding of the distribution and intensity of fishing effort, and sensitivities of benthic habitats to certain types of fishing, there are still gaps in our knowledge. First, we lack information about recovery of various habitats to disturbance. The reopening of several areas closed to bottom trawling since June 2006, as part of Amendment 28, presents an opportunity to monitor recovery of several soft bottom habitats and their associated benthic communities. We are hopeful additional studies of recovery of hard bottom habitats will be conducted before the next review of groundfish EFH.

Second, we don't fully understand the role of DSCS to managed species in our region. A significant amount of resources have been dedicated to compiling information on DSCS in the region (see Clarke et al. 2017, Whitmire and Clarke 2007). NOAA's Deep-Sea Coral and Research and Technology Program, in cooperation with other Federal, state and private partners, has compiled a vast database of records of deep-sea corals and sponges in the region. Additionally, the program has released several site characterization reports developed by NOAA researchers. While much of this information has been used by the public to develop proposals for modifying EFH regulations, it has been difficult to integrate point records of presence into models of fishing impacts. The ongoing modeling effort by NOAA NCCOS and BOEM will likely provide useful coastwide habitat suitability surfaces. A 2015 summit considered the role of DSCS to managed species, and resulted in a report to the Council for their April 2015 meeting; however, synthesis of those findings has yet to be fully published.

Third, information on the distribution of fishing effort, particularly from bottom trawling and certain fixed gears has not be summarized at fine enough spatial scales. Vessel monitoring system (VMS) data could improve the spatial resolution of fishing effort data, but to date these data have not been summarized for appropriate geographic extents and time periods. Furthermore, increasing the ping rate of VMS would offer even better interpretation of fishing tracks, particularly in the vicinity of closed areas and sensitive habitats.

Lastly, we need updated and more detailed information on the distribution of benthic habitats. Less than half of the continental shelf and upper slope has been mapped with modern, high-resolution multibeam sonar, though coverage rates vary throughout the region (see PFMC 2012). Ideally, habitats would be mapped to a consistent classification scheme, such as the Coastal and Marine Ecological Classification Standard (CMECS). Habitat maps are a critical input to models that predict groundfish species distributions, habitat suitability for biogenic organisms such as corals and sponges, and help quantify the effects of fishing. Although detailed information on the distribution of seafloor sediments and habitat types exists for some areas, coverage and detail are lacking or inconsistent for much of the FMP area.

All of these improvements in information could be integrated into a new and improved model of fishing effects on EFH, similar to what was recently done for groundfish EFH in Alaska (Smeltz et al. 2019). Improving the knowledge base on the aforementioned topics may provide the Council and NMFS more options for managing groundfish fisheries in ways that best balance habitat protection and sustainability of the fishery.

9 ACKNOWLEDGMENTS

We would like to acknowledge the many individuals and groups who contributed to development of this document. The ad hoc EFH Review Committee, chaired by Brad Pettinger, spearheaded the gathering of the information base used in this review of groundfish EFH, and drafted two reports to the Council. The NWFSC synthesized much of the information provided during Phase 1. Marlene Bellman, now with the Northwest Indian Fisheries Commission, Kayleigh Somers and Blake Feist (both at NWFSC) played crucial roles in helping to analyze the cumulative impacts of fishing. Stacey Miller, Owen Hamel, and Jim Hastie, each with NOAA Fisheries, provided reviews that greatly improved this document.

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