# PACIFIC COAST FISHERY ECOSYSTEM PLAN

## For the U.S. Portion of the California Current Large Marine Ecosystem

Final Draft for Public Review

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CalCOFI | California Cooperative Oceanic Fisheries Investigations |
| CCE | California Current Ecosystem |
| CCIEA | California Current Integrated Ecosystem Assessment |
| CDFW | California Department of Fish and Wildlife |
| CEBA 1 | Comprehensive Ecosystem-Based Amendment 1 |
| CMECS | Coastal and Marine Ecological Classification Standard |
| CPFV | Charter passenger fishing vessel |
| CPS | Coastal pelagic species |
| CSVI | Community Social Vulnerability Indicator |
| CVA | Climate vulnerability assessment |
| DLCD | Department of Land Conservation and Development (Oregon) |
| DPS | Distinct Population Segment |
| EBFM | Ecosystem-based fishery management |
| EC species | Ecosystem component species |
| EEZ | Exclusive Economic Zone |
| EFH | Essential Fish Habitat |
| EFHCA | Essential Fish Habitat Conservation Area |
| ENSO | El Niño/Southern Oscillation |
| ESA | Endangered Species Act |
| ESR | Ecosystem Status Report |
| ESU | evolutionarily significant unit |
| F | Fishing mortality |
| FEP | Fishery Ecosystem Plan |
| FGC | Fish and Game Commission (California) |
| FGDC | Federal Geographic Data Committee |
| FMEP | Fisheries Management and Evaluation Plan (Idaho) |
| FMP | Fishery Management Plan |
| GIS | Geographic information system |
| HAB | harmful algal bloom |
| HCR | Harvest control rule |
| HMS | Highly migratory species |
| IEA | Integrated Ecosystem Assessment |
| km | Kilometers |
| m | Meters |
| MBTA | Migratory Bird Treaty Act |
| MEA | Millennium Ecosystem Assessment |
| MFMP | Marine Fisheries Management Plan (Oregon) |
| MLMA | Marine Life Management Act (California) |
| MMPA | Marine Mammal Protection Act |
| MPA | marine protected area |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |

| | |
|---|---|
| MSE | Management strategy evaluation |
| MSY | maximum sustainable yield |
| nm | nautical mile |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanographic and Atmospheric Administration |
| NPC | North Pacific Current |
| NPGO | North Pacific Gyre Oscillation |
| OCMP | Oregon Coastal Management Program |
| ODFW | Oregon Department of Fish and Wildlife |
| OY | optimum yield |
| PacFIN | Pacific Fishery Information Network |
| PDO | Pacific Decadal Oscillation |
| PFMC | Pacific Fishery Management Council |
| PSMFC | Pacific States Marine Fisheries Commission |
| RCA | Rockfish Conservation Area |
| SAFE | Stock status and fishery evaluation (document) |
| SFA | Sustainable Fisheries Act |
| SSC | Scientific and Statistical Committee |
| U&A | Usual and Accustomed [places] |
| USFWS | United States Fish and Wildlife Service |
| VMS | vessel monitoring system |
| WDFW | Washington Department of Fish and Wildlife |
| WFWC | Washington Fish and Wildlife Commission |

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# Chapter 1 Vision, Purpose, Goals and Objectives

The California Current Ecosystem (CCE) is a dynamic, diverse environment in the eastern North Pacific Ocean. Spanning nearly 3,000 km from southern British Columbia, Canada to Baja California, Mexico, the CCE encompasses the United States Exclusive Economic Zone (EEZ), the coastal land-sea interface, and adjacent terrestrial watersheds along the U.S. West Coast.

The Pacific Fishery Management Council (Council or PFMC) first adopted a Pacific Coast Fishery Ecosystem Plan (FEP) in 2013. In 2019, the Council began revising and updating its FEP, starting with a discussion of the FEP's visionary language. This draft Chapter 1 begins with statements of the Council's vision for the CCE, and includes the purpose statement for the FEP itself, and a set of Goals and Objectives for the CCE and for the Council's work in the ecosystem.

## *1.1 Vision for the California Current Ecosystem*

*The Pacific Fishery Management Council envisions a thriving and resilient California Current Ecosystem that continues to provide benefits to current and future generations and supports livelihoods, fishing opportunities, and cultural practices that contribute to the wellbeing of fishing communities and the nation.*

To achieve this vision, the Council manages species to healthy population levels that provide sustainable harvest opportunities while preserving biodiversity and ecological relationships. The Council also develops management measures to ensure fair and equitable sharing of harvest benefits, to conserve habitats, and to minimize the bycatch of protected and non-target marine life. These Council policies are implemented through its fishery management plans (FMPs) and through this FEP to improve managed species resiliency to variability and change in the climate and ocean environment. The Council is supported in this work through the continued commitment of partner agencies to scientific research and ongoing monitoring of the biological, ecological, physical, social, and economic characteristics of the ecosystem.

## *1.2 Purpose of the Fishery Ecosystem Plan*

The purpose of the FEP is to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations, and management policies that coordinate Council management across its FMPs and the CCE. An FEP should provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader CCE. The FEP should also coordinate information across FMPs for decision-making within the Council process and for consultations with other regional, national, or international entities on actions affecting the CCE or FMP species. Additionally, an FEP should identify and prioritize research needs and provide recommendations to address gaps in ecosystem knowledge and FMP policies, particularly with respect to the cumulative effects of fisheries management on marine ecosystems and fishing communities. The Council intends its work under this FEP to serve as an open and transparent forum for all who wish to civilly engage in the discussions of how the public resources of the CCE should be conserved and managed.

The FEP is meant to be an informational document, and is not meant to be prescriptive relative to Council fisheries management. Information in the FEP, results of the Integrated Ecosystem Assessment (IEA), and the Annual State of the California Ecosystem Report are available for consideration during the routine management processes for fisheries managed in each FMP. How exactly these items will affect fishery management decisions is at the discretion of the Council.

## *1.3 Goals and Objectives*

The FEP's goals and objectives, below, are intended to address the Council's Vision for the CCE (Section 1.1) and Purpose for the FEP (Section 1.2). This FEP and related activities integrate fisheries management policies across all Council FMPs, while recognizing that the Council's authority is generally limited to managing fisheries and the effects of fisheries on the marine ecosystem, protected species, and to consultations on the effects of non-fishing activities on essential fish habitat (EFH). The Council's work often requires Council members to think about their larger goals for the ecosystem itself. In some cases these goals and objectives are relevant to ocean resource management and policy processes external to the Council.

Goal 1: Provide a framework and public forum to improve and integrate ecosystem information for use in Council decision-making.

> Objective 1a: Provide annual and regular opportunities for the Council and its advisory bodies to consider physical, biological, social, and economic information on the CCE with an emphasis on environmental and climate conditions, climate change, habitat conditions, ecosystem interactions, and changing socio-economic drivers;
>
> Objective 1b: Identify research and monitoring priorities to address knowledge gaps, including indicators and reference points to monitor trends and drivers in key ecosystem features;
>
> Objective 1c: Provide a nexus to regional, national, and international ecosystem-based management endeavors;

Goal 2: Conserve and manage species' populations and the ecological relationships among them to realize long-term benefits from marine fisheries while avoiding irreversible or long-term adverse effects on fishery resources and the marine environment.

> Objective 2a: Map trophic energy flows and other ecological interactions within the CCE to better understand trophic relationships and the potential ecosystem effects of fishing, and to understand the effects of trends in marine mammal, seabird, and other protected species' populations and diets on fish stock abundance;
>
> Objective 2b: Assess variability in fisheries income and vessel participation rates to ascertain whether CCE fishing rates have affected long-term stability and wellbeing for fishing communities;

Goal 3: Implement fisheries management that ensures continued ecosystem services for the well-being of West Coast communities and the nation.

> Objective 3a: Continue to provide for commercial, recreational, ceremonial, subsistence, and non-consumptive uses of the marine environment;
>
> Objective 3b: Continue to monitor and engage in opportunities to minimize and mitigate the effects of non-fishing activities on the ecosystem to better ensure that conservation benefits are not undermined by negative impacts of these activities;
>
> Objective 3c: Support education efforts to promote understanding of CCE biophysical processes, how the ecosystem affects human well-being, and of the potential risks and benefits to ecosystem services from climate variability and change;

Goal 4: Protect and restore marine habitat diversity and integrity to the extent practicable.

> Objective 4a: Maintain a diverse portfolio of protected habitat types in a way that meets the needs of the ecosystem and fishing communities;

Objective 4b: Promote awareness of and encourage lost fishing gear recovery projects, the development of fishing gear recovery technology, and fishing gear recycling programs as a means of protecting habitat from derelict fishing gear and ghost fishing.

Goal 5: Manage fisheries to support goals for protected species' recovery.

Objective 5a: Review the status and trends of protected species' populations to facilitate understanding their role in the ecosystem within and across FMPs;

Objective 5b: Manage and minimize bycatch and bycatch mortality of protected species within and across FMPs to the extent practicable;

Goal 6: Promote fishery management that is sufficiently adaptive to account for the effects of climate variability and change, ocean acidification, marine heat waves, harmful algal blooms, and hypoxia.

Objective 6a: Improve monitoring of the ecosystem and climate variability;

Objective 6b: Incorporate climate and ecosystem data into stock assessments and forecasts when applicable;

Objective 6c: Assess the effects of climate variability and change on the ecosystem's long-term stability and recommend research needed to understand the effects of potential shifts in species' abundance and distribution.

# Chapter 2 Ecosystem Issues in the Council Process

This chapter describes the Council's long-term schedule for reviewing and updating the FEP, and its annual schedule for reviewing and considering ecosystem initiatives and the California Current Ecosystem Status Report (ESR). These schedules and processes ensure that the Council has regular opportunities to consider ecosystem issues, and allow the Council and its advisory bodies to better integrate ecosystem science into management processes and measures developed under the Council's four FMPs.

## *2.1 Schedule and Process for Developing and Amending the FEP and the Ecosystem Initiatives*

From 2010 through early 2013, the Council and its advisory bodies drafted an FEP, collaborating with the public through various drafts and revisions. In April 2013, the Council adopted the final FEP and FEP appendix with the expectation that the FEP itself would not be amended until at least 2018. From 2013-2021, the Council developed and implemented ecosystem initiatives through the FEP appendix, revising and updating that appendix as appropriate. In 2018, the Council reviewed the FEP and began the FEP update process with a discussion of the FEP's visionary language in 2019.

This document, the main body of the FEP, will not be amended until the Council determines that an FEP review and revision process is necessary. At that time, the Council may consider appointing new ad hoc advisory bodies to review and recommend revisions to the FEP. The Council does not anticipate initiating an FEP review process until 2029. In addition to the main body of the FEP, which consists of Chapters 1-5, the Council may choose to add one or more appendices to the FEP without opening the main body of the FEP to revision.

Appendix A to the FEP:

1) provides the Council with a process for considering ecosystem-based management initiatives to address issues of interest to the Council that may cross authorities of two or more of its FMPs;
2) briefly documents completed FEP initiatives; and
3) provides additional potential cross-FMP initiatives for review and consideration by the Council and the public.

Each year at the Council's March meeting, the Council and its advisory bodies will:

- review progress to date on any ecosystem initiatives the Council already has underway;
- review the list of potential ecosystem initiatives provided in Appendix A to the FEP, receive new ecosystem initiative proposals, assess whether any existing or newly proposed initiatives help implement the FEP's Goals or Objectives, and determine whether any of those initiatives merit Council attention in the coming year;
- if initiatives are chosen for Council efforts, request background materials from the appropriate entities; and
- identify candidate ecosystem research topics for Scientific and Statistical Committee (SSC) review to support improvements in the indicators included in the Annual Report.

In March 2029, or sooner if necessary, the Council will assess whether to initiate a review and update of the FEP.

Each year at the SSC's September meeting, the SSC will review the selected proposed research during the September meeting with participation by the Ecosystem Advisory Subpanel and Ad Hoc Ecosystem

Workgroup, as appropriate; resulting revisions to ESR indicators are reported to the Council the following March.

Each initiative in Appendix A includes suggestions for background information needed to support consideration of the initiative and suggestions for the expertise needed on an ad hoc team to develop the initiative. If the Council determines that it wishes to address a new ecosystem initiative, it would begin by requesting relevant background information from the appropriate agencies and other entities, which would then be made available to the Council and its advisory bodies at a subsequent Council meeting, scheduled at the Council's discretion. Upon review of the background informational materials, the Council will decide whether to further pursue that initiative, and may then request nominations for appointments to an ad hoc team to be tasked with developing the initiative. Any materials developed through the ad hoc team process would, as usual with Council advisory body materials, be made available for review and comment by all of the Council's advisory bodies and the public during the Council's policy assessment and development process.

## *2.2 Ecosystem Initiatives, 2013-2021*

The FEP's Appendix A provides examples of potential ecosystem-based fishery management (EBFM) initiatives, processes by which the Council can address issues and challenges that affect two or more Council FMPs or coordinate major Council policies across the FMPs. Appendix A is separate from the FEP and may be modified without the Council having to also modify the FEP or reconsider its contents. The Council has an annual process for reviewing the ecosystem initiatives and assessing whether changes are needed to Appendix A, or whether analyses are needed to provide background work for new ecosystem initiatives.

FEP Initiative 1 was designed to prohibit new directed commercial fishing in Federal waters on unmanaged, unfished forage fish species until the Council has had an adequate opportunity to both assess the scientific information relating to any proposed directed fishery and consider potential impacts to existing fisheries, fishing communities, and the greater marine ecosystem. The Council worked on FEP Initiative 1 from September 2013 through March 2015, ultimately adopting amendments to all four of its FMPs as Comprehensive Ecosystem-Based Amendment 1 (CEBA 1). The Council and National Marine Fisheries Service (NMFS) implemented FEP Initiative 1 through two sets of Federal regulations: updating and clarifying the fishing gears allowed to be used in the West Coast EEZ, and prohibiting directed fishing for, yet allowing incidental catch of: round herring (*Etrumeus teres*) and thread herring (*Opisthonema libertate* and *Opisthonema medirastre*), mesopelagic fishes of the families *Myctophidae*, *Bathylagidae*, *Paralepididae*, and *Gonostomatidae*, Pacific sand lance (*Ammodytes hexapterus*), Pacific saury (*Cololabis saira*), silversides (family *Atherinopsidae*), smelts of the family *Osmeridae*, and pelagic squids (families: *Cranchiidae*, *Gonatidae*, *Histioteuthidae*, *Octopoteuthidae*, *Ommastrephidae* except Humboldt squid (*Dosidicus gigas*), *Onychoteuthidae*, and *Thysanoteuthidae*).

FEP Initiative 2 was a Council-wide review of the annual California Current Ecosystem Status Report of the National Oceanic and Atmospheric Administration (NOAA) Fisheries Northwest and Southwest Fisheries Science Centers. Under Initiative 2, the Council facilitated a year-long scoping process involving ecosystem scientists, fishery managers, and the public in a conversation about ecosystem science within the Council process. The Council began FEP Initiative 2 in September 2015 and completed it in September 2016. Through the initiative process, Council advisory bodies and the public considered: physical and oceanography indicators; biological indicators; human dimensions indicators; freshwater, estuarine and marine habitat indicators; and risk assessments and applications of indicators to decision-making. Ultimately, this review process improved both the understanding Council process participants have of the ecosystem itself and the applicability of the ecosystem status reports to Council work.

The Council launched FEP Initiative 3, the Climate and Communities Initiative in September 2017. This initiative combined ideas from two of the potential initiatives in the FEP appendix, one on the socio-economic effects of fisheries and one on the effects of climate variability and change on managed fish stocks. The goal of the Climate and Communities Initiative was to "consider, develop, and implement strategies for improving the flexibility and responsiveness of our management actions to near-term climate shift and long-term climate change, and strategies for increasing the resiliency of our managed stocks and fisheries to those changes." In 2018, the initiative began with educational webinars on the state of scientific information on the potential effects of climate change on the physical, biological, social and economic environments.

Over 2018-19, it became apparent that the Council needed to engage in a larger conversation about the effects of climate on fish stocks, fisheries, and fishing communities with its membership, its advisory bodies, and the public. To support that conversation, the Council held a scenario planning process for the effects of climate variability and change on its managed stocks from November 2019 through September 2021. Scenario planning is a strategic planning process that helps organizations think about and meet new challenges through discussions around a suite of different possible descriptions of future conditions. For this initiative, four scenarios were designed to help the Council think creatively about the risks and opportunities associated with relatively greater or lesser year-to-year climate variability, and generally increasing or decreasing abundance of our managed stocks. In September 2021, the Council reviewed reports on the completed scenario planning process and closed out the first phase of this initiative Council. For 2022 and beyond, the Council intends to work from the results of that first phase to plan a suite of new work for itself and requests for information from its partner agencies on scientific information and analyses to be used in the Council process, potential revisions to the fisheries management process and programs, and potential new collaborations on preparing for climate variability and change.

### *2.3 Ecosystem Status Reports*

In support of its ecosystem-based management processes, the Council asked that National Marine Fisheries Service (NMFS), in coordination with other interested agencies, provide it with an annual state-of-the-ecosystem report at each of its March meetings, beginning in March 2014. The Council asked that the report:

- be bounded in terms of its size and page range to about 20 pages in length, and
- not wait for the "perfect" science to become available, should there be scientific information that does not come with definitive answers and numbers, but which may be useful for the Council to consider.

The Council received its first California Current ESR in November 2012. Since March 2014, NMFS's Northwest and Southwest Fisheries Science Centers have collaborated to deliver ESRs to the Council and its advisory bodies at each March meeting. From 2015 through 2016, the Council's work on the second ecosystem initiative to provide a coordinated review of ecosystem indicators brought Council process participants together to ensure that the reports provide the information that is most interesting and useful to the Council process. The SSC has been engaged in the annual report development process since its inception, providing scientific review of new indicators and a thorough vetting process for ecosystem scientists to share and test new ideas. Information in the report is intended to improve the Council and public's general understanding of the status and functions of the CCE and is not tied to any specific management measures or targets for Council-managed species. When the Council receives future annual ESRs, it anticipates continuing to review the reports' contents so that they may be tailored to provide information that best meets management needs.

### 2.4 Geographic Range of the FEP

The geographic range for the Pacific Coast FEP is the entire U.S. West Coast EEZ (see Figure 2-1). The West Coast EEZ does not encompass all of the CCE, nor does it include all of the waters and habitat used by many of the Council's more far-ranging species. The Council also recognizes the importance of freshwater and estuarine ecosystems to the CCE and may expand this initial effort to include these ecoregions in the future. The Council does not believe that designating the EEZ as the FEP's geographic range in any way prevents it from receiving or considering information on areas of the CCE or other ecosystems beyond the EEZ.

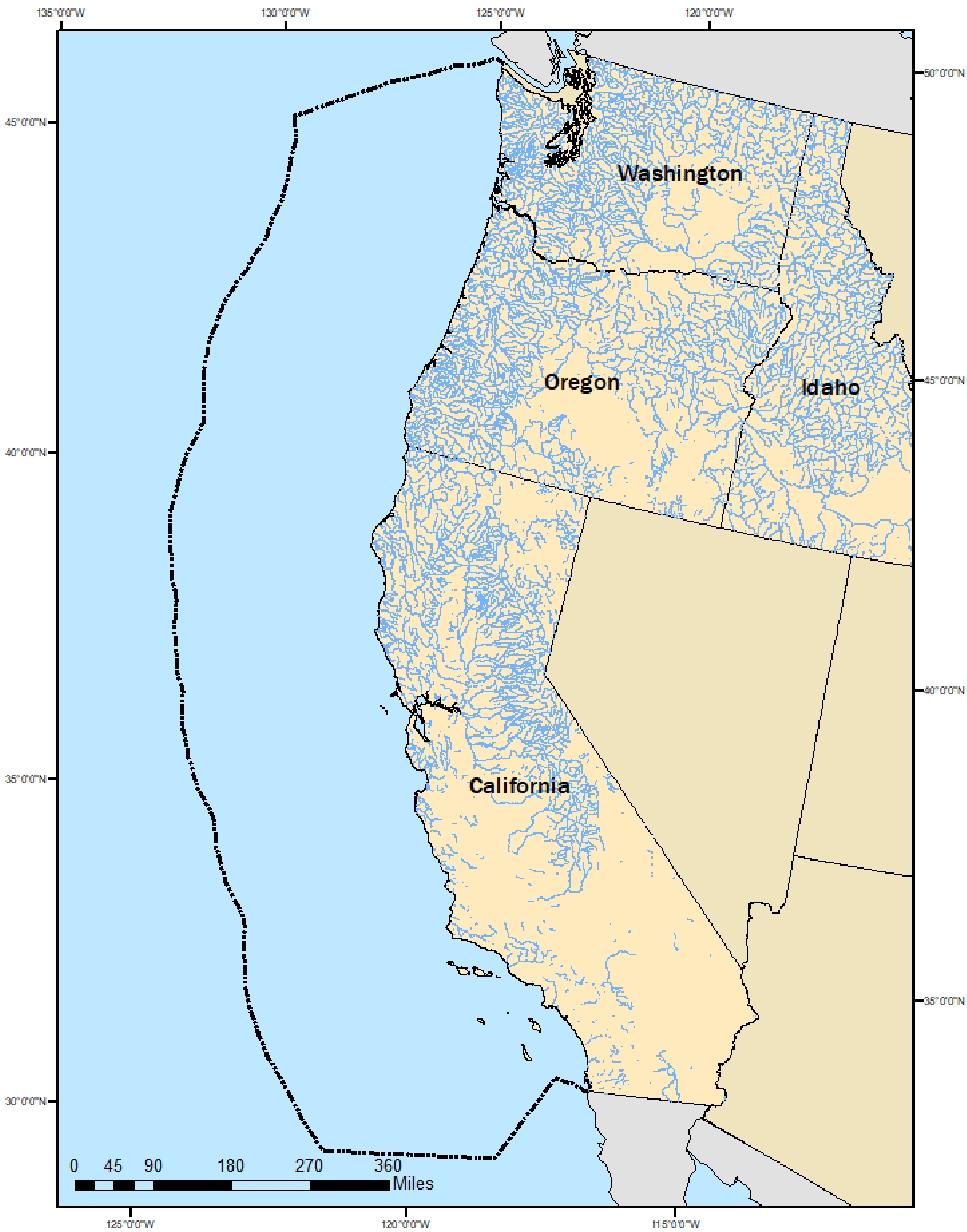


**Figure 2-1. Geographic range of the FEP.**

# Chapter 3 California Current Ecosystem Overview

While the CCE is considered one of the world's large marine ecosystems, it can also be described as a social-ecological system in which human social and economic systems and components are linked to biophysical systems and components and feedback on one another (Díaz*, et al.* 2015; Duraiappah*, et al.* 2014; Levin*, et al.* 2016, Figure 3-1; Ostrom 2009). The biophysical part of the system has climate and ocean drivers such as ocean circulation, sea surface temperature, and upwelling at its base. These drivers are key influences and produce major patterns in the CCE. Within those major patterns, habitat interacts with the effects of climate and ocean drivers on animal and plant life in the ecosystem. The species using that habitat may be managed by the Council or other entities, may be the prey, predators, or competitors with Council-managed species and may be indicators of ecosystem integrity (Foley et al. 2013). Council-managed fisheries, and human systems more broadly, affect and are affected by the larger biophysical system and the components of the system, and are agents of change within the system.

Like the biophysical environment, the human dimension of the CCE is composed of multiple interrelated components (Figure 3-1). Human well-being (c.f., Díaz*, et al.* 2015) is mediated by broad social forces or drivers, local social systems, and human activities. Social drivers—such as population growth and settlement patterns, national and global economic and political systems, historical legacies, dominant cultural values, and class systems—constrain or enable local social systems and human activities in ways that directly or indirectly affect human well-being. Likewise, local social systems that vary geographically and across different social groups—such as state and local laws and policies, regional economies, local institutions and infrastructure, social networks and social hierarchies, diverse cultural values and knowledge, and more—affect human well-being directly or indirectly, and constrain or enable human activities related to the natural environment. These activities generate benefits for humans, and they are also ways by which humans affect the natural environment.

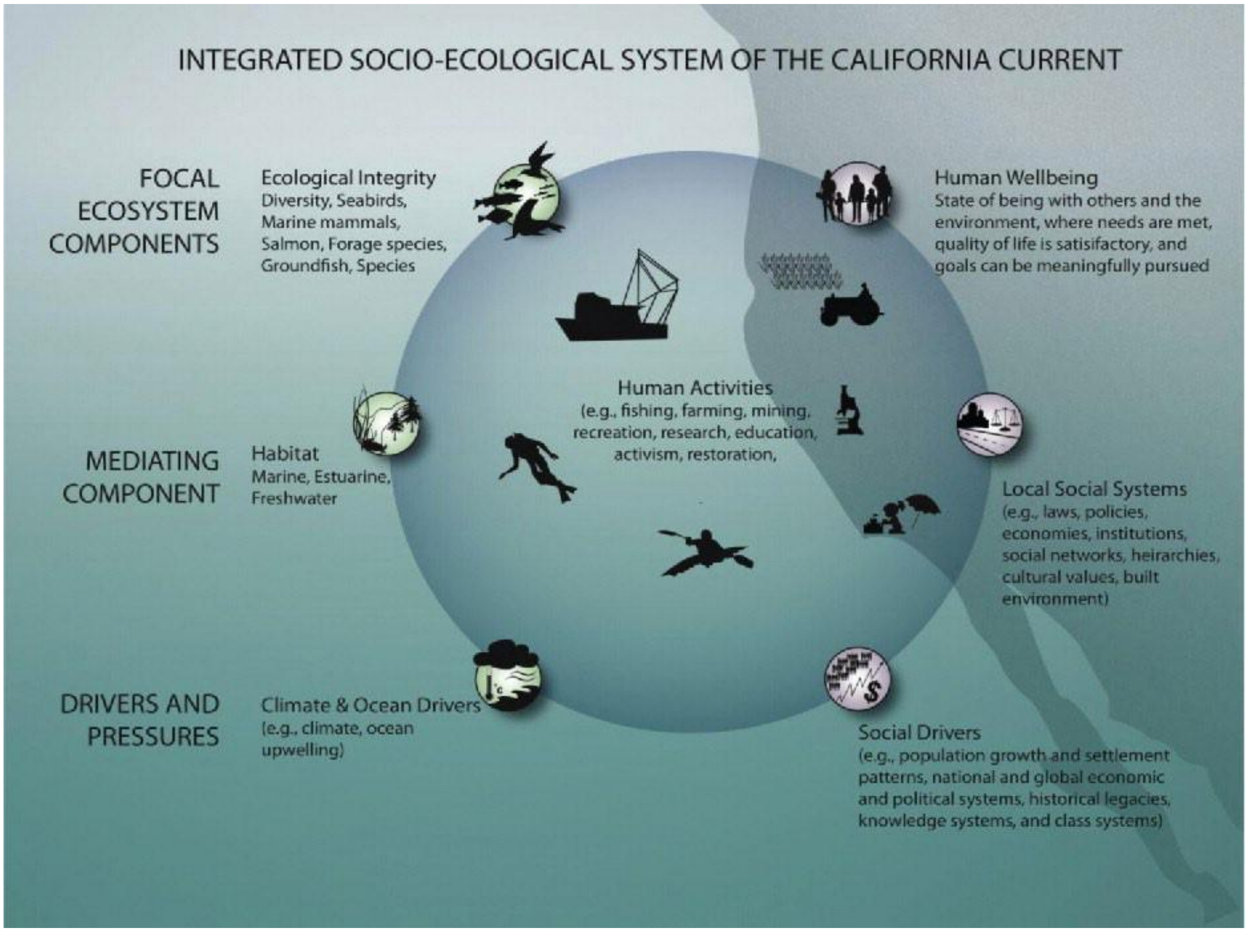


**Figure 3-1. A conceptualization of the social-ecological system of the California Current showing broad biophysical and social drivers, the potential mediating effects of habitat and local social systems and the management endpoints of ecological integrity and human well-being. (From Levin et al. 2016.)**

In this chapter, we describe the U.S. portion of the CCE as it relates to federally-managed fisheries, beginning with biogeographic subregions, associated oceanographic and geological features, biological components, and social and economic components of our particular social-ecological system.

### *3.1 Major Biogeographic Subregions of the CCE*

Although there are many ways of thinking about dividing the CCE into subregions, Francis, *et al*. (2009) have suggested three large-scale CCE subregions:

- Northern subregion extending from the northern extent of the CCE off Vancouver Island to a southern border occurring in the transition zone between Cape Blanco, Oregon and Cape Mendocino, California;
- Central subregion extending southward from that transition zone to Point Conception, California; and
- Southern subregion from Point Conception to Punta Baja, on the central Baja California Peninsula.

Each of these major CCE subregions experience differences in physical and oceanographic features such as wind stress and freshwater input, the intensity of coastal upwelling and primary productivity, and the width and depth of the continental shelf. Regional-scale features such as submarine ridges and canyons add to the distinct character of each subregion. Similarly, in inland waters, physical forcing from the ocean drives biological processes in estuaries (Raimonet and Cloern 2016). Ocean conditions also determine weather patterns that affect the hydrology of streams, rivers, and lakes far inland (Di Lorenzo and Mantua 2016). At the same time, freshwater and estuarine drivers also influence oceanographic processes, through river plumes that transport sediment, nutrients, and pollutants out to the ocean and onto the continental shelf (Checkley*, et al.* 2009; Hartwell 2008; Kim*, et al.* 2018; Warrick and Farnsworth 2009). The complexities generated by interacting ocean and river currents concentrate resources, drawing pelagic predators (Brodeur and Morgan 2016; Phillips*, et al.* 2017). These physical, hydrological, and oceanographic differences translate into differences in the ecosystem structure of each subregion. The portions of the three CCE subregions within the U.S. EEZ are discussed in more detail below.

### *3.1.1 Northern Subregion: Strait of Juan de Fuca, Washington to Cape Blanco, Oregon*

This subregion is approximately 375 miles long, with the U.S. portion extending from its northernmost point at Cape Flattery, Washington south to Cape Blanco, Oregon. This area corresponds approximately to the "Northern California Current Ecosystem" subregion reported in the annual Ecosystem Status Report to the Council (Harvey*, et al.* 2020b, Fig. 2.1c ). The upwelling winds for which the CCE is best known are relatively weak in this subregion; this northern subregion nonetheless includes some of the CCE's most productive areas (Hickey and Banas 2008). The southward-flowing California Current is also relatively weak in the north, and the flow can even shift poleward off the Washington coast when the bifurcation of the North Pacific current shifts southward.

A key feature of this subregion is the abundant freshwater input from the Straits of Juan de Fuca and the Columbia River. Both provide a steady supply of terrestrial nutrients to the euphotic zone. In the absence of all other forces, a large freshwater discharge such as the Columbia River mouth behaves as a "buoyancy flow," where a buoyant freshwater jet rides over the dense saline oceanic water and moves poleward (Wiseman and Garvine 1995), (Horner-Devine*, et al.* 2009). Two generalized flow regimes have been observed with the Columbia River freshwater plume: (1) southward upwelling-favorable wind stress causes the Columbia River plume to meander southward and offshore and (2) northward downwelling-favorable wind stress causes the plume to meander poleward and along the coastline. Phytoplankton biomass concentrations are generally higher off the Washington coast than off the Oregon coast despite mean upwelling-favorable wind stress averaging three times stronger off the Oregon coast (Banas*, et al.* 2009).

The U.S.-Canada border is a political boundary that divides the region. Otherwise, based on biological and oceanographic features, the northern boundary of the CCE is as dynamic as the whole ecosystem and can shift dramatically from year to year. The rough boundary between the CCE and the Gulf of Alaska marine ecosystem is generally off Vancouver Island, with Brooks Peninsula serving as a notable geographic point dividing the greater upwelling of the CCE from the relatively relaxed upwelling of the Gulf of Alaska (Lucas*, et al.* 2007). The continental shelf is relatively wide in this subregion and broken up by numerous submarine canyons and oceanic banks. Hickey (1998) describes two major canyons, Astoria and Juan de Fuca, and one major bank, Heceta Bank, all of which are important both oceanographically and for fisheries productivity.

Features like the Juan de Fuca eddy and Heceta Bank also help retain nutrients and plankton in coastal areas, at times contributing to harmful algal blooms (Giddings*, et al.* 2014). The many submarine canyons in this region can also intensify upwelling, adding to primary productivity. These and other factors combine to produce chlorophyll concentrations in this subregion that can be five times higher than off Northern California, despite the weaker upwelling winds (Hickey and Banas 2008).

### 3.1.2 Central Subregion: Cape Blanco to Point Conception, California

In the region just north of Cape Blanco, the shelf narrows in width, winds and upwelling intensify, and coastal waters move offshore. At or near Cape Blanco, what had been a simple, lazy southward current becomes a maze of swirling eddies and turbulent coastal flows that continue approximately 170 miles southward to Cape Mendocino (Botsford and Lawrence 2002). The area between Cape Blanco and Cape Mendocino experiences the strongest winds and upwelling in the CCE. This transition area also includes the southern boundary of oil-rich, subarctic zooplankton populations. This subregion then continues southward for another approximately 465 miles to Point Conception, an area that corresponds approximately to the "Central California Current Ecosystem" subregion reported in the annual ESR (Harvey*, et al.* 2020b, Fig. 2.1c ).

The Mendocino Escarpment is another key geological feature of this region, the largest east-west submarine ridge within the U.S. West Coast EEZ, extending westward from Cape Mendocino to just beyond the 200 nm EEZ boundary, as if pointing toward the Steel Vendor Seamount about 270 miles off the California coast (Figure 3-2). South of the Mendocino Escarpment, the narrow continental shelf creates notably different habitat ranges for bottom-dwelling organisms (Williams and Ralston 2002). This area south of Cape Mendocino also features several submarine canyons (Vizcaino Canyon, Noyo Canyon, Bodega Canyon, Monterey Canyon, and Sur Canyon) that enhance the high relief shelf and slope structure and demersal fish habitats. Biogeographic barriers extend out to sea because of strong winds related to the high relief coastal mountains and the funneling of air at high speeds from the Klamath and Sacramento basins to the coast. There are several distinct upwelling zones in this subregion near major points, such as Point Reyes, northern Monterey Bay, and Point Sur. Outflow from the Sacramento River system through the San Francisco Bay Delta region is a significant source for freshwater input into the CCE in this subregion.

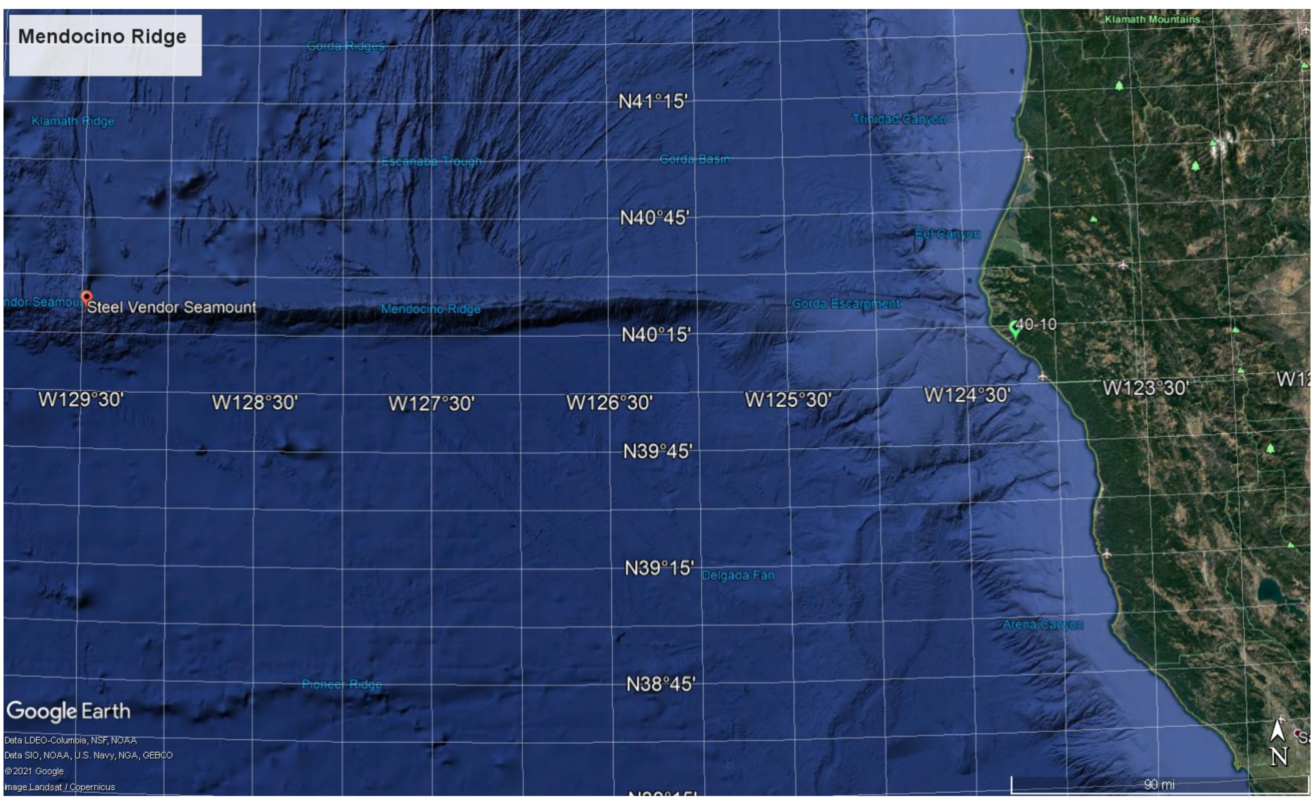


**Figure 3-2. The Mendocino Ridge and Steel Vendor seamount.**

### 3.1.3 Southern Subregion: Point Conception to U.S. - Mexico border

This approximately 236 mile-long subregion is substantially different from the north and central areas. The topography from Point Conception to the U.S.-Mexico border is complex, the shelf is typically more narrow and shallow, and the coastline suddenly changes from a north-south to an east-west orientation at Point Conception. This area of the coast, which corresponds approximately to the "Southern California Current Ecosystem" subregion reported in the annual ESR (Harvey*, et al.* 2020b, Fig. 2.1c ), is also sheltered from large-scale winds and is a transition point between large-scale wind-driven areas to the north and the milder conditions of the south. There is also a seasonal cyclonic gyre in the Southern California Bight area that mixes cooler CCE water with warmer waters from the southeast (Hickey and Banas 2008). To the east of a line running south of Point Conception, winds are weak, while further offshore, to the west, wind speeds are similar to those along the continental shelf of the central subregion. The Santa Barbara Channel remains sheltered from strong winds throughout much of the year.

In contrast to the relatively contiguous continental shelf in the central subregion, the offshore region from Port San Luis to the U.S.-Mexico border encompasses some of the most diverse basin and ridge undersea topography along the U.S. West Coast. Islands top many marine ridges (e.g., the Channel Islands) and some of the most southerly topographical irregularities are associated with the San Andreas Fault. This complex topography, in combination with the influence of subtropical waters from the south, results in a marine community that is very different from more northern subregions.

As in the Northern subregion, the international boundary divides what could be considered a common region. Based on ecology and oceanography, the Southern subregion extends south to Punta Baja, Mexico (30° N. latitude). A fourth subregion of the CCE exists in Mexican waters, reaching from Punta Baja to the tip of the Baja California Peninsula at Cabo San Lucas (U.S. GLOBEC 1994). In addition, a semi-permanent feature, the Ensenada Front, spans the region near the U.S-Mexico border and can inhibit movement of marine organisms (Kahru*, et al.* 2012; Moser and Smith 1993).

## 3.2 Oceanographic and Geological Features of the CCE

The oceanographic and geological features of the CCE form the large-scale physical base of the ecosystem. These features greatly influence current and wave patterns and provide habitats that influence species distributions and productivity. However, understanding the habitats of the species we manage requires more than just considering physical features. The vegetation and plant communities that interact with physical features and some of the more sessile animals that can themselves form and shape habitats are discussed in Section 3.3.

### 3.2.1 Habitat Classification

The oceanographic and geological features of the CCE greatly influence current and wave patterns and provide habitats that influence species distributions and productivity. Habitats are one of a variety of important ecological characteristics for managed fish species, and a common language by which to describe habitats and convey information about them is important for effective and efficient management. Previously, benthic habitats of the CCE were described using a classification scheme developed by Greene, *et al*. (1999) for deep seafloor habitats, which organized them according to physical features in a hierarchical system of levels. In 2012, the Federal Geographic Data Committee (FGDC) endorsed the Coastal and Marine Ecological Classification Standard (CMECS), a structured catalog of ecological terms that provide a framework for interpreting, classifying, and inter-relating observational data with the goal of facilitating assessment, monitoring, protection, restoration, and management of biotic assemblages, harvested and protected species, vital habitats, and important ecosystem components (FGDC 2012).

CMECS attempts to encompass all aspects of marine habitat, starting with the broadest and narrowing to the most specific using 6 elements – the biogeographic and aquatic settings, and the water column, biotic, substrate, and geoform components. The final product is a biotope that combines both biotic and abiotic features to create a unique combination of environmental variables that make up a particular habitat:


**Figure 3-3. Benthic habitat in the CCE.**

- Biogeographic setting – this setting identifies areas based on species aggregations and features influencing the distribution of organisms.
- Aquatic setting – CMECS classifies the coastal and marine environment in three systems: Marine, Estuarine, and Lacustrine (freshwater).
- The water column component describes the water column in terms of key features related to habitat, including features related to vertical layering, temperature, salinity, and biogeochemistry.
- The geoform component describes the major geomorphic and structural characteristics of the coast and seafloor with descriptors for geologic, biogenic, and anthropogenic features.
- The substrate component describes the composition and size of sea floor materials.
- The biotic component classifies the composition of floating and suspended biota and the biological composition of the benthos.

The CMECS components can work independently or in combination with each other, as needed and available data permits.

At present, spatial high-resolution seafloor mapping is limited to particular areas of interest within the CCE, while much of the CCE is mapped or interpreted at relatively low resolution. Available data have been compiled into geographic information system maps to aid with management planning and EFH designations/reviews, with some data available through online mapping tools. A basic CMECS habitat seabed induration map depicting hard, mixed, and soft substrates (Figure 3.4, based on classification scheme by (Greene*, et al.* 1999) was used during the most recent groundfish EFH review for the designation of EFH Conservation Areas (EFHCAs). This map (and source data) is available through the FRAM Data Warehouse (Figure 3-3; https://www.webapps.nwfsc.noaa.gov/data/map).

Subsequent to the recent groundfish EFHCA designations, and to better define future EFHCA designations, the treaty tribes of western Washington, in cooperation with NOAA (NMFS and the Olympic Coast National Marine Sanctuary) used CMECS as the first step towards developing a more comprehensive toolset for the analysis of marine habitats. They have compiled the geoform and substrate component data, and are in the process of developing the biotic and water column components (Figure 3-4; https://geo.nwifc.org/ocean/). This map illustrates some of the complexity of benthic habitats in the CCE from Cape Flattery, WA to Point Arena, CA.

### *3.2.2 Geological Features of the CCE*

The CCE is geologically diverse and active. It includes all three types of global tectonic plate boundaries: 1) transform or strike-slip, 2) convergence or subduction, and 3) divergence or spreading. The Mendocino Triple Junction, where three plates meet, lies just south of the state boundary between California and Oregon, making the region geologically complex. Plate movements result in slipping, uplifting, landslides, and other changes in the physiographic features off the West Coast.

In general, the CCE has a relatively narrow shelf, steep slope, and wide abyssal plain. Some important geologic features are shown in Figure 3-4. The shelf, ranging from shore to depths of about 200 m, is generally less than 35 nm wide along most of the West Coast. Washington and Oregon have the broadest continental shelf anchoring a north-south trend of decreasing shelf width from Cape Flattery to Point Conception, California. The continental margin from the Strait of Juan de Fuca to Cape Mendocino features abundant methane seeps, which alter both the chemical and physical composition of the seafloor (Merle*, et al.* 2021). Most of the CCE north of the Southern California Bight also has a narrow slope with deep (abyssal depth) basins fringed on the west by volcanically active ridges. The Southern California Bight region is bathymetrically complex and differs dramatically from areas to the north. The shelf is generally very narrow but widens in some areas of the Bight to include several islands that are an expression of the ridge and basin topography. As described above, Cape Blanco, Cape Mendocino, Point Conception and Punta Eugenia are prominent features of the coastline and significantly influence oceanographic conditions offshore. They are often identified as boundaries separating biogeographic regions of the coast. Smaller capes are also dotted along the coastline and have more localized influences.

Major offshore physiographic features of Washington and Oregon include the continental shelf and slope, submarine canyons, and the Cascadia Basin. Low benches and hills characterize the upper slope. The lower slope intersects the deep seafloor of the Cascadia Basin at 2,200 m depth off the north coast, and at about 3,000 m off the central and southern Oregon coast. Off northern California, the Eel River Basin, located on the continental shelf and stretching from the waters offshore of Oregon, has a high sedimentation rate, fed by the Eel, Mad, and Klamath Rivers. The offshore region of the southern California Bight encompasses some of the most diverse topography along the West Coast. The complex series of northwest-southeast-oriented basins and ridges on the continental border south of Point Conception, with islands topping most of the ridges, makes this region unique.

**Figure 3-4. Important geological features in the CCE. [Image to be inserted.]**

### *3.2.3 Oceanographic Features of the CCE*

The CCE is an eastern boundary current system, featuring the California Current flowing southward from approximately Vancouver Island to the Baja Peninsula (Checkley (Bograd*, et al.* 2016; Checkley and Barth 2009), see Figure 3-5. The CCE is dominated by strong coastal upwelling, particularly north of 36° N. latitude, and is characterized by fluctuations in physical conditions and productivity over multiple time scales (Bograd*, et al.* 2009; Checkley and Barth 2009; Mann and Lazier 1996; Parrish*, et al.* 1981). Food webs in these types of ecosystems tend to be structured around coastal pelagic species that have historically exhibited boom-bust cycles over decadal time scales (Bakun 1996; Checkley and Barth 2009; Fréon*, et al.* 2009). By contrast, the top trophic levels of such ecosystems are often characterized by marine mammals and large bodied fish such as salmon, tuna, and billfish. Some of these predators are highly mobile, and thus their dynamics span multiple ecosystems and even ocean basins. Ecosystems analogous to the CCE include other eastern boundary current systems, such as the

Humboldt Current off the western coast of South America, the Benguela Current off sub-Saharan west Africa, and the Canary Current off Spain and northern West Africa (Fréon*, et al.* 2009).

The CCE is characterized by several distinct water masses including, but not limited to, the California Current (Figure 3-2). The California Current originates where the eastern-flowing west wind drift known as the North Pacific Current (NPC) collides with the North American continent. The NPC on average abuts land at the southern end of Vancouver Island (approximately 48.5̊ °N. latitude), but the central point of contact ranges from southern Alaska to southern Oregon (Cummins and Freeland 2007). Upon colliding with the landmass, the NPC bifurcates into the southward-flowing California Current (shown in Figure 3-2) and the northward-flowing Alaska Current. The location of the bifurcation of the NPC is significant, as there is a positive correlation between the latitude of bifurcation and nutrient load of the California Current (Sydeman*, et al.* 2011). The California Current transports fresh, cold, oxygenated and nutrient-rich water equatorward and ranges from 50 to 500 km offshore (Mann and Lazier 1996).

The California Undercurrent is another major water mass in the CCE. The California Undercurrent flows poleward over the continental shelf at depths of 150-300 m and is composed of Pacific Equatorial water, which is saline, warm, high in nutrients, and low in oxygen (Checkley and Barth 2009). During the winter, the California Undercurrent merges with the seasonal, wind-driven, poleward-flowing, nearshore Davidson current such that the bulk of water over the continental shelf is moving north between fall and early spring. The California Undercurrent can transport Pacific Equatorial water as far north as southern Alaska (Thomson and Krassovski 2010).

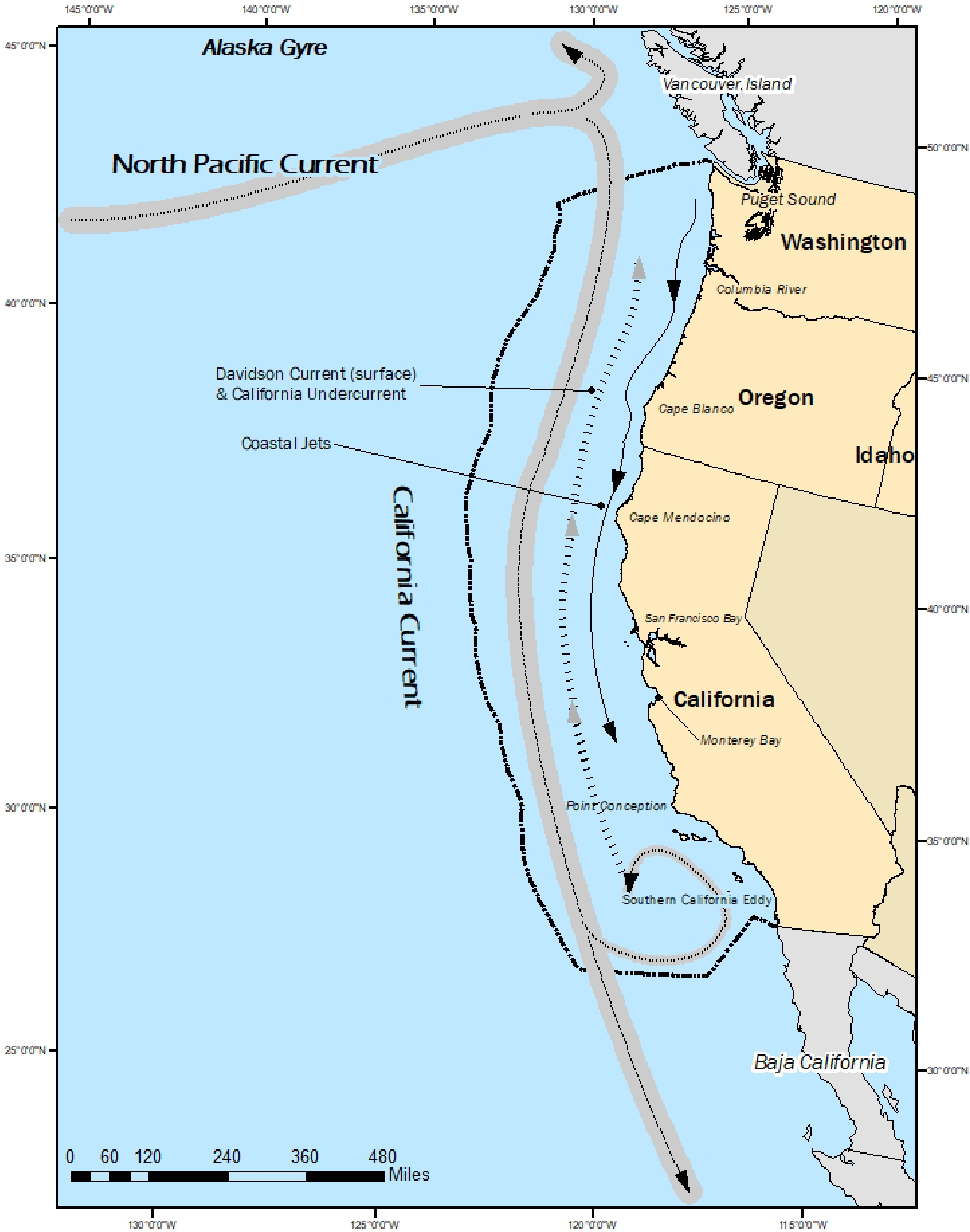


**Figure 3-5. Current regime of the CCE.**

Wind-driven, coastal upwelled water is another important water mass in the CCE (Checkley and Barth 2009). Upwelling tends to be strongest in spring and is fueled by northwesterly winds that transport water offshore and cause nearshore upwelling. Upwelled water is typically cold, saline, nutrient-rich, and deoxygenated. Upwelled waters in the CCE are highly productive, with upwelled nutrients driving the primary productivity that serves as the base of the food web. However, as this organic matter sinks into deeper water it is respired, consuming oxygen in the process, and in conjunction with climate change, is leading to increasingly severe seasonal hypoxia in waters off Oregon and Washington (Christian and Ono 2019 and references therein ).

The degree of upwelling in the CCE is typically monitored through the use of an upwelling index (Bakun 1973, 1975; Mason and Bakun 1986; Schwing 1996). See also this description of the Bakun Index. More recent indexes include the coastal upwelling transport index and the biologically effective upwelling transport index. These indexes use ocean models and use satellite and in situ data to improve upon the Bakun upwelling index, providing estimates of vertical transport near the coast and of vertical nitrate flux, which improve our understanding of biological responses to upwelling (Harvey*, et al.* 2019; Jacox*, et al.* 2018). See also this description of West Coast upwelling indexes.

Coastal upwelling can also induce jets that develop over the continental shelf during the spring and summer, which tend to be driven by localized forcing and to vary on smaller spatial and temporal scales more than offshore processes (Hickey 1998). The location of jets can be influenced by the coastal topography (capes, canyons, and offshore banks), particularly the large capes such as Cape Blanco, Cape Mendocino, Point Conception, and Punta Eugenia. The flow from the coastal upwelling jets can be diverted offshore, creating eddies, fronts, and other mesoscale changes in physical and biological conditions, and even often linking up to the offshore California Current (Hickey 1998). Central Pacific water, which is warm, moderately deoxygenated, moderately saline, and nutrient-poor, is located offshore of the California Current. In the southern CCE, Central Pacific water regularly impinges upon the continental shelf during summer and fall and year-round in warm El Niño or marine heatwave years. For information on current marine heatwaves in the CCE see the California Current Integrated Ecosystem Assessment (CCIEA) Marine Heatwave Tracker webpage.

Freshwater input forms an important water mass in the northern CCE (Checkley and Barth 2009). The main sources of freshwater are the Columbia River and the Fraser River via the Strait of Juan de Fuca. Freshwater plumes are low salinity, warm, and high in oxygen and nutrients, and can be transported far from river mouths. In summer, freshwater typically moves south, while poleward transport tends to occur in winter. The nutrient-rich freshwater plumes provide important feeding grounds for marine organisms at multiple trophic levels. The spatial extent and temporal persistence of the various water masses in the CCE are highly dynamic. Changes in the size and duration of water masses affect marine organisms by redistributing populations that may reside exclusively within a particular water mass, and by fueling changes in overall population size. For example, upwelling of nutrient-rich water can augment primary production, which then propagates throughout the food web.

Substantive changes in productivity that often take place at slower rates during multi-year and decadal periods of altering ocean condition and productivity regimes are superimposed on the effects of these shifting water masses that drive much of the interannual variability of the CCE. Climatologists and oceanographers have identified and quantified both high- and low-frequency variability phenomena in numerous ways. The El Niño/Southern Oscillation (ENSO) is the dominant mode of interannual variability in the equatorial Pacific, with impacts throughout the rest of the Pacific basin (including the California Current) and the globe (Mann and Lazier 1996). During the negative (El Niño) phase of the ENSO cycle, jetstream winds are typically diverted northward, often resulting in increased exposure of the West Coast of the U.S. to subtropical weather systems (Cayan*, et al.* 1989). Concurrently in the coastal ocean, the effects of these events often include reduced upwelling winds, a deepening of the thermocline, intrusion of offshore (subtropical) waters; dramatic declines in primary and secondary production, poor recruitment, growth and survival of many resident species (particularly salmon and groundfish); and northward extensions in the range of many tropical species. In more recent years, however, biological responses to ENSO events have been somewhat unpredictable in the CCE. For example, in the past ecologically important species such as rockfishes (Ralston*, et al.* 2014) and northern anchovy (Chavez*, et al.* 2003) declined under warm, ENSO conditions but both thrived from 2014-2016 (Schroeder*, et al.* 2018; Thompson*, et al.* 2019) even though this was the warmest three-year period on record (Jacox*, et al.* 2018).

While the ENSO cycle is generally a high-frequency event (taking on the order of three to seven years to complete a cycle), lower-frequency variability has been associated with what is now commonly referred to as the Pacific (inter)Decadal Oscillation, or PDO (Mantua*, et al.* 1997). The PDO is the leading principal component of North Pacific sea surface temperatures (above 20° N. latitude), and superficially resembles ENSO over a decadal time scale. During positive regimes, coastal sea surface temperatures in both the Gulf of Alaska and the California Current tend to be higher, while those in the North Pacific Gyre tend to be lower; the converse is true in negative regimes. The effects of the PDO have been associated with low-frequency variability in over 100 physical and biological time-series throughout the Northeast Pacific, including time-series of recruitment and abundance for commercially important coastal pelagics, groundfish, and invertebrates (Mantua and Hare 2002). An additional decadal scale driver of marine conditions within the CCE is the North Pacific Gyre Oscillation (NPGO) (Di Lorenzo*, et al.* 2008). The NPGO is related to the sea surface height of the North Pacific Gyre and is driven by regional and basin scale variations in wind-driven upwelling and horizontal advection. The NPGO has been found to be highly positively correlated with salinity, nitrate, and chlorophyll-a and negatively correlated with oxygen variability. Occurring in less predictable cycles, marine heatwaves have emerged as a concern for resource managers. Marine heatwaves occur when ocean temperatures are much warmer than usual for an extended period of time (defined by NOAA as sea surface temperatures greater than 1.29 standard deviations from the norm), and the frequency of these conditions has increased in recent decades (Jacox*, et al.* 2020).

## *3.3 Biological Components of the CCE*

This section defines the major biological components of the CCE in terms of trophic levels – a biological component's position within the larger food web. A biological component's trophic level is roughly defined by its position in the food web. Lower trophic level species consist of, or feed predominantly on, primary producers (phytoplankton, etc.). Higher trophic level species are largely top predators such as marine mammals, birds, sharks, and tunas.

### *3.3.1 Phytoplankton, Plants, Kelp and Structure-Forming Invertebrates*

We classify marine organisms with chlorophyll in the CCE into three categories: phytoplankton, seagrass, and macro-algae. Phytoplankton constitute the base of the pelagic food web and exhibit seasonal blooms that can be toxic. Seagrass beds form important habitats within and are considered EFH for groundfish. Large macroalgae (kelp) attach to the benthos and provide habitat for many fishes and invertebrates. Much of the scientific information on structure-forming invertebrates has been collected in recent years, both as a result of improvements in scientific observation technology and of funding and direction expressly provided in section 408 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), reauthorized in 2007.

#### 3.3.1.1 Phytoplankton and microalgal blooms

Phytoplankton refers to planktonic organisms with chloroplasts. From an evolutionary perspective, phytoplankton is extremely diverse and includes species from the domains (domain is a higher taxonomic category than kingdom) bacteria (e.g., cyanobacteria) and protista (e.g., diatoms and dinoflagellates) (Bailey 2021). The most predominant phytoplankton groups within the CCE include:

- Diatoms (*Bacillariophyceae* spp.) – eukaryotic cells with hard silica-based shells, dominant in upwelling areas, occasionally harmful algal bloom (HAB) forming
- Dinoflagellates (*Dinoflagellata* spp.) – eukaryotic cells, many of which are slightly motile, often dominate in stratified regions, and more commonly form HABs than diatoms
- Cyanobacteria – prokaryotic cells, predominant in offshore regions, but still abundant in nearshore regions (~20 percent of phytoplankton productivity)

Diatoms are probably the most important phytoplankton phylum in terms of overall productivity and importance as a food resource for higher trophic levels. Diatoms grow rapidly in nearshore regions where upwelling provides cool, nutrient-rich water. In turn, diatoms are grazed upon by most of the low trophic level species (described above) and early life stages of fishes and zooplankton. Occasionally, certain species of diatoms may constitute HABs. Specifically, the diatom *Pseudo-nitzschia multiseries* produces a powerful neurotoxin known as domoic acid that can bio-accumulate in the tissues of fish (described in more detail below in Section 3.3.2) and mollusks such as razor clams (*Siliqua patula*). While diatoms are an important prey for copepods, their protective silica casing prevents them from being readily preyed upon by many smaller microzooplankton. However, diatoms enhance reproduction rates, total lipids, and essential fatty acid stores of meso-zooplankton herbivores, which can ultimately increase survivorship and/or growth of higher trophic level fish stocks (Miller, *et al.* 2017; Peterson and Du 2015).

Dinoflagellates are another important low trophic level resource in the CCE. Dinoflagellates may out-compete diatoms when silica is limited, since dinoflagellates do not require silica for growth. Dinoflagellates are also typically preferred by other microzooplankton and small crustacean zooplankton as a food source as compared to diatoms, due to their relatively enriched nutrient content, and lack of a hard silicon encasement (Kleppel 1993; Leising, *et al.* 2005). Because of this, when dinoflagellates predominate these lowest trophic levels, there is a more complex food web of organisms between phytoplankton and higher predators. In diatom-dominated systems (nearshore upwelling), in contrast, diatoms may be directly consumed by small fish and some fish larvae. In addition, certain dinoflagellate species facilitate survival of first feeding larval anchovy, and may thus impact anchovy recruitment variability (Scura and Jerde 1977).

Cyanobacteria are more important in offshore regions, where, although they do not have a high biomass, they may have high growth rates, providing for rapid nutrient turnover (Sherr, *et al.* 2005). Cyanobacteria are primarily consumed by unicellular microzooplankton that may be prey for other microzooplankton. Hence, food webs dominated by cyanobacteria tend to have a low biomass at the higher trophic levels due to the relatively large number of trophic links.

Seasonally, diatoms tend to bloom nearshore in the later winter or early spring, in a progression from south to north. The timing of this bloom tends to follow a change in upwelling strength, from the predominant downwelling condition during the fall and spring, to a net cumulative upwelling in the late winter early spring (Lynn, *et al.* 2003). This change from downwelling to upwelling and the resulting phytoplankton blooms are termed the spring transition (Holt and Mantua 2009). Year-to-year variability may occur in this timing, due to large-scale changes in wind patterns across the Pacific basin.

Occasionally, there are brief periods of mixing or upwelling that occur prior to the main spring transition, which may also result in localized phytoplankton blooms of short duration, which may disappear before the main spring transition time. Blooms of dinoflagellates and other phytoplankton types tend to occur significantly after the main spring transition. In particular, dinoflagellates often bloom in the fall period, upon the cessation of upwelling, as the waters stratify.

#### 3.3.1.2 Seagrasses

Seagrass species found on the West Coast of the U.S. include eelgrass (*Zostera* spp.), widgeongrass (*Ruppia maritima*), and surfgrass (*Phyllospadix* spp.). These grasses are vascular plants (kingdom Plantae), not seaweeds (kingdom Protista), and form dense beds of leafy shoots year-round in the lower intertidal and subtidal areas. A combination of bottom-up (light, nutrients, etc.) and top-down (consumer interactions, disease) processes influence seagrass dynamics (Hughes*, et al.* 2004). Eelgrass is found on soft-bottom substrates in intertidal and shallow subtidal areas of estuaries and occasionally in other nearshore areas, such as the Channel Islands and Santa Barbara littoral zones. Surfgrass is found on hard-bottom substrates along higher energy coasts. Eelgrass beds are among the areas of highest primary productivity in the world (Herke and Rogers 1993; Hoss and Thayer 1993) and are critical habitat for early stages of marine and anadromous fishes, including salmon (e.g., Hughes*, et al.* 2013; Kennedy*, et al.* 2018). Because of the ecological importance of seagrass for many protected and managed species (Shelton*, et al.* 2017; Waycott*, et al.* 2009), there have been several recent efforts to better characterize seagrass beds nationwide and, more comprehensively, for the U.S. West Coast (Beheshti and Ward 2021; Sherman and DeBruyckere 2018). Geographic information system data for seagrass beds were located and compiled as part of the groundfish EFH assessment.

#### 3.3.1.3 Macro-algal (kelp) beds

Along the Pacific coast there are two major canopy-forming species of kelp, the giant kelp (*Macrocystis pyrifera*) and the bull kelp (*Nereocystis leutkeana*). Unlike seagrasses, kelps fall within the kingdom Protista. Kelps can form forests that provide habitat for a diverse mix of species including fishes, invertebrates, marine mammals, and seabirds. Kelp forests provide cover or nursery grounds for many adult, young-of-the-year, or juvenile nearshore and shelf rocky reef fishes, such as bocaccio (*Sebastes paucispinis*), lingcod (*Ophiodon elongatus*), flatfish, other groundfish, and state-managed species including kelp bass (*Paralabrax clathratus*), white seabass (*Atractoscion nobilis*), and Pacific bonito (*Sarda chiliensis lineolata*). Common invertebrates inhabiting kelp forests include abalone (*Haliotidae* spp.), sea urchins, spiny lobsters, and crabs. Sea otters (*Enhydra lutris*) also associate with kelp forests (Lee*, et al.* 2016; Shelton*, et al.* 2018). Kelp plays an important role in the diet of some reef fishes and many invertebrates (e.g., urchins and abalone). In addition, when plants are ripped up after storms, the resulting kelp detritus functions as beach enrichment or contributes nutrients to the benthic environment when drifting plants sink.

Along the coasts of Washington and Oregon, and southward to Northern California, kelp forests are predominantly composed of bull kelp in nearshore rocky reef areas, although these occur as far south as Point Conception. Giant kelp is distributed from Sitka, Alaska to central Baja California, forming dense beds from central California southward through the Southern California Bight and off the Baja Peninsula. Kelp forests are normally found in association with nearshore, rocky substrate – bull kelp occurs in water as deep as 75 feet, while giant kelp forests can occupy reefs at 120 feet in areas with excellent water clarity. In the Southern California Bight, kelp beds also occur on sandy surfaces, where they attach to worm tube reefs. Several other canopy-forming species are found in lesser abundance off southern California and the Channel Islands including *Macrocystis integrefolia*, the elk kelp (*Pelagophycus*, *Cystoseira*), and the invasive *Sargassum horneri*.

Kelp distribution, productivity, growth, and persistence depends on a variety of factors including nutrient availability, severity of wave action, exposure, water quality, turbidity, sedimentation, water temperature, geology, pollution, and grazer abundance (e.g., sea urchins). Nitrogen and light are two of the most important parameters affecting kelp productivity. Under ideal environmental conditions, giant kelp grows up to two feet a day. It thrives in nutrient-rich, cool water (50 to 60 °F); in wave-exposed areas, fronds may reach a length of 150 feet. Hence, conditions that decrease coastal upwelling and nutrient availability (typically warm conditions), decrease kelp growth (Dayton*, et al.* 1999). Warm water events such as El

Niño and heatwaves, alone or in combination with severe storms, can wreak havoc on kelp beds—ripping out plants, reducing growth, and leaving only minimal or no canopy (Byrnes*, et al.* 2011; McPherson*, et al.* 2021; Reed*, et al.* 2011; Rogers-Bennett and Catton 2019; Thomsen*, et al.* 2019). Seasonal effects are often more localized, and more large-scale, low-frequency episodic changes in nutrient availability seem to result in the most significant changes due to cascading community effects. For example, the status and success of understory kelps such as *Pterogophora*, *Eisenia,* and *Laminaria* can be affected through competition for light, effects on growth, reproduction, establishment, and survivorship.

In response to the cumulative impacts of environmental and ecological stressors, bull kelp forests along the Northern California and Southern Oregon coast have deteriorated dramatically since 2014. In 2013, Sea Star Wasting Syndrome caused mass mortalities of sea stars (*Pisaster* spp.), many of which prey on urchins (Hewson*, et al.* 2014). The following year began a period of warm water conditions as a result of a multi-year large-scale marine heatwave (2014-2015) and a strong El Niño (2015-2016, Bond*, et al.* 2015; Jacox*, et al.* 2016). These conditions facilitated purple urchin (*Strongylocentrotus purpuratus*) populations to increase and aggressively prey on seaweeds. Numerous studies explored the role of sea urchins in kelp forests and the dynamics of overgrazing by urchins on kelp resulting in loss of whole kelp forests or the creation of "urchin barrens" (Pearse and Hines 1979; Tegner and Dayton 2000). Urchin grazing can destroy kelp forests at a rate of 30 feet per year. These compounding factors decimated many once-productive kelp forests (McPherson*, et al.* 2021; Rogers-Bennett and Catton 2019; Thomsen*, et al.* 2019).

In California, there is an active commercial fishery for urchins. Kelp has been commercially harvested since the early 1900s in California, and there was sporadic commercial harvesting in Oregon although it is currently prohibited. Pharmaceutical, food, industrial, and forage uses of kelp include herring-roe-on-kelp, algin, stabilizers, aquaculture food for abalone, and human food products (bull kelp pickles).

Extensive studies since the 1960s addressed concerns regarding the impact of giant kelp harvesting on the nearshore ecosystem. Overall, there was no evidence of long-term effects of harvesting (Dayton*, et al.* 1999; North and Hubbs 1968). Potential impacts include temporary displacement of adult or young-of-the-year fishes to nearby unharvested reefs, predation on those young-of-the-year by larger displaced fishes (Houk and McCleneghan 1993; O'Connor and Anderson 2010), increased growth of sub-canopy species, increased harvesting of fishes and invertebrates by anglers or divers when harvesters create pathways through the beds, and delayed regrowth of kelp.

#### 3.3.1.4 Structure-Forming Invertebrates

Characterizing habitat formed by invertebrates requires the use of a human-occupied submersible, remotely operated vehicle, autonomous underwater vehicle, or shallow water diving operations, any of which require deploying equipment that is challenging and expensive to use even on small geographic scales (Etnoyer and Morgan 2005; Krieger and Wing 2002; Whitmire and Clarke 2007; Yoklavich and O'Connell 2008). However, laboratory studies can also be used to examine habitat preferences in fishes under controlled conditions and provide the opportunity to introduce predation as a factor influencing habitat preference (e.g., Bizzarro*, et al.* 2017; Ryer*, et al.* 2004). Spatial predictive modeling also has been used to characterize the potential spatial distributions of deep-sea corals and sponges (*Porifera* spp.) offshore of the continental U.S. West Coast to a depth of 1,200 m (Poti*, et al.* 2020). That modeling study identified areas where deep-sea corals and sponges were more likely and less likely to occur and can be used in regional ocean planning efforts and assessments, and to prioritize areas needing more detailed surveys.

In 2018, NOAA's Deep Sea Coral Research and Technology Program launched a collaborative four-year research initiative to study deep-sea corals and sponges in U.S. West Coast waters, co-led by the Northwest Fisheries Science Center and Channel Islands National Marine Sanctuary. In recent years there also have been targeted explorations on board the Ocean Exploration Trust's vessel *Nautilus*. Since 2015, explorations have occurred in the CCE from the Southern California Borderlands to the Cascadia Margin, and most have included visual surveys of the benthos, mapping of areas using multibeam, and collections of benthic invertebrates.

Tissot (2006) narrowed the question of which invertebrate taxa and associated morphologies should be viewed as having the potential to serve as habitat for other species by characterizing structure-forming invertebrates as those that, like some coral species, add functional structure to benthic habitats by nature of their large size (e.g., black corals (*Antipatharia* spp.), sponges, anemones (*Metridium* spp.), and sea pens (*Subselliflorae* spp.) and through having complex morphologies (e.g., black corals, sea pens, and basket stars). Megafaunal invertebrates that aggregate in high numbers, such as sea urchins and sea pens, could also be considered structure-forming in areas where the physical environment is otherwise low-relief (Tissot*, et al.* 2006).

Hourigan, *et al*. (2017) listed 135 species of corals identified in the U.S. West Coast EEZ, of which four species were classified as having adequate individual or colony size and morphological complexity to be considered of high structural importance: *Lophelia pertusa*, *Antipathes dedrochristos*, *Paragorgia arborea*, and *Primnoa pacifica* (see also Whitmire and Clarke 2007). Several additional classes and individual species of coral were identified as being of medium structural importance: *Dendrophyllia oldroydae*, *Bathypathes* sp., *Isidella* sp., and *Keratoisis* sp. Corals of the West Coast EEZ are distributed over a variety of bottom habitats, with higher concentrations on hard bottom (not sand) and medium-to-high relief rocky habitat. With their morphologically complex forms, corals can enhance the relief and complexity of physical habitat (See also Whitmire and Clarke 2007), although the literature remains divided on whether West Coast deep-sea corals serve to aggregate fish (Auster 2005; Etnoyer and Morgan 2005; Tissot*, et al.* 2006).

In addition to corals, sponges have the potential to provide habitat for fishes and other invertebrates. In recent years, targeted collecting of sponges and subsequent taxonomic and genetic descriptions have led to an increasing knowledge of sponge distribution on the West Coast. Other studies have shown evidence that sponges may be important habitat for certain species. Marliave (2009) found quillback rockfish (*Sebastes maliger*) using colonies of cloud sponges (*Aphrocallistes vastus*) as nursery habitat in southern British Columbia's coastal waters, which can be within the northern extent of the CCE. Powell (2018) characterized glass sponge grounds of Grays Canyon, Washington and found spot prawns (*Pandalus platyceros*) were strongly associated with sponge abundance.

U.S. West Coast studies of the effects of trawling on benthic invertebrate populations and associated fish assemblages found variations between trawled and untrawled areas (Barnett*, et al.* 2017a; Engel and Kvitek 1998; Hixon and Tissot 2007; Lindholm*, et al.* 2008; Pirtle 2005; Yoklavich*, et al.* 2018). Documented disturbance and damage to deep-sea corals and sponges in areas of longtime (> 65 years) bottom trawling off southern Oregon and Northern California. They found that the overall frequency of disturbance to deep-sea corals and sponges throughout the study area was 2 percent. However, there was evidence of more damage to corals than sponges. For example, 45 percent of the bamboo coral colonies in the study area were damaged.

Hiddink, *et al*. (2017) found that depletion of benthic biota was related to depth of penetration of gear, with otter trawls showing the least depletion and hydraulic dredges showing the most. Interestingly, a recent California study found the greatest detrimental effects of trawl gear used in California flatfish fisheries came from the trawl doors, with more quickly recoverable effects from the small footropes pulled between those doors (Lindholm*, et al.* 2013). Similarly, Hannah, *et al*. (2013) found that technical modifications to shrimp trawl footropes used off Oregon could reduce trawl disturbance of benthic macroinvertebrates.

### 3.3.2 Low Trophic Level Species

Low trophic level species are defined as species that feed either primarily or partially on the lowest trophic level in the ecosystem. CCE low trophic level species include species targeted by fisheries, such as those managed under the Coastal Pelagic Species (CPS) FMP, non-target species that are included in FMPs as ecosystem component species, and numerous other unmanaged species. The low trophic level species of the CCE may be roughly separated into the following groups:

- Small pelagic fish – sometimes known as "baitfish" or "forage fish," includes species such as Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), smelts (*Osmeridae* spp.), etc., which are relatively small (< ~ 300 mm total length) as adults and feed on plankton
- Ichthyoplankton – pelagic larval stages of almost all fish in the CCE that consume phytoplankton and zooplankton, and are consumed by many fishes and zooplankton
- Euphausiids (*Euphausiacea* spp.), or krill, and Copepods (*Copepoda* spp.) – crustaceous and sometimes school-forming zooplankton that are either relatively large (krill) and feed on phytoplankton and zooplankton or smaller (copepods) and feed on phytoplankton, other zooplankton, and microzooplankton
- Gelatinous zooplankton – soft-bodied zooplankton, such as jellyfish, pelagic gastropods (*Gastropod* spp., primarily pteropods), salps (*Salpidae* spp.), doliolids (*Doliolida* spp.), and apendicularians (*Appendicularia* spp.)
- Other crustacean zooplankton – includes shrimps, mysids (*Mysidae* spp.), and other less numerically dominant but important organisms that consume other zooplankton, phytoplankton, and microzooplankton
- Microzooplankton – unicellular zooplankton that feed at high rates on phytoplankton, other microzooplankton, and bacteria

#### 3.3.2.1 Small pelagic fish and squid

A large portion of forage fish in the CCE are small pelagic fish as adults. In addition, pelagic juvenile life stages of species such as rockfishes and salmon constitute significant prey for many marine predators (Crawford 1987; Cury*, et al.* 2000). Forage fishes are numerically the most common type of fish in the CCE. Forage fish and squid feed nearly exclusively on phytoplankton (typically diatoms), small pelagic crustaceans, and copepods (Emmett*, et al.* **2005**). These small fishes are also preyed upon by myriad predators and thus function as major pathways of energy flow in the CCE. Large swings in population sizes are common for most forage fish species and have been particularly noted by fishermen and scientists working in and on Council-managed CPS fisheries. For example, northern anchovy was very high from the 1960s to the late 1980s, but fell in the early 1990s and mostly remained low until 2015, when the population abruptly rose and remained high through at least 2021. The Pacific sardine population also fluctuates and, in recent years, rose through the 1990s, peaked in the early 2000s and then fell to low levels again in the 2010s. Large distributional shifts are also common and can resonate throughout the ecosystem as population dynamics of multiple marine predators are tightly correlated with the distribution and abundance of forage fishes (McClatchie*, et al.* 2016; Santora*, et al.* 2014). Market squid (*Doryteuthis opalescens*) populations also fluctuate, with population booms linked to La Niña conditions and busts linked to El Niño conditions (Perretti and Sedarat 2016; Van Noord and Dorval 2017). In addition, during and subsequent to the 2014-2016 marine heatwave, abundances of southern mesopelagic forage fishes such as Panama lightfish (*Vinciguerria lucetia*) and Mexican lampfish (*Triphoturus mexicanus*) have been very high (Thompson*, et al.* 2021; Thompson*, et al.* 2019). The larger-bodied and more abundant species in this category tend to be managed under the CPS FMP, while the smaller-bodied fish species and noncommercial squid species are included in the Council's Shared Ecosystem Component Species category. New West

Coast fisheries for Shared Ecosystem Component Species were prohibited in 2016 through the Council's first FEP ecosystem initiative (PFMC 2016).

### 3.3.2.2 Ichthyoplankton

The early life history of the vast majority of fishes in the CCE consists of a pelagic larval (ichthyoplankton) stage. Most ichthyoplankton consume phytoplankton shortly after birth and incorporate small zooplankton into their diets as they grow (Moser and Watson 2006). Ichthyoplankton are also consumed by many fishes and zooplankton (Bailey and Houde 1989; Bax 1998; Paradis*, et al.* 1996). Ichthyoplankton of most fish species reside in the upper 200 m of the water column, are readily caught by nets, and their abundance provides indices of the spawning stock biomass of adults (Harvey*, et al.* 2020a; Moser and Watson 2006).

California Cooperative Oceanic Fisheries Investigations (CalCOFI) has regularly collected ichthyoplankton samples from fixed locations off Southern California since 1951. Enumeration of fish larvae reveals that the most abundant CalCOFI larvae include northern anchovy, Pacific whiting (*Merluccius productus*), Pacific sardine, jack mackerel (*Trachurus symmetricus*), shortbelly rockfish (*Sebastes jordani*), and unidentified rockfishes (*Sebastes* spp.) (Moser*, et al.* 2001; Peabody*, et al.* 2018). In addition, the mesopelagic species Panama lightfish, northern lampfish (*Stenobrachius leucopsarus*), California smoothtongue (*Leuroglossus stilbius*), eared blacksmelt (*Lipolagus ochotensis*), and Mexican lampfish are very common in CalCOFI samples. These mesopelagic species all vertically migrate to the surface at night and are thus often important forage for predators in both deep and shallow water.

For Central and Northern California, ichthyoplankton time series are considerably shorter, although survey data suggest that northern anchovy, Pacific herring (*Clupea pallasii*), Pacific sardine, and whitebait smelt (*Allosmerus elongatus*) have been the most abundant and important forage species in these regions at least through 2009 (Bjorkstedt*, et al.* 2010; Orsi*, et al.* 2007). Ichthyoplankton data are more limited for the CCE north of Cape Mendocino, but existing studies suggest that off Washington and Oregon, smelts are often highly abundant in nearshore shelf waters, and that tomcod (*Microgadus proximus*) and Pacific sandlance are often fairly abundant (Barceló*, et al.* 2021; Brodeur*, et al.* 2008; Kendall and Clark 1982; Richardson and Pearcy 1976).

### 3.3.2.3 Krill and Copepods

Euphausiids (commonly known as krill), primarily the species *Euphausia pacifica* and *Thysanoessa trispinosa*, are also important forage in the CCE (Brinton and Townsend 2003). These species primarily eat phytoplankton (diatoms) and small zooplankton, and in turn are the food for many species of fish, birds, and marine mammals. Euphausiids can form large conspicuous schools and swarms that attract larger predators, including whales. Due to their high feeding rates, fast growth rates, and status as a key prey for many species, euphausiids play a critical role in the overall flow of energy through the CCE. In recognition of that critical role in the ecosystem, Federal regulations implementing the CPS FMP prohibit the harvest of krill off the U.S. West Coast [50 CFR §660.502].

Copepods and other small crustacean zooplankton have similar roles to krill within the CCE. However, copepods and small crustacean zooplankton do not tend to form large dense schools, although at times, and for brief periods (a few hours to a few days), they may be found at locally higher densities as they aggregate near physical (e.g., horizontally along physical fronts, or vertically near the main thermocline) or biological fronts (e.g., near aggregations of their phytoplankton prey). Copepods eat phytoplankton, microzooplankton, and other smaller crustacean zooplankton, and in turn are food for krill, fish larvae, and small pelagic fish. The annual ESR includes indices of copepod and krill abundance to help the Council and the public understand the relative productivity of the CCE, and distinguishes between the more fatty northern copepod species and the lower-nutrition southern copepod species ((Harvey*, et al.* 2020a).

#### 3.3.2.4 Gelatinous zooplankton

When prevalent, gelatinous zooplankton provide an alternate pathway for energy flow that may or may not augment production at higher trophic levels (Brodeur*, et al.* 2011). Gelatinous zooplankton include a variety of forms, from free-floating jellyfish that passively ambush zooplankton and small larval fish prey, to appendicularians that build large gelatinous "houses" used to filter large quantities of the smallest phytoplankton classes from the water column. While gelatinous zooplankton grow at high rates, and have high feeding rates, their bodies are mostly composed of water; as a result, gelatinous zooplankton are not typically a nutritious food source for larger organisms, with the exception of certain turtles that specialize on gelatinous prey (Narazski *et al.* 2013). Thus, systems dominated by gelatinous zooplankton as the primary predators of phytoplankton tend to have limited production of fish species, and have been labeled "dead-end" ecosystems (Verity and Smetacek 1996), although this notion has recently been called into question (Hays *et al.* 2018). Typically, gelatinous zooplankton blooms are found offshore in oligotrophic (low nutrient) regions, although blooms occasionally predominate nearshore during warmer periods. An exception are pteropods: pelagic gastropods that form large gelatinous nets much larger than their body size, used to capture falling detritus in the water column. Unlike the other taxa in this group, pteropods are known to be an important food source for at least salmon, and possibly other fish species (Brodeur, 1990).

#### 3.3.2.5 Shrimp and other crustacean zooplankton

An important feature of many of the larger crustacean zooplankton is that they undergo daily vertical migrations from depths as deep as several hundred meters during the day primarily to avoid visual predators, such as fish, up to near the surface at night to feed in relatively productive waters. One of the largest-bodied species in this group, pink shrimp (*Pandalus jordani*), is the only West Coast shrimp species targeted in a prominent commercial fishery. Other small crustaceans, such as shrimps and mysids, tend to be less abundant, but can be important in some areas. Mysids often form swarms in shallow nearshore waters, and may be an important food source for outmigrating smolts (Brodeur 1990). In a markedly different pattern of vertical distribution, several of the dominant species of copepods, those of the genus *Calanus* and *Neocalanus* in particular, undergo a wintertime dormant period, wherein they descend to great depths (~400-1,000 m) for anywhere from four to eight months of the year (Dahms 1995). These copepods then emerge in the springtime to reproduce. Thus, copepods have a marked seasonality in their availability to higher trophic levels, potentially often leading to a mismatch between prey and predator abundance.

#### 3.3.2.6 Unicellular microzooplankton

Unicellular microzooplankton include a diverse array of organisms, such as heterotrophic dinoflagellates, ciliates, and choanoflagellates. These organisms primarily eat other microzooplankton, phytoplankton, cyanobacteria, and bacteria. The CCE biomass of unicellular microzooplankton is not often high; however, their grazing rates are on par with the growth rates of phytoplankton (Li*, et al.* 2011). Thus, it is these unicellular microzooplankton – not crustaceans or fish – that consume the majority of phytoplankton standing stock and production within many areas of the CCE (Calbet and Landry 2004). A large portion of the energy that flows into microzooplankton does not reach higher trophic levels, but is returned to detrital pools, or recycled within the microzooplankton trophic level. This retention of energy within the unicellular microzooplankton trophic level is known as the "microbial loop" and, when prevalent, decreases the overall productivity of higher trophic levels. Unicellular microzooplankton are a key prey source for copepods, gelatinous zooplankton, and other small crustacean zooplankton due to their enriched nitrogen relative to carbon, in comparison to similarly-sized phytoplankton.

### *3.3.3 Mid to High Trophic Level Fishes and Invertebrates*

The Council manages three major groups of mid to high trophic level fish assemblages: groundfishes, anadromous fishes (principally salmonids, but including sturgeon and other species as well), and highly migratory species (HMS). In addition, the adult stages of a large number of invertebrate species, such as larger-bodied crab and squid species, are also considered mid to high trophic level species. Seasonal patterns appear to be the greatest drivers of migrations and variable distributions for most mid to higher trophic level species, both pelagic and benthic, although interannual and longer-term climate variability is important to the distribution and abundance of many of the pelagic species. For example, warm years (and regimes) and the recent marine heatwave have brought desirable gamefish such as tunas and billfish farther north and inshore (Maccall 1996; Pearcy 2002; Sanford*, et al.* 2019).

#### 3.3.3.1 Groundfishes

Groundfishes occupy a range of trophic niches and habitats (Love*, et al.* 2002). Large groundfishes, such as cowcod (*Sebastes levis*) and bocaccio, as well as Pacific halibut, California halibut (*Paralichthys californicus*), arrowtooth flounder (*Atheresthes stomias*), petrale sole (*Eopsetta jordani*), sablefish (*Anoplopoma fimbria*), lingcod, cabezon (*Scorpaenichthys marmoratus*), shortspine thornyheads (*Sebastolobus alascanus*), several of the skates (*Rajidae* spp.), and a handful of other groundfish species are almost exclusively piscivorous. These fishes feed largely on juvenile and adult stages of other groundfish, as well as forage fishes, mesopelagic fishes, and squids. A broader range of species, including many rockfishes, are omnivorous mid-trophic level predators that may be piscivorous at times but also feed on krill, gelatinous zooplankton, benthic invertebrates and other prey. Pacific whiting, often the most abundant groundfish in the CCE, shows strong ontogeny in food habits, since younger, smaller whiting feed primarily on euphausiids and shrimps but switch to an increasing proportion of Pacific herring, northern anchovy, and other fishes (as well as other whiting) as they reach 45-55 cm length, and are almost exclusively piscivorous by 70-80 cm (Buckley*, et al.* 1999; Emmett and Krutzikowsky 2008).

Higher trophic level predators have the potential to play a structuring role in the ecosystem, particularly over smaller spatial scales (e.g., individual reefs or habitat areas). Despite the rarity of piscivorous rockfish individuals relative to more abundant omnivorous or planktivorous rockfishes (Thompson*, et al.* 2017), visual surveys have shown that the piscivorous species can be relatively abundant in many isolated and presumably lightly-fished rocky reef habitats (Jagielo*, et al.* 2003; Yoklavich*, et al.* 2002; Yoklavich*, et al.* 2000). In relatively undisturbed rocky reefs, concentrations of smaller, fast-growing rockfishes are considerably lower, while reefs thought to have undergone heavier fishing pressure tend to have greater numbers of smaller, fast-growing, and early-maturing species. Similar large-scale community changes are described by Levin (2006), who found broad-scale changes in CCE groundfish assemblages sampled by the triennial bottom trawl surveys on the continental shelf between 1977 and 2001. Levin, *et al*. (2006) demonstrated declining rockfish catches, from over 60 percent of the catch in 1977 to less than 17 percent of the catch in 2001, with greater declines of larger species, while flatfish catches increased by a similar magnitude. Due to the adoption of rebuilding plans and high recruitment classes, many of the rockfish species have recovered in recent years (Keller*, et al.* 2019; Thompson*, et al.* 2017).

The potential for intra-guild competition or top-down forcing, both in small-scale rocky reef systems and throughout the larger ecosystem, is also supported by theoretical considerations and simulation models. Baskett (2006) developed a community interactions model that incorporated life history characteristics of the diminutive, planktivorous pygmy rockfish (*Sebastes wilsoni*) and the apex predator, piscivorous yelloweye rockfish (*S. ruberrimus*) to consider community dynamics within a marine reserve. Without interspecific interactions, the model predicted that larger piscivores would recover, given minimal levels of dispersal and reserve size. When community interactions were taken into account, initial conditions, such as the starting abundance of the piscivores and the size of the reserve, became more important with respect to the ultimate stable state. Under some circumstances (low piscivore biomass, or high planktivore biomass) recovery could be unlikely. Such results are consistent with similar simulations of community interactions in marine systems (MacCall 2002; Walters and Kitchell 2001), and speak to the importance of considering such interactions in the design, implementation, and monitoring of recovery efforts for rebuilding species.

Ocean climate variability has an important influence on the recruitment, abundance, and distribution of groundfishes in the CCE (Haltuch*, et al.* 2020; Malick*, et al.* 2020; Santora*, et al.* 2017b; Schroeder*, et al.* 2018; Tolimieri*, et al.* 2018). Source waters appear to be particularly important for the recruitment of fishes to adult populations. For example, high abundances of pelagic juvenile rockfishes are associated with high transport of subarctic waters that are cool, fresh, and oxygen-rich. In contrast, low rockfish recruit abundance is associated with higher transport of subtropical waters, which brings warmer, more saline, and more oxygen-deficient waters into the CCE (Schroeder*, et al.* 2018). There is increasing attention to the potential for climate change to alter the distribution and abundance of groundfishes, on the West Coast and beyond, and such shifts may have effects on availability to fisheries and fishing communities (Karp*, et al.* 2019).

Enhanced production of pelagic juvenile Pacific whiting and Pacific sanddabs (*Citharichthys sordidus*) is also related to high transport of subarctic waters and strong upwelling (Ralston*, et al.* 2015; Sakuma*, et al.* 2016), and variations in sablefish and petrale sole recruitment are strongly linked to oceanographic variables related to transport and temperature (Haltuch*, et al.* 2020; Tolimieri*, et al.* 2018). In addition, ocean temperatures have been shown to affect the spatial distribution of groundfish in the CCE. For example, Malick, *et al*. (2020) found that warmer than average subsurface temperatures are associated with higher biomass of adult Pacific whiting north of Vancouver Island, and lower biomass offshore of Washington and southern Vancouver Island. Cooler than average temperatures are associated with higher biomass of juvenile Pacific whiting coastwide.

#### 3.3.3.2 Anadromous Species

Anadromous species spend their early life stages in freshwater rivers and streams, then out-migrate to estuaries, and eventually to the ocean, where they mature before returning to their natal streams to spawn. Species with anadromous life histories necessarily rely on a wide variety of habitats that can be negatively affected by many different human activities.

Over a dozen anadromous species are found in the CCE (Table 3-1). About half of these are protected under the Endangered Species Act (ESA), although the Council has fishery management objectives for only Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and pink salmon (*O. gorbuscha*) under the Pacific Coast Salmon FMP. The complex habitat needs of Pacific salmon are reflected in the EFH designated for Council-managed salmon stocks, which extends from inland mountain streams out to the farthest extent of the EEZ (see Figure 3-6).

**Table 3-1. Anadromous fish species found on the Pacific coast of the United States.**

| Scientific name | Common name |
|---|---|
| *Entosphenus tridentatus* | Pacific lamprey |
| *Acipenser medirostris** | Green sturgeon |
| *Acipenser transmontanus* | White sturgeon |
| *Alosa sapidissima#* | American shad |
| *Oncorhynchus clarki clarki* | Coastal cutthroat trout |
| *Oncorhynchus gorbuscha* | Pink salmon |
| *Oncorhynchus keta** | Chum salmon |
| *Oncorhynchus kisutch** | Coho salmon |
| *Oncorhynchus mykiss** | Steelhead trout |
| *Oncorhynchus nerka** | Sockeye salmon |
| *Oncorhynchus tshawytscha** | Chinook salmon |
| *Salvelinus confluentus** | Bull trout |
| *Hypomesus transpacificus** | Delta smelt |
| *Spirinchus thaleichthys* | Longfin smelt |
| *Thaleichthys pacificus** | Eulachon |
| *Morone saxatilis†* | Striped bass |
| *Gasterosteus aculatus* | Three-spined stickleback |

*At least some stocks listed under the Endangered Species Act – see Table 3-5. †Introduced species

Salmon have long been a mainstay of CCE fisheries. Chinook and coho salmon are the most widely distributed in the CCE and are commercially important. The saltwater ecosystems off central California are generally the southernmost marine habitat occupied by these two species. During their oceanic life stage, Chinook and coho stocks tend to be distributed on the continental shelf within 200-400 km of their origin, although portions of any population may disperse farther (Beamish, *et al.* 2018; Riddell, *et al.* 2018). West Coast stocks of these two species tend to use certain portions of the ocean with consistent timing (e.g., Shelton, *et al.* 2018). Most Chinook caught in CCE fisheries are from ocean-type populations; stream-type Chinook from the Columbia River usually migrate northward on the continental shelf to the Gulf of Alaska (Riddell, *et al.* 2018). Chum, sockeye, and pink salmon (*Oncorhynchus keta, O. nerka,* and *O. gorbuscha*) historically had spawning runs in rivers in California but regular spawning runs for these species currently occur north from the northern Oregon coast, Columbia River, and Olympic Peninsula, respectively.

Cohort strength in CCE salmon populations is typically determined during the first year at sea. Abundances of adjacent salmon stocks often fluctuate together, with no evidence of covariation between stocks of distant regions, suggesting regional environmental processes affect temporal variation in survival rates (Pyper, *et al.* 2001). Correlative studies have established links to large-scale ocean conditions but have not elucidated causal mechanisms (e.g., Dorner, *et al.* 2017; Henderson, *et al.* 2018; Logerwell, *et al.* 2003; Scheuerell and Williams 2005). The correlative studies suggest that cool and warm phases affect post-smolt survival (Bi, *et al.* 2011; Mantua, *et al.* 1997). In particular, the abundance of lipid-rich northern copepods associated with cold conditions appear to facilitate recruitment, even though coho and Chinook do not feed on them directly (Beamish, *et al.* 2018). Observations from studies like these led to investigations seeking to mechanistically link oceanographic and biological metrics to salmon recruitment, with an eye toward improved forecasting and management of salmon fisheries especially in relation to environmental thresholds (e.g., Peterson, *et al.* 2020; Satterthwaite, *et al.* 2020).

Much recent work on salmon ocean ecology in the CCE has focused on predation, diet, and growth. Beamish and Mahnken (2001) proposed the 'critical size, critical period' hypothesis in which salmon productivity is a function of early natural marine mortality, mostly related to predation, followed by physiologically-based mortality when juvenile salmon fail to reach a critical size by the end of their first marine summer and do not survive the following winter. Support has been found for both parts of this hypothesis, although not always (e.g., Beacham*, et al.* 2017). In some cases, predation soon after ocean entry was influential (e.g., Friedman*, et al.* 2019; Wells*, et al.* 2017). Interestingly, in some cases, predation at later stages had important effects (Chasco*, et al.* 2017b; Seitz*, et al.* 2019). Diet composition during the first ocean year has also been related to eventual adult returns (Dale*, et al.* 2017; Hertz*, et al.* 2016). In other cases, growth was important (e.g., Miller*, et al.* 2014; Tomaro*, et al.* 2012) but the effects of growth on survival and recruitment are not always straightforward (e.g., Miller*, et al.* 2013). For example, young salmon require more resources during warm years, which can lead to lower survival despite high consumption rates (Daly and Brodeur 2015). Studies such as these will be important to understand the effects that ecosystem changes have on CCE salmon stocks now and in the future.

Crozier, *et al*. (2019) broadly assessed the vulnerability of 33 Pacific salmon and steelhead population units to the effects of climate change, with an emphasis on those units listed as threatened or endangered under the ESA. Various life history and habitat characteristics, such as freshwater or estuarine residence time or migration barriers, are thought to affect the ability of particular population units to withstand the harmful potential effects of climate changes such as increased stream temperatures or reduced or altered prey availability. During the Council's 2020-2021 workshops for the FEP's Climate and Communities Initiative, there was notable concern about the effects of climate change on salmonid populations, which workshop participants had viewed as more affected by human activities than marine species. Working with the Council and its advisory bodies, NMFS has developed a suite of annual ESR indicators for the abundance and reproductive potential of Pacific salmonid populations that touch on freshwater and ocean conditions, prey availability, and known smolt production (Harvey*, et al.* 2020b).

Bycatch in CCE fisheries is a concern for green sturgeon (*Acipenser medirostris*), white sturgeon (*A. transmontanus*), and eulachon (*Thaleichthys pacificus*). Green sturgeon are the most marine-oriented of the West Coast sturgeons and disperse widely in estuarine and coastal waters (Moser*, et al.* 2016). They are often found in non-natal estuaries in the CCE (Lindley*, et al.* 2011; Schreier*, et al.* 2016; Schreier and Stevens 2020). The southern Distinct Population Segment of green sturgeon, which spawns in the Sacramento River, is listed as threatened (71 FR 17757, April 7, 2006) under the ESA. Sturgeon from the Southern Distinct Population Segment (DPS) may disperse to estuaries on the Washington and Oregon coasts (Lindley*, et al.* 2011; Schreier*, et al.* 2016). They are regularly reported as bycatch in coastal gillnet and trawl fisheries, including the California halibut fishery (Heublein*, et al.* 2017; Moser*, et al.* 2016). White sturgeon most often use rivers and estuaries but occasionally may make long-distance marine movements (Heublein*, et al.* 2017) and are hence subject to similar hazards. Eulachon in the CCE were listed as threatened in 2010 (Gustafson*, et al.* 2011) and are distributed from Northern California northward, with the largest spawning run in the Columbia River (Willson*, et al.* 2006). Eulachon often occur in mixed-species schools with Pacific herring and northern anchovy (Willson*, et al.* 2006) and are subject to bycatch in pink shrimp trawl fisheries (Gustafson*, et al.* 2011; Hannah*, et al.* 2015; Lomeli*, et al.* 2019).


**Figure 3-6. Salmon essential fish habitat.**

### 3.3.3.3 Highly Migratory Species

HMS include billfish (such as sailfish, marlin, and swordfish), tunas, oceanic sharks, and a variety of (generally southern) large coastal piscivores (Table 3-2). HMS are key targets for both commercial and recreational fisheries with long histories of exploitation. The Council's HMS FMP is unique in that the relative impact and role of fishing activities under the jurisdiction of the Council for most HMS are generally modest, since many HMS spend limited time subject to fisheries within the EEZ. Exceptions where West Coast vessels harvest an appreciable fraction of North Pacific catches include North Pacific albacore (*Thunnus alalunga*), swordfish (*Xiphias gladius*), common thresher shark (*Alopias vulpinus*), and blue shark (*Prionacae glauca*). A principal challenge associated with HMS resources (and the HMS FMP) is collaborating between the broad assemblage of nations and regulatory entities that are involved in HMS exploitation and management (see Section 3.5.6).

**Table 3-2. Species in the HMS FMP.**

| Group | Common Name | Scientific Name | FMP Management Unit Species (MUS) | FMP Ecosystem Component Species (ECS) | Prohibited Species |
|---|---|---|---|---|---|
| Tunas | North Pacific albacore | *Thunnus alalunga* | X | | |
| | Yellowfin tuna | *Thunnus albacares* | X | | |
| | Bigeye tuna | *Thunnus obesus* | X | | |
| | Skipjack tuna | *Katsuwonus pelamis* | X | | |
| | Pacific bluefin tuna | *Thunnus orientalis* | X | | |
| Sharks | Common thresher shark | *Alopias vulpinus* | X | | |
| | Shortfin mako or bonito shark | *Isurus oxyrinchus* | X | | |
| | Blue shark | *Prionace glauca* | X | | |
| | Great white shark | *Carcharodon carcharias* | | | X |
| | Basking shark | *Cetorhinus maximus* | | | X |
| | Bigeye thresher shark | *Alopias superciliosus* | | X | |
| | Pelagic thresher shark | *Alopias pelagicus* | | X | |
| | Megamouth shark | *Megachasma pelagio* | | | X |

| Group | Common Name | Scientific Name | FMP Management Unit Species (MUS) | FMP Ecosystem Component Species (ECS) | Prohibited Species |
|---|---|---|---|---|---|
| Billfish | Striped marlin | *Tetrapturus audax* | X | | |
| | Swordfish | *Xiphias gladius* | X | | |
| Other | Dorado or dolphinfish | *Coryphaena hippurus* | X | | |
| | Common mola | *Mola mola* | | X | |
| | Escolar | *Lepidocybium flavobrunneum* | | X | |
| | Lancetfishes | *Alepisauridae* | | X | |
| | Louvar | *Luvarus imperialis* | | X | |
| | Pelagic stingray | *Dasyatis violacea* | | X | |
| | Wahoo | *Acathocybium solandri* | | X | |
| | Opah* | *Lampris* sp. | | | |

* Opah is not an MUS, ECS, or prohibited species of the HMS FMP, but is a marketable species caught during HMS fishery operations.

CCE predators, including HMS, consume a variety of forage fish and forage fish prey (Koehn*, et al.* 2016; PFMC 2016). Variability in prey has implications for how energy flows through the CCE food web, as well as the foraging costs and net energy gain of HMS, which migrate long distances to reach the CCE (Childers*, et al.* 2011; Fujioka*, et al.* 2018). For example, by switching between coastal- and offshore-associated prey species, albacore may exert spatiotemporally variable predation pressure on forage species, with implications for the CCE pelagic food web (Wade*, et al.* 2007);Glaser, 2010 #405;Glaser, 2011 #406}. These trophic links are likely to be highly dynamic, especially for HMS. Therefore, key ecosystem issues associated with HMS population dynamics are primarily associated with high and low frequency changes in the availability of target stocks in response to changes in climate conditions, as manifested by seasonal changes in water masses, changes in temperature fronts or other boundary conditions, and changes in prey abundance. As suggested by Muhling, *et al*.(2019), a better understanding of spatiotemporal overlap and trophodynamics of predators and prey is required in the CCE to achieve EBFM.

Ecosystem variables are not the only potential drivers of biomass for HMS. Although generalized to the entire North Pacific, Sibert, *et al*. (2006) noted that increases in the biomass of some HMS are consistent with predictions by simple ecosystem models (e.g., Cox*, et al.* 2002; Kitchell*, et al.* 1999) as a result of declines in predation mortality. For fisheries in the Central North Pacific region, Polovina, *et al*. (2009) suggested that the cumulative effect of fishing on high trophic levels and consistent response by mid-trophic level predators indicates that the pelagic longline fishery may itself function as a keystone species in this system. Specifically, with increasing fishing pressure, catch rates (and presumably biomass) of top predators such as billfish, sharks, and large tunas (bigeye and yellowfin) declined, while the catch rates of mid-trophic level species such as mahi-mahi (*Coryphaena hippurus*), pomfret (*Brama japonica*), and escolar (*Lepidocybium flavobrunneum*) increased.

Given the transboundary nature of HMS stocks, some portion of the stocks in the CCE may have similar dynamics to those in the Eastern Tropical Pacific, and other stocks have dynamics similar to those in the Central Northern Pacific. Effective management thus requires international cooperation and collaboration. In addition, management of HMS-directed fisheries also requires minimizing the bycatch of protected species, such as sea turtles, seabirds, and marine mammals. A greater appreciation of the relationships among climate variables, gear selectivities, and the spatial distributions of both target and bycatch species will continue to improve management of HMS resources, and will be key to both single species and ecosystem-based management approaches.

#### 3.3.3.4 Invertebrates

In considering invertebrates it is important to recognize that in many complex or biologically diverse communities (such as intertidal, kelp forest ecosystems, planktonic communities), small and generally overlooked species often represent high trophic levels and key roles that are well beyond the scope of this evaluation. For example, high-trophic level invertebrates include various species of predatory copepods or jellyfish in pelagic ecosystems, and the predatory sun star (*Pycnopodia* spp.) in intertidal ecosystems. However, through both direct and indirect effects, these invertebrate species may influence the dynamics of Council-managed species (e.g., Burt*, et al.* 2018).

Dungeness crab (*Metacarcinus magister*) range from Santa Barbara, California, northward to the Aleutian Islands and are subject to the West Coast's most lucrative commercial fishery. Like other mid-trophic level species, Dungeness crab occupy lower trophic levels at their larval and juvenile stages. Because of their high value to West Coast fisheries, Dungeness crab have been the subject of numerous studies on the potential effects of ocean acidification and climate change on crustaceous species (e.g., Bednaršek*, et al.* 2020; Trigg*, et al.* 2019). Some of the potential effects of climate change on habitat availability for benthic crustaceans and fish may be less obvious than for more pelagic species, and may include the combined pressures of reduced suitability through changes in sea bottom temperature, pressure, acidification, and hypoxia (Brown and Thatje 2015; Nye*, et al.* 2009; Thatje 2021).

Other mid-to-high trophic level invertebrates of the CCE include the larger-bodied squid species, such as Humboldt squid, and can have significant effects on the ecosystem in years when their populations are more abundant. Changes in physical forcing and resultant prey communities in the CCE can drive poleward expansion of Humboldt squid into the CCE, increasing the potential for high levels of squid predation on several fish species, potentially resulting in changes across trophic levels (Field*, et al.* 2008; Stewart*, et al.* 2013).

### *3.3.4 High Trophic Non-Fish Vertebrates: Mammals, Birds, and Reptiles of the CCE*

Marine mammals, seabirds, and marine reptiles of the CCE serve as mid- to high-trophic level predators in the CCE, some of which are protected species under the Marine Mammal Protection Act (MMPA) or ESA. Many are recovering from past exploitation (e.g., sea lions (*Otariinae* spp.), yet others still face cumulative threats that have limited their recovery or contributed to their decline (e.g., Southern Resident Killer Whales (*Orcinus orca*)). Many populations forage in the CCE seasonally, and breed elsewhere, such as fur seals (*Callorhinus ursinus,* which breed in the Bering Sea), Humpback whales (*Megaptera novaeangliae,* which breed off the coast of Mexico or central America), sooty shearwaters (*Puffinus griseus,* which breed in New Zealand), and leatherback turtles (*Dermochelys coriacea,* which breed in the western tropical Pacific). Top predators that do breed in the CCE, such as sea lions and elephant seals (*Mirounga angustirostris*), often migrate or forage far from their breeding grounds seasonally, although some of the larger seabird populations that breed within the CCE (such as common murres (*Uria aalge),* auklets (family *Alcidae),* and gulls (*Laridae* spp.)) typically do not have extensive foraging ranges. The literature on movements and migrations for any given population is substantial, but Block, *et al*. (2011) provide an excellent synthesis of the range of movements for many of these (and highly migratory fish) populations based on a concerted effort to tag top ocean predators over the past decade as part of the Tagging of Pacific Predators program. Additionally, Block *et al.* (2011) describe the seasonal patterns of productivity, thermal variability, and other ocean processes that drive migration within, to, and from the CCE.

Seasonal patterns in coastal upwelling and relaxation serve as one of the greatest drivers of migrations and variable distributions in the CCE, although inter-annual and decadal climate variability also shapes the distribution and abundance of many of these higher trophic level species. Recent anomalous events have led to increased presence of warm water species sighted in the CCE (Becker*, et al.* 2019; Sanford*, et al.* 2019) but also unusual mortality events of California sea lions (*Zalophus californianus*), Guadalupe fur seals (*Arctocephalus townsendi*), and large whales (16 U.S.C. §1421c). Modeling efforts have also explored the response of marine mammals and seabirds to warm water or upwelling anomalies (Sydeman*, et al.* 2009, common murres ), predicted effects of climate change on higher order predator populations over the next century (Hazen*, et al.* 2013), and the increased risk from changes in human activities and range shifts such as for humpback and blue whales (*Balaenoptera musculus*) (Abrahms*, et al.* 2019; Santora*, et al.* 2020). Many of these top predators may be able to provide insight on ecosystem status when oceanographic or forage measurements are unavailable, with a few CCE species suggested as climate and ecosystem sentinels (Hazen*, et al.* 2019).

Both migrant (such as sooty shearwater and black-footed albatross, (*Phoebastria nigripes*)) and resident seabirds (such as common murres and rhinoceros auklets, (*Cerorhinca monocerata*)) have been described as having either warm or cool water affinities, and vary their distribution, abundance, productivity, and, for generalists, their diet accordingly (Sydeman*, et al.* 2001); (Sydeman*, et al.* 2009). One of the most abundant migratory seabirds in the CCE, sooty shearwaters, declined by as much as 90 percent immediately following the 1977 regime shift from mostly negative (cold) to positive PDO (warm) conditions (Veit*, et al.* 1996), although numbers have been variable since that time and it remains unclear whether there was an actual decline in population or a shift in distribution (Bjorkstedt*, et al.* 2010). Understanding such changes in the population dynamics of seabirds is increasingly essential for effective fisheries management, providing the means to minimize interactions between fisheries and threatened or endangered species (Crowder and Norse 2008; Howell*, et al.* 2008; Maxwell*, et al.* 2015). NMFS includes seabird indicators in the annual ESR, particularly noting large-scale wrecks (die-offs) of bird species that have been associated with the marine heat wave of 2014-2015 and other warming anomalies in more recent years (e.g., Garfield and Harvey 2016).

Large-scale seasonal area closures to the HMS FMP's West Coast large mesh drift gillnet fishery is an example of a measure implemented to minimize interactions with leatherback sea turtles that forage intensively on jellyfish (*Scyphozoa* spp.), particularly off central California, from late spring through the fall (Benson*, et al.* 2011). This closure has shown to be in the right place and at the right time to minimize bycatch risk of leatherback sea turtles (Eguchi*, et al.* 2017), but changing such closed areas annually – if not more frequently – could increase fishing opportunity while still maintaining conservation goals (Hazen et al 2018). Similarly, a loggerhead sea turtle (*Caretta caretta*) closure has been enacted during El Niño-like conditions in the Southern California Bight with recent indicators developed to provide more explicit advice to management {50 CFR 660.713(c)(2), \Welch, 2018 #138-https://coastwatch.pfeg.noaa.gov/loggerheads/}. Within the U.S. portion of the CCE, turtle conservation efforts prioritize minimizing turtle-fisheries interactions. However, multiple sea turtle species (*Cheloniodea* spp.) are critically endangered and much of this population vulnerability lies beyond the control of the Council and other U.S. management entities. Reversing long-term sea turtle population declines will ultimately require a multinational, holistic strategy directed at minimizing bycatch in an array of international fisheries, and multiple national policies and enforcement to reduce nesting beach threats connected with light conditions, warming temperatures, and egg poaching (Dunn*, et al.* 2019; Dutton and Squires 2011; Harrison*, et al.* 2018).

Although historical removals of marine mammals described earlier collectively kept most pinniped and whale populations at low to moderate levels until the middle to late 20th century, most populations have increased, many dramatically, over the last several decades. Humpback whales in the CCE are now thought to number over 2,700 individuals across multiple populations; blue whales over 1,500; elephant seals, a minimum estimate of 84,000; California sea lions on the order of 275,000; and short-beaked common dolphins (*Delphinus delphis*) over 830,000 animals (Carretta*, et al.* 2020). Appreciation for the cumulative historical impacts of whaling and sealing, and the potential cascading impacts to marine ecosystems, has grown as many marine mammal populations have recovered (Estes*, et al.* 2006; National Research Council 1996). Currently, researchers have proposed that California sea lion (Laake*, et al.* 2018) and blue whale (Monnahan*, et al.* 2015) populations appear to be approaching some level of carrying capacity.

Increasing mammal populations have direct impacts on many salmonid populations and have indirect impacts when combined with human alterations to habitat, such as dams, that serve to aggregate salmonids where they are easy prey for California sea lions (Chasco*, et al.* 2017a; Chasco*, et al.* 2017b). Although most mammal populations experience some incidental mortality as a consequence of fishing operations, mortality sources generally do not exceed estimates of potential biological removals. One of the goals of the MMPA is that the incidental mortality or serious injury of marine mammals in fisheries should be reduced to insignificant levels approaching zero. All FMPs are managed to be consistent with this goal. In recent years there has been concern regarding high mortality rates for some cetaceans, particularly blue whales and sub-populations of humpback whales, caused by large ship strikes within and outside of fisheries (Abrahms*, et al.* 2019; Berman-Kowalewski*, et al.* 2010; Rockwood*, et al.* 2017), as well as due to entanglements (Ingman*, et al.* 2021; Santora*, et al.* 2020).

### *3.3.5 Trophic Interactions in the CCE*

Trophic interactions involve all species in the CCE, since virtually all can be consumed during early life and most organisms without chloroplasts must eat other creatures to survive. Sections 3.1 and 3.2 of the FEP discuss the effects of oceanographic forces on nutrient provisioning through upwelling and other mechanisms. Section 3.3 of this FEP is roughly arranged from lowest trophic levels upward, to reflect the transfer of trophic energy upwards from each trophic level. The capacity of organisms to obtain nutritional food sources has major implications for growth, recruitment and population dynamics. Only about 30-35 percent of energy is transferred upwards from each trophic level; thus, 65-70 percent of the energy is lost to recycling (Fenchel 2003; Paffenhofer 1976). Understanding oceanographic forces, nutrient cycles, and associated trophic interactions is critical for developing scientific questions and ideas to inform ecosystem-based management.

Unravelling trophic interactions during early life stages for species with planktonic larvae is an important component of ecosystem-based management because larval survival impacts recruitment and ultimately population sizes of most fisheries. Most organisms need to begin feeding within minutes to days after birth, and the capacity to obtain food during early life (e.g., until reaching a juvenile stage for fishes) is thought to be the most important factor controlling recruitment to the adult population (Hare 2014; Hjort 1926). Getting insight on larval feeding dynamics is very difficult, however, because it is necessary to sample both larva and their prey fields, determine what is in larval guts, and link this to recruitment dynamics (Robert*, et al.* 2014). Existing studies that have carried out these efforts consistently find that there is strong preference by larvae for particular prey species, that preferred prey can change as larvae age, and that the capacity to consume preferred prey throughout their lives correlates with faster growth, lower mortality (either through starvation or predation), and higher recruitment (Robert*, et al.* 2014). By contrast, there is rarely correlation between overall zooplankton biomass and recruitment, further strengthening the need to resolve specific trophic interactions at small spatial scale to elucidate fishery recruitment (Agostini*, et al.* 2007).

Current understanding of trophic interactions at spatial and temporal scales relevant to larvae is very limited in the CCE, largely due to the enormity of collecting appropriate data. While traditional sampling methods have limited capacity to elucidate larval trophic dynamics, emerging technologies hold to promise to provide new insight. High resolution video images collected by gliders or towed cameras and processed with artificial intelligence-driven picture recognition software provide a deep understanding of interactions between larvae and their predators and prey (Swieca*, et al.* 2020). Environmental DNA can provide highly detailed data on prey and is being used to discern assemblage structure of cyanobacteria, protists and zooplankton, and fish in the CCE (Goodwin*, et al.* 2017). Compound-specific stable isotope analysis can now be used very precisely discern the trophic position of larval prey and Swalethrop, *et al.* (In Review) found that the trophic position of larval anchovy prey explained 61 percent of variation in anchovy spawning stock biomass two years later between 1960 and 2005. Recent improvement in modeling of larval growth and mortality based on variability in length~age relationships hold promise to predict fish recruitment (Hinchliffe*, et al.* 2021). Taken together, improvement to sampling and analysis hold promising potential to better understand small scale trophic interactions that are crucial for predicting recruitment.

In contrast with small scales, trophic interaction involving juvenile and adult fishes as well as piscivores is much better resolved in the CCE. For example, science-planning discussions following the adoption of the 2013 FEP led to increased diet work at the NMFS Fisheries Science Centers, inspiring the cataloging of diet information for hundreds of fishes in the CCE. In addition, the Environmental Assessment for the Council's CEBA 1 provides a thorough review of CCE diet publications through 2015, focusing on the feeding habits of Council-managed species, ESA-listed species, and MMPA and Migratory Bird Treaty Act (MBTA) managed species (PFMC 2016). In a comprehensive review of the diets of upper trophic level bony fishes, cartilaginous fishes, sea birds, cetaceans and pinnipeds, Szoboszlai, *et al*. (2015) found that juvenile rockfishes, northern anchovy, euphausiid krill, Pacific herring and market squid were the top five most consumed prey in the CCE. There has been tremendous progress in quantifying predator-prey relationships in the CCE in recent years.

The detailed understanding of macro trophic interactions can inform how changes in the forage base will permeate through the ecosystem. Although food-web-modelling studies show that most predators can switch among various forage species as their abundances vary (Koehn*, et al.* 2016), the energetic value of various prey varies tremendously among predator species. For example, during the 2015-2016 marine heatwave in the CCE, northern anchovy abundance skyrocketed while krill plummeted (Thompson*, et al.* 2019). Anchovy are valuable prey for sea lions, and the sea lion pups thrived following the rise of anchovy (Thompson*, et al.* 2019). Anchovy are too large to be consumed by rhinoceros auklet (*Cerorhinca monocerata*), and chick survival was very low under high anchovy/low krill conditions during the marine heatwave (Sydeman*, et al.* 2009). In general, the increasing frequency of extreme warm water events produced novel trophic interactions by mixing novel forage species and predators with human uses of the oceans (Morgan*, et al.* 2019). These changes have resulted in both prey and predator distribution shifts with new human-wildlife conflicts (Santora*, et al.* 2020) and changes in bycatch patterns leading to the examination of adaptive management approaches (See Agenda Item F.1.a,GMT Report 1, June 2020). It is likely that continued warming will induce more novel interactions between marine prey, predators and people.

Understanding trophic interactions is critical for effective ecosystem-based fisheries management. A stated goal of NMFS is to implement next-generation stock assessments that broaden "the scope of the stock assessment paradigm to be more holistic and ecosystem-linked" (Lynch*, et al.* 2018). Elucidating trophic interactions is paramount for this objective because, for example, when setting harvest limits for forage species, assessors will need to consider leaving a robust forage base for higher trophic level species that depend on the forage. In addition, by evaluating preferred prey for larvae, managers may augment the power to predict recruitment class strength and thus better prepare for ecosystem conditions in the near future. Working towards a more complete understanding of trophic interactions in the CCE will help ensure that fisheries "be managed in an ecosystem context to ensure that interacting effects among fisheries, ecosystems, and human activities are accounted for." (National Marine Fisheries Service 2016).

## *3.4 Fisheries of the CCE*

### *3.4.1 Historical Industrial CCE Fisheries*

The perception of the effects of fisheries exploitation on the environment has varied over time. Fréon, *et al.* (2005) and others (Duarte*, et al.* 2020; MacCall 2009) defined a set of time periods that help frame the history of exploitation and the accompanying evolution of associated science. The period before the 20th century is best described as the "inexhaustible" period, when conventional European-centered wisdom held that fisheries could not have an appreciable impact on the resources (but see, e.g., Hoffmann 1996). Prior to the 1900s, global fisheries landings were minimal relative to contemporary catches. During the industrial exploitation period of 1900-1950, global landings for some species increased, and then often decreased dramatically. The rise and fall of the Pacific sardine fishery is a classic example of such an industrial fishery, and the collapse that followed led to what might be considered the conventional management period of 1950-1975.

The mid-20th century saw the development of most of the basic foundations of contemporary fisheries science, including functional relationships addressing productivity, such as fisheries oceanography, stock/recruit relationships, as well as population dynamics models such as surplus production models and virtual population analyses that allow hypothesis testing on the interactions of functional aspects and sustainability of populations to exploitation. The conventional management period also saw some of the greatest development of industrial fisheries, coupled with the application of the newly-developed science of fisheries management. However, the conventional management period also coincided with the world's largest fisheries failure, the crash of the Peruvian anchoveta (*Engraulis ringens*) fishery in the early 1970s, which had been responsible for up to one quarter of global fisheries landings at the time. The anchoveta fishery collapse had tremendous ecosystem consequences (Jahncke 1998) and led to what Fréon, *et al.* (2005) described next as the "doubt" period from the mid-1970s through the mid-1990s.

In the late-20th century "doubt" period, researchers and managers recognized the limitations and constraints of the sciences, and placed renewed emphasis on the role of climate as a driver of population and fishery dynamics. Based on the Freon, *et al*. (2005) suggestion of major eras of fisheries management, the ecosystem-based management period has emerged from the mid-1990s to the present. This period is characterized by a gradual and wide recognition that ecosystem factors are important to marine resource science and management, but most management actions tend to be in an assemblage-based context that integrates single-species assessment model results. While a single-species focus in stock assessment still underpins U.S. fisheries population management, ecosystem-based frameworks are gaining influence (Kaplan*, et al.* 2012; Lehodey*, et al.* 2008), providing the ability to quantify changes in ecosystems, particularly as they relate to fishery exploitation.

The marine and nearshore ecosystems of the CCE have been exploited at industrial levels for well over two centuries, and had long supported populous and culturally sophisticated Native American communities for millennia (McEvoy 1986; Trosper 2003). Figure 3-7 (updated from Field*, et al.* 2006) presents an accounting of the history of the most substantial marine resource removals over the past two centuries, illustrating both the magnitude of removals as well as the sequential nature of the development of the major fisheries in the region. European-era exploitation in this ecosystem began with the rapid conversion of the energy at the top of the food web into commodities. The great whales, fur seals, elephant seals, sea lions, otters, and many seabird colonies were transformed into oil, pelts, and food. Exploitation continued with the depletion of many salmon populations due to fishing and the massive alteration or elimination of their freshwater habitat that affected recruitment. Next arose the classic tale of the rise and fall of the Pacific sardine fishery, and subsequent fisheries for northern anchovy, mackerel, Pacific herring, and market squid. Throughout the past two centuries, some fisheries grew unsustainably fast, rapidly depleting resources (typically low turnover resources) in short pulses, including fisheries for: abalone, black and white seabass, and various elasmobranchs such as basking (*Cetorhinus maximus*), soupfin (*Galeorhinus galeus*), and dogfish (*Squalus acanthias*) sharks. Fisheries for many groundfish, including Pacific and California halibuts, sablefish, lingcod, Pacific ocean perch (*Sebastes alutus*), and other rockfishes seemed to be sustainable at low levels prior to the 1950s development of modern industrial fisheries.

The large-scale removals of marine mammal populations began in the late 18th and early 19th centuries, at the scale of the entire North Pacific (Ogden 1933; Scammon 1874). Although New England whalers had been operating in the North Pacific since the late 1700s, they initially avoided coastal waters of the CCE due to the “savage disposition” of California gray whales (*Eschrischtius robustus*, Gordon 1987).

However, whalers had been targeting CCE whale populations, and by the 1850s as many as a dozen shore-based whaling stations were spread out between Crescent City and San Diego, California, targeting a mix of gray, humpback, and other whales encountered in coastal waters. Gray whales were subsequently harvested to near extinction in the lagoons of Baja California, Mexico, by the 1870s, and the first pulse of coastal whaling ended shortly thereafter. Similarly, exploitation of sea otters, fur seals, and elephant seals began during the late 19th century, with all of these animals taken for a mix of pelts, food, and oil. Many of these populations were commercially extinct by the late 1800s, during which time sea lions, harbor seals, and seabirds were also exploited. For example, the harvest of seabird eggs on the Farallon Islands and elsewhere was as great as 14 million eggs between the mid-1800s and 1900, with the result that the common murre population on the Farallons may have declined from nearly half a million birds to less than 5,000 by the 1920s (Ainley and Lewis 1974 ; Estes*, et al.* 2007; Estes*, et al.* 2016; Estes*, et al.* 2011; McCauley*, et al.* 2015).

Both shoreside and at-sea whaling operations were widespread throughout the North Pacific during the second wave of whaling in the 1910s and 1920s, with catches of all species diminishing rapidly in the early 1920s (Estes*, et al.* 2006; Tonnessen and Johnsen 1982). It is interesting to consider that these removals occurred in concert with the major expansion of the Pacific sardine fishery, since stomach contents data from whales caught off California show humpback, as well as fin (*Balaenoptera physalus*) and sei (*Balaenoptera borealis*), whales fed primarily on sardines, as well as euphausiids, anchovies, herring, and other prey (Clapham*, et al.* 1997). If whales historically represented a substantial fraction of sardine (and other coastal pelagic) mortality, the decline of whale and other predator populations (e.g., fur seals, sea lions, tunas) might have led to a greater than average availability of sardines, contributing to that fishery’s expansion throughout the early 1920s and the early 1930s. Populations of most marine mammals in the CCE have recovered to, with some perhaps even exceeding, historical levels of abundance in recent decades. Appreciation for the historical impacts of whaling and sealing, and the potential cascading impacts to marine ecosystems, has grown as marine mammal populations have recovered (Estes*, et al.* 2006; National Research Council 1996; Springer*, et al.* 2003), and a basic understanding of the relative significance of both contemporary and historical trends and abundance of predators should be an integral component of an ecosystem approach to managing CCE fisheries.

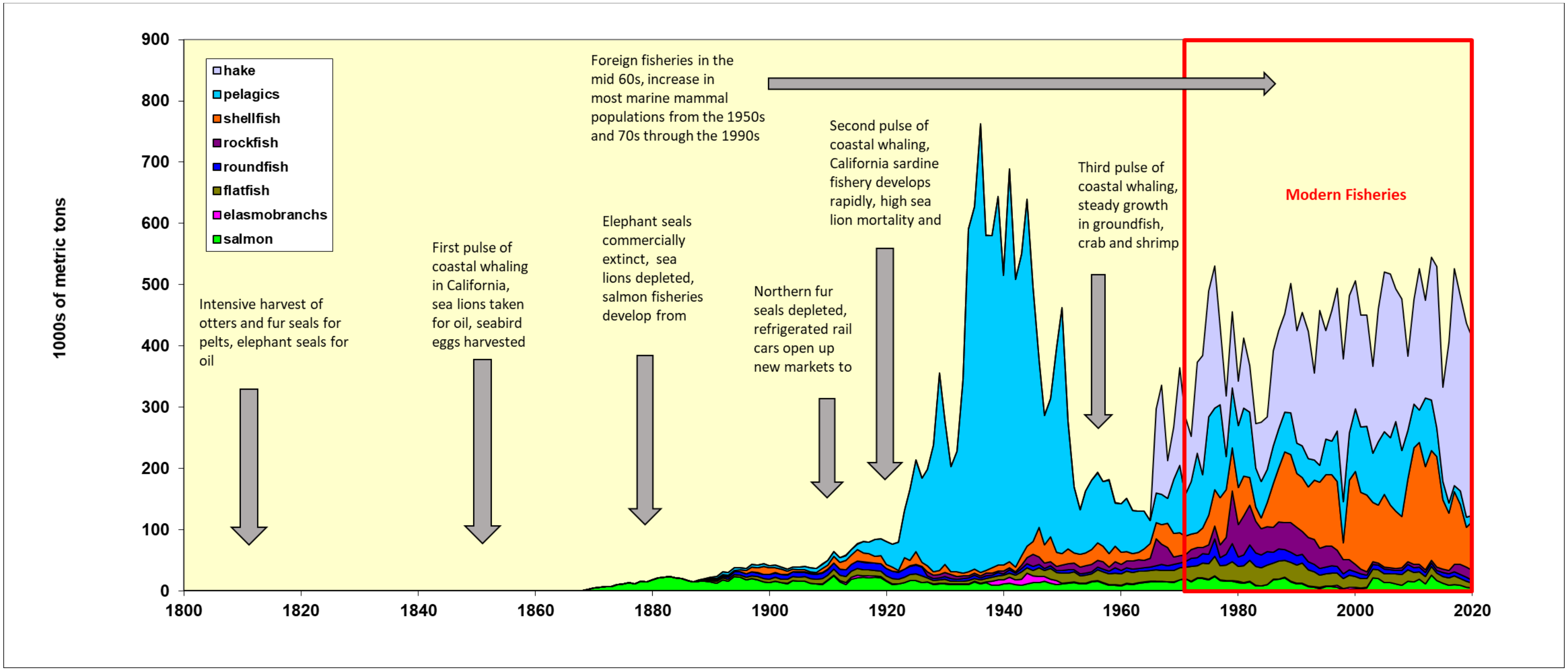


**Figure 3-7. Major fisheries removals and developments within the U.S. portion of the CCE over the past two centuries.**

Salmon fishing represented the foundation of the livelihoods of native communities for thousands of years prior to West Coast settlement by Europeans, and salmon fishing preceded sardine fishing as the first major finfish to be exploited throughout CCE (both inland and offshore) waters (Lyman 1988; McEvoy 1986). Unsustainable salmon removals likely began with the rapid late-19th century development of the Sacramento River salmon fisheries, spreading rapidly northwards as Sacramento fisheries were overexploited (McEvoy 1986, 1996). Fishing and canning operations quickly developed on the Columbia River, where the salmon fishery grew from just tens of thousands of pounds in 1866 to over 20 million pounds by 1876 and over 40 million by 1885 (Cobb 1930). Salmon have continued to be among the most valued and vulnerable fisheries in the CCE with the associated fisheries management challenges and habitat issues remaining the subject of continual controversy. As the bridge between freshwater, estuarine, and marine environments, salmon have evolved complex population structures and life histories to cope with the variability in each of these environments. Prior to western contact, Pacific salmon had evolved complex meta-population structures, and the physical template provided by high quality freshwater habitat is thought to have provided the insurance needed for such population structures to persist under highly variable ocean conditions (Nickelson and Lawson 1998). Ongoing degradation of freshwater and estuarine habitats has contributed to a decline in the diversity of populations and life history types, increasing the vulnerability of both the remaining populations and the associated fisheries to climate variability (Lindley*, et al.* 2009).

Of the major historical fisheries in the CCE, probably the most noteworthy is the Pacific sardine fishery, immortalized by John Steinbeck in *Cannery Row*. Although sardines had been fished in California waters since the mid-1800s, markets for canned sardines (and later highly lucrative markets for fishmeal and fertilizer) did not develop until World War I, largely in response to declining salmon canning opportunities in California. Sardine fishing rapidly expanded throughout the coast, from British Columbia to Southern California, and coastwide landings grew from roughly 70,000 metric tons per year in 1920 to a peak of over 700,000 metric tons in 1936. Both the sardine population and the fishery began to decline sharply shortly after World War II, with sardines disappearing sequentially from north to south, leading to debates that continue to this day regarding the relative contributions of fishing and environment with respect to the interactions between fisheries and climate more generally. By the time the fishery was closed in 1968, the sardine population had declined by several orders of magnitude, and fluctuations were noted in other coastal pelagic species (CPS) fisheries as well. After remaining scarce for several decades, sardine populations began to rise in the mid-1980s. By the 1990s, sardine were once again targets of commercial landings, and sardine were once again caught as far north as Vancouver Island. In the mid-2000s, however, populations again began to decline and once again fell first in the north and then in the south. By 2015, sardine were at low enough levels that the PFMC closed the directed commercial sardine fishery. As of 2020, sardine population size was low throughout the CCE.

The Pacific mackerel (*Scomber japonicus*) fishery was closed in 1972 as a result of declines in that population (which reversed in the late 1970s), while the northern anchovy fishery grew in the 1960s and 1970s, apparently in response to increases in abundance. Decades of studies devoted to understanding the proximate causes of the sardine decline, and comparable declines and dynamics in other ecosystems, have led researchers to appreciate the role of climate in driving variability in the recruitment and ultimately population sizes of CPS, and it is now hypothesized that the sardine fishery exacerbated what would have likely been a natural decline in the abundance of sardine in the 1950s and 1960s (Baumgartner*, et al.* 1992; Chavez*, et al.* 2003; Checkley and Barth 2009; Maccall 1996). The recovery of Pacific sardines in the 1980s and 1990s was generally associated with changes in environmental conditions, resulting in a resurgent fishery as well as a more conservative management regime. However, there is still limited understanding of the specific environmental mechanisms that induce recruitment fluctuation in CPS and the optimal management measures for balancing conservation needs with fisheries.

Pacific halibut and other groundfish have been harvested throughout the CCE region for millennia. By 1892, coastwide catches of halibut and other flatfish, cod, rockfishes, and sablefish combined were over 10 million pounds per year, with the majority taken from coastal inland waters of San Francisco Bay, the Columbia River estuary, and Puget Sound. Through the early 20th century, longline fisheries for Pacific halibut and sablefish expanded, as did paranzella (two-boat trawl) fisheries that had begun as early as 1876 in San Francisco. The introduction of otter trawls to West Coast fisheries following World War I was associated with a gradual expansion of the trawl fleet northwards, and by the late 1930s the center of West Coast trawling had shifted from San Francisco to Eureka (Scofield 1948). A sharp increase in effort and landings occurred during World War II, spurred on by both a need for inexpensive protein from flatfish and rockfishes (much of which was ordered by the U.S. Army), and engine lubricant from the livers of dogfish, soupfin, and basking sharks. Demand for groundfish dipped slightly after the war, but trawlers kept busy as a market for mink food supplemented markets for fresh and frozen fish. The fishery grew steadily in the 1950s and 1960s following the postwar dip, and diversified as fisheries for Dungeness crab, pink shrimp, and albacore tuna developed and expanded alongside existing fisheries for salmon and groundfish.

In the late 1960s through the 1980s massive fleets of Japanese, Russian, and Polish trawlers, many of them recent expatriates of declining whale fisheries, began intensively fishing the CCE's continental shelf and slope waters. The size and capacity of these trawlers stood in sharp contrast to the U.S. coastal fleets of trollers, draggers, and crab boats, and helped fuel the desire to nationalize marine resources and develop greater domestic fishing capacity. Senator Warren Magnuson captured the mood of the day, when he advised fishermen and scientists that "You have no time to form study committees. You have no time for biologically researching the animal. Your time must be spent going out there and catching fish… Let us not study our resources to death, let's harvest them" (Magnuson 1968). As the growing conservation movement of that era drove passage of a plethora of environmental legislation in the early 1970s, environmental concerns soon matched the desire to nationalize marine resources. The Fishery Conservation and Management Act of 1976 (later reauthorized as the Magnuson-Stevens Fishery Conservation and Management Act, or MSA) ultimately included objectives of both developing domestic fisheries as well as attaining sustainability as defined by the concept of maximum sustainable yield (MSY). While MSY was treated as a "target" in the 1976 Act, it has since evolved to represent a "limit" reference point, reflecting evolving attitudes about sustainable fishery management.

### 3.4.2 Current Fisheries

This section presents an overview of the CCE fisheries; descriptions of specific Council-managed fisheries are found in the FMPs and associated stock assessment and fishery evaluation (SAFE) documents. Commercial, recreational, and tribal fisheries are addressed, although tribal commercial fisheries landings and revenue are included in the coastwide landings and revenues for all commercial fisheries in Section 3.4.2. In Section 3.4.3, Fishing Communities, we discuss the social and economic characteristics of West Coast communities.

Most commonly, a "fishery" is defined in terms of the objective (profit, recreation, identity), the regulatory framework, the targeted species, and the gear used to catch the fish. Thus, an example of a fishery is the commercial limited entry sablefish fixed gear fishery: the objectives (human consumption and fisheries profit), a regulatory component (a limited entry permit system), a target species (sablefish), and a gear type (fixed gear, covering bottom longlines and pots). Fisheries may be further categorized by other environmental characteristics such geography (north, south, nearshore, offshore), oceanographic domain (pelagic, benthic), habitat, and seasonality. A more fine-grained description may include social and demographic characteristics of fishery participants and the supporting communities (ports, processors, input suppliers). Looking at fisheries from the perspective of participants – vessels and their operators – inverts the characterization. Fishermen may participate in several fisheries per year; and there are long-term shifts in participation measured by the number of vessels within a fishery and across fisheries. Technology, the status of targeted species, climate variability, social values, and regulatory interventions can also change a fishery's essential characteristics over time. Figure 3-8, excerpted and detailed from Figure 3-7, shows major fishery removals for 1970 – 2020, overlain with major climate events and revisions in fisheries regulations.

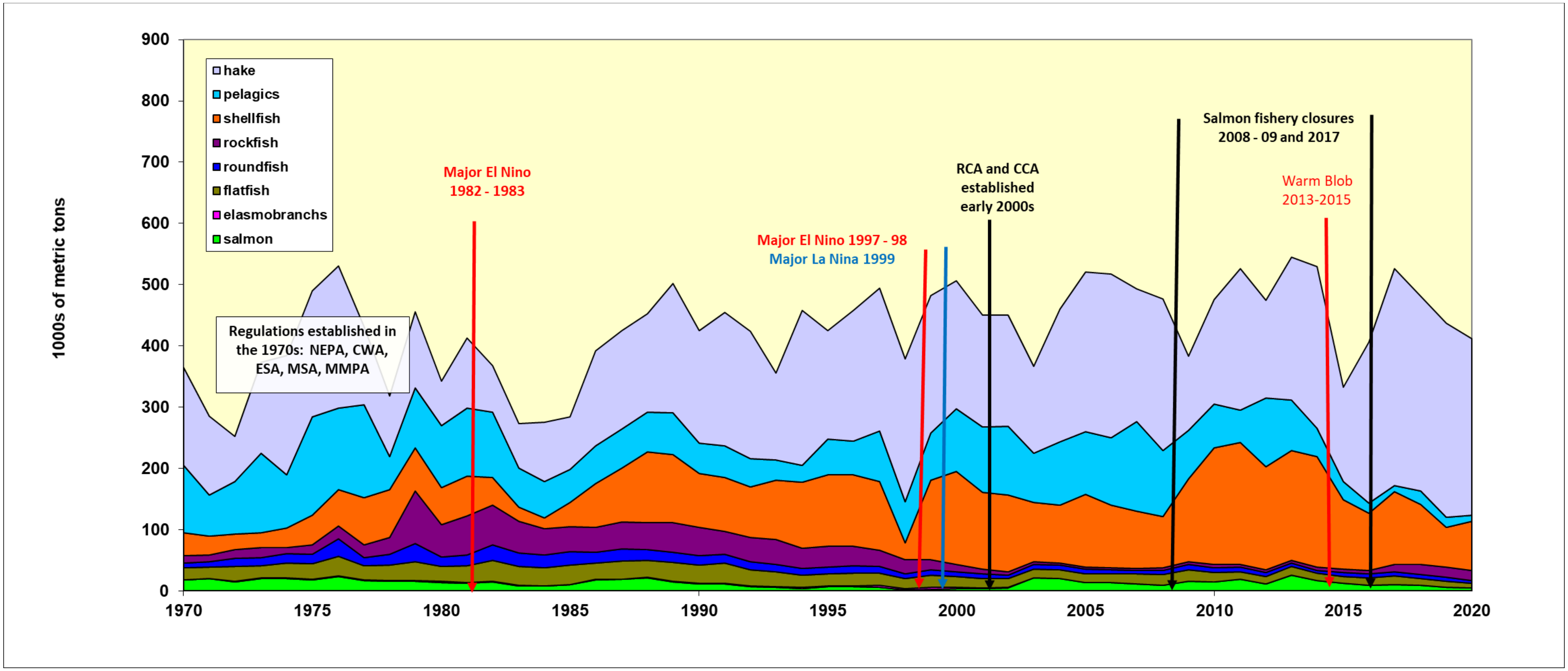


**Figure 3-8. Excerpt of Figure 3-7, showing fishery removals and other events since 1970.**

#### 3.4.2.1 Commercial Fisheries

West Coast commercial fisheries can be identified by generally accepted definitions, as described above, although definitions may differ somewhat in their specifics across participants, managers, and researchers. Table 3-3 inventories and describes commercial fisheries accounting for 89 percent of coastwide landings and 69 percent of ex-vessel revenue during the past 10 years. These fisheries interact with an ecosystem with high biodiversity making the fisheries necessarily diverse in the species that they target, the gear used, fishing locations, and in where landings of different species are made. Table 3-3 is organized by whether they target species with gear that operates in the water column and off the ocean bottom (pelagic) or with gear that contacts the ocean bottom (benthic).

Among the fisheries described in Table 3-3 the Dungeness crab pot fishery is by far the most economically important, accounting for a third of total coastwide revenue over the past decade. Revenue in the Dungeness crab fishery is followed by market squid and pink shrimp trawl in terms of revenue, all three of which are largely state-managed fisheries. The Dungeness crab pot, albacore hook-and-line (pole/troll), salmon troll fisheries, and groundfish nearshore fixed gear fishery show the highest levels of participation in terms of vessel numbers, and vessels participating in these fisheries realize much of their landings and revenue in other fisheries. This suggests that these fisheries are important contributors to economic viability of many smaller fishing operations. In contrast, vessels in trawl fisheries for groundfish and pink shrimp tend to be much more specialized, deriving a large share of landings and revenue from these target fisheries.

**Table 3-3. Major fisheries of the West Coast, by water column location, gear, and target species**

| Pelagic or Benthic? | Gear? | Target Species |
|---|---|---|
| Pelagic | Net: Round haul gear (purse seine, drum seine, lampara net). | Pacific sardine, northern anchovy, market squid, and tunas (skipjack, yellowfin. and Pacific bluefin tuna). Vessels mainly fish off Central and Southern California; however, with the mid-2000s growth in the Pacific sardine stock, vessels also targeted sardine off the mouth of the Columbia River. |
| Pelagic | Net: scoop, brail, or purse seine gear to provide live bait for recreational fisheries targeting pelagic species. | Pacific sardine and northern anchovy. Incidental/bycatch includes "white croaker, queenfish, Pacific and jack mackerels, and various small fishes collectively known as "brown bait" that can include juvenile barracuda, Osmerids, Atherinids, and market squid" (CPS SAFE). (Commercial vessels, principally baitboats targeting albacore, also catch live bait for use in their fishing operations.) Other species such as Pacific herring (Oregon) and market squid (Southern California) are occasionally caught for the live bait market. Nearshore fishery, especially bays and estuaries. |
| Pelagic | Net: drift gillnet gear. | Swordfish and common thresher shark targeted off California (mostly in the Southern California Bight). Relatively high level of incidental/bycatch including tunas, other pelagic sharks, and ocean sunfish. Historically, the fishery also had relatively high take of sea turtles and marine mammals, but a large decline in participation and implementation of various mitigation measures has reduced this protected species take. By statute, California has implemented a phase out program for this fishery. |

| Pelagic or Benthic? | Gear? | Target Species |
|---|---|---|
| Pelagic | Hook-and-line: troll gear, or baitboats using hook-and-line gear. | North Pacific albacore. These gear types are selective and there is minimal bycatch in the fishery. Historically, the fishery occurred off California, although the fishery has shifted north in recent decades and now occurs mainly off Oregon and Washington. Fishing can occur far offshore, even outside the West Coast EEZ, depending on the distribution of albacore. |
| Pelagic | Hook-and-line: pelagic longline gear. | Tunas and swordfish. The HMS FMP prohibits pelagic longline fishing within the EEZ, prohibits the retention of striped marlin, and prohibits targeting swordfish with the shallow-set gear configuration. The Council has declined to adopt measures that would authorize an ESA-compliant fishery targeting swordfish. However, vessels permitted to operate under the Western Pacific Fishery Management Council's Pelagics FEP may target swordfish and land in West Coast ports. In the last decade, by Hawai'i vessels have accounted for 40 percent of West Coast swordfish landings, although tuna landings are increasing and accounted for slightly more than half of landings in 2019. Other frequently landed species include dorado (mahi-mahi) and opah. |
| Pelagic | Hook-and-line: troll gear. | Chinook and coho salmon, various stocks with distinct spawning populations. Depending on the stock, salmon migration occurs at different times of year but in aggregate the fishery has a distinct seasonal pattern with catches picking up in May and peaking August to October. |
| Pelagic | Trawl: mid-water trawl. | Pacific whiting. This is a large volume fishery with a relatively low incidental/bycatch rate although bycatch of overfished rockfish species and Chinook salmon have led to management constraints. Vessels are divided between at-sea and shoreside fisheries, with the at-sea sector further subdivided between mothership processing vessels accepting fish from catcher boats and catcher-processor vessels. Most catcher-processor and mothership vessels also fish in Alaska waters for part of the year, as do many of the catcher vessels (slightly more than half the revenue earned by vessels in the at-sea fleet comes from fishing in Alaska). |
| Pelagic | Trawl: mid-water trawl. | Pelagic rockfish species, principally widow rockfish and yellowtail rockfish. These two species account for about two-thirds of catch; since they are using the same type of gear, Pacific whiting may be caught incidentally (Steiner 2019). Landings of pelagic rockfishes were a major component of the West Coast groundfish fishery in the 1980s and 1990s, but were effectively prohibited beginning around 2000 due to measures to rebuild overfished rockfish stocks. With successful rebuilding of these species, the fishery reemerged in the mid-2010s. |
| Pelagic | Harpoon: swordfish. | Highly selective gear with no unintentional catch. Operates in the Southern California Bight, sometimes using spotter planes to locate swordfish schools. |

| Pelagic or Benthic? | Gear? | Target Species |
|---|---|---|
| Benthic | Trawl: bottom trawl gear. | Vessels tend to target Dover sole, thornyheads, and sablefish in deepwater on the continental slope (200-300 fathoms,) or flatfish (with petrale sole and Dover sole major sources of revenue), and other groundfish species on the continental shelf (<100 fathoms). Both strategies can be characterized as multispecies with relatively high levels of incidental yet retained catch. Fishery occurs primarily off Washington and Oregon with some activity in Northern California. |
| Benthic | Trawl: single and double-rigged shrimp trawl gear. | Pink shrimp, which occur on sandy and mud bottoms all along the West Coast, although the fishery is centered in Oregon. Pink shrimp vessels use bycatch reduction devices and light emitting diode lights to reduce bycatch including protected species such as eulachon. |
| Benthic | Trawl: bottom trawl. | California halibut, taken in nearshore areas in Central California, primarily off of San Francisco and around Point Conception (Richerson*, et al.* 2019). Bycatch includes the southern DPS of green sturgeon, which is listed as threatened under the ESA. |
| Benthic | Fixed gear: bottom longline and pot/trap. | Sablefish, with allowable and incidental catch of other groundfish species such as thornyheads, rockfishes, flatfish, spiny dogfish, and skates. Bycatch may also include Pacific halibut, which may be retained in some times and areas when taken with longline gear. |
| Benthic | Hook-and-line | Rockfishes and other groundfish species in nearshore areas. Varied catch is generally retained. |
| Benthic | Hook-and-line: longline | Pacific halibut. Bycatch includes rockfishes and sablefish. Pacific halibut may be directly targeted, or may be retained (when permitted) in salmon and sablefish hook-and-line fisheries. |
| Benthic | Pot/trap: Dungeness crab. | Bycatch of other species unusual, although Dungeness crabs that do not meet regulatory requirements for size and sex are discarded with the expectation that they will survive to reproduce. |
| Benthic | Pot/trap: Spiny lobster. | Bycatch of other species is unusual, although cabezon, lingcod, and sublegal lobsters may occur as bycatch. Southern California Bight fishery. |

The annual California Current ESR (e.g., Harvey*, et al.* 2019) provides trends in landings (mt) and revenue (millions of dollars) over time for the major West Coast fisheries. Over the 2015- 2019 period, coastwide landings of all species, including at-sea from processing, have increased by more than a third, primarily due to Pacific whiting catches  (Harvey*, et al.* 2020b). However, because of low catch and revenue in 2015, the recent five-year period is unrepresentative. Over 20 years landings show substantial variability, with 2019 landings below the mean value for the period (Figure 3-9). Inflation-adjusted (to 2020) ex-vessel revenue increased to a peak in 2013, and after a large decline in 2015, has been fairly stable. These broad trends mask considerable variation across species groups; while CPS landings fell by almost 90 percent and salmon by close to half during this period, crab landings increased by almost 70 percent and groundfish by over 40 percent.


**Figure 3-9. West Coast at-sea and shoreside landings and inflation-adjusted ex-vessel revenue, 2000-2019. Solid lines - one standard deviation above and below the mean (dotted line).**

From the perspective of fishery participants, the degree to which they participate in different fisheries across time and space may be more socially, economically, and ecologically important than the broad landings trends outlined above. A fishing business that participates in more than one fishery increases revenue diversification, which can result in a more stable income stream and reduce financial risk for that business. The ESR includes a metric of revenue diversification for vessels making landings on the West Coast, based on the work of Holland and Kaperski (2016). Revenue diversification for West Coast vessels has generally declined over the time period examined (1981-2018), with a slight increase in the early 1990s and a significant decline thereafter. Fishery management interventions in the form of license limitation and catch shares are likely major contributors to fishery specialization, perhaps reflecting a broader trend of capital intensification that includes vessel and equipment costs. A slight increase in revenue diversification into the early 1990s may reflect unconstrained growth in participation across fisheries that prompted these management interventions.

The interconnectedness of fisheries can also be evaluated through network analyses. Fuller, *et al*. (2017) conducted one such analysis, using West Coast landings data to define fisheries through a métier analysis which clusters trips (individual landings) based on gear used and species composition of landings. They evaluated fishery participation networks at a regional level using port groups defined in the Pacific Fisheries Information Network (PacFIN) data set. They demonstrated significant diversity in network structure across these regions, evaluated the relative importance of different fisheries with these networks, and measured the resilience of the network, which can be related to social vulnerability. Using this methodology, fishery cross participation was reported for the first time in the 2021 ESR (see section 6.4). Figure 3-10 reproduces Figure 2 in Fuller, *et al*. (2017) presenting a coastwide representation of fishery connectivity and diversity across port regions. The analysis generally confirms the observation made above about the importance of the Dungeness crab pot, albacore tuna troll, and salmon (Chinook) troll fisheries with respect to cross participation. Frawley, *et al*. (2021) also used network analysis focusing on the albacore troll fishery, supplemented by informant interviews, to incorporate fishery participant perceptions. They also used a métier analysis methodology to characterize fisheries based on gear and landings composition. Results in terms of network structure are similar, but they evaluated changes over time rather than space. Generally, the importance of Dungeness crab pot and albacore troll fisheries (measured by node size and edge weight) has increased over time.

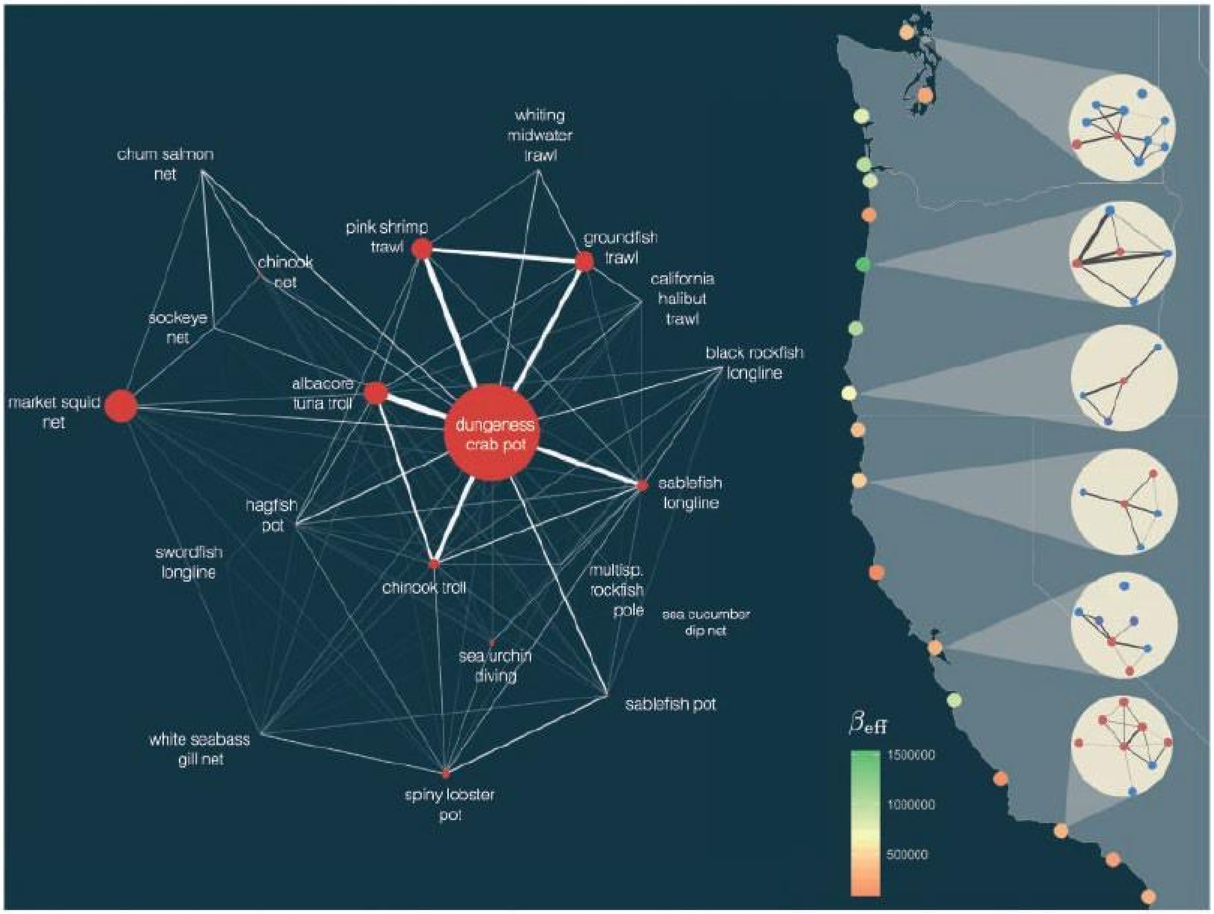


**Figure 3-10. Summary of fisheries connectivity on the US west coast. The large network on the left is the fisheries connectivity network for the whole US CCE. In scaling down, fisheries connectivity networks can be derived for each port or port-group. (Source: Fuller, *et al.*, 2017)**

Fisheries seasonality is another important factor driving participation. Seasonal variation in landings is primarily a function of species availability, but may be reinforced by regulations restricting when species may be targeted. Such restrictions may be motivated by either economic (e.g., product quality) or ecological considerations (e.g., protected species interactions). Figure 3-11 shows West Coast commercial fisheries landings and inflation-adjusted ex-vessel revenue by FMP in each month of the year, aggregated over 1999-2019 while Figure 3-12 shows a more detailed view at the species level. Clear patterns emerge showing when highest landings by weight occur in which fisheries, and when the most lucrative fisheries occur during the year. (As discussed above, Dungeness crab accounts for a large proportion of ex-vessel revenue but is not federally managed, as reflected in the high values for "None" in Figure 3-11) The highest commercial landings by volume occur during the summer months, when Pacific whiting are available in the EEZ, and are targeted by vessels catching and processing at sea, or bringing their catch to shoreside processors.

Participants may follow an annual cycle, based on different species becoming available for harvest at different times of year. Both the Dungeness crab pot fishery and albacore troll fishery are very seasonal, and complementary in their seasonality, likely contributing to the high level of cross-participation in these fisheries. The Dungeness crab fishery is typically open during the winter months (late-December onward) when crab meat quality is at its best, while albacore landings mainly occur July through October. In contrast, shoreside landings of groundfish tend to be fairly steady throughout the year, but with higher landings levels in the summer months. Looking at other fisheries, squid landings are higher in winter months, peaking in November, while sardine landings are concentrated between July and September. Depending on the stock, salmon migration occurs at different times of year but in aggregate the fishery has a distinct seasonal pattern with catches picking up in May and peaking August to October.

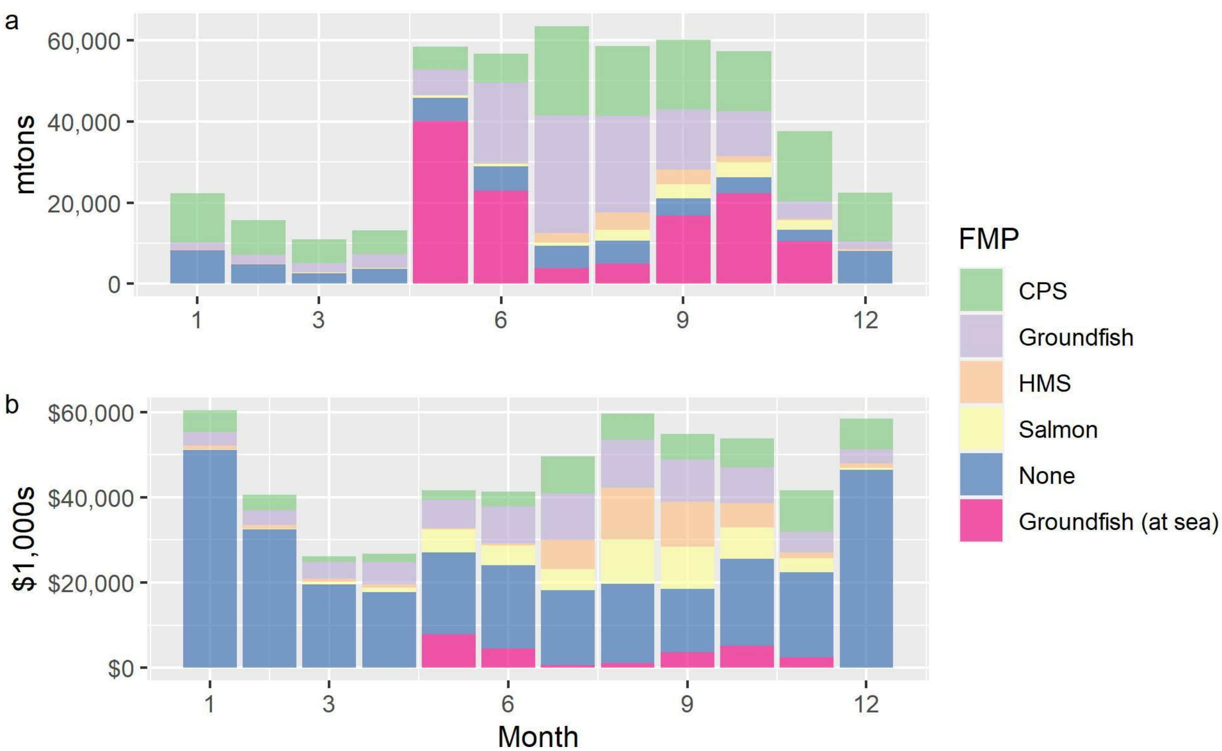


**Figure 3-11. Average monthly landings and inflation-adjusted ex-vessel revenue ($1,000s) by FMP, 2000-2019.**

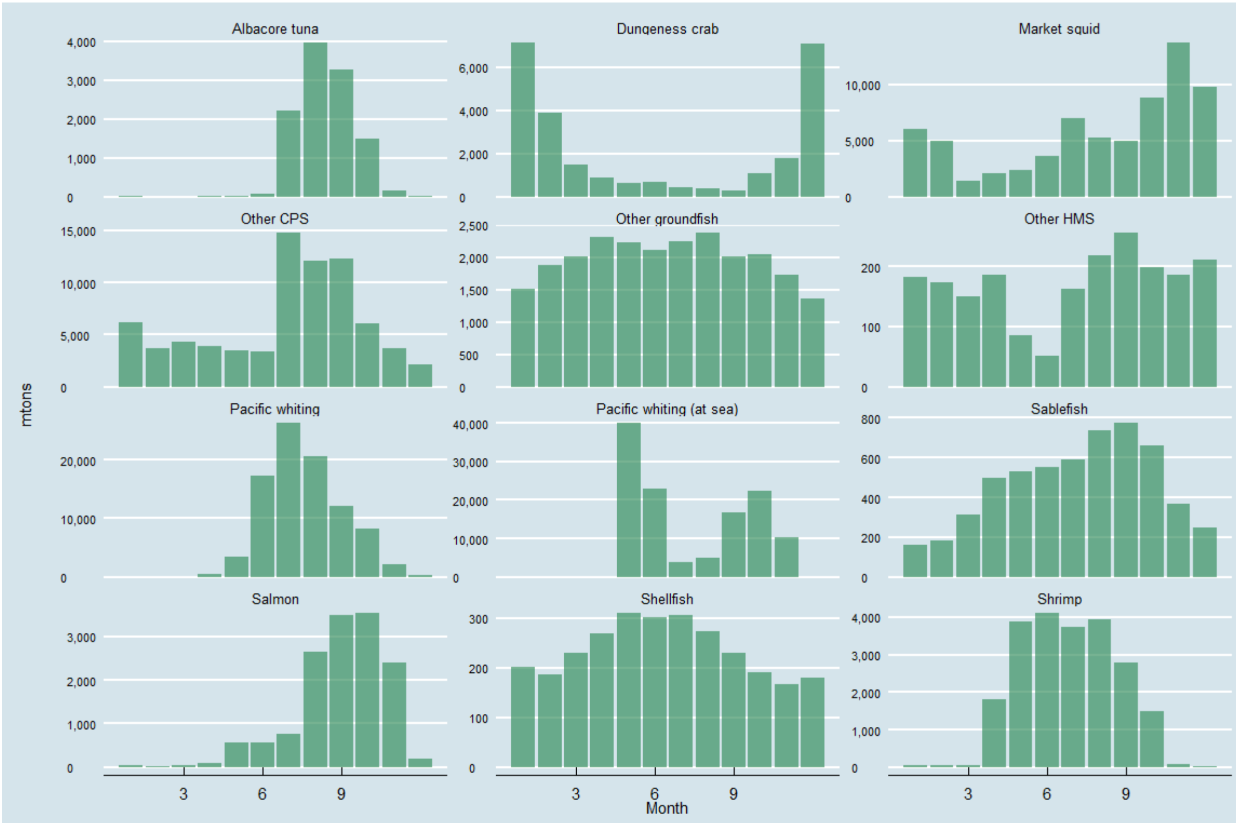


**Figure 3-12. Average landings volume by month for selected species, 2000-2019.**

### 3.4.2.2 Recreational Fisheries

West Coast recreational fisheries focus strongly on a few particularly popular species. Of the Council-managed species, Chinook and coho salmon are consistently popular recreational targets, although recreational fishing for coho is prohibited in California. Other favorite recreational targets are tunas, nearshore rockfish species, Pacific halibut, and Pacific mackerel. Many popular recreational targets are state-managed species, particularly those taken in fisheries off California. All finfish species are overwhelmingly taken using hook-and-line gear, although some fish are caught by spear divers and other gear like crab pots.

**Washington and Oregon – the Northern CCE**

Primary target species for saltwater anglers in this region include salmon, lingcod, albacore, Pacific halibut, and nearshore rockfishes (primarily black, *Sebastes melanops,* blue, *S. mystinus*, and Deacon, *S. diaconus*), all of which are managed under Council FMPs. In this region, recreational fishing for Council-managed species is primarily boat-based, occurring aboard private and charter vessels in ocean waters. While recreational fishing is important to coastal residents, anglers from more populated inland areas tow boats to the coast to fish for marine species and people from all over come to the coast to fish on charter/party (commercial passenger fishing vessel or CPFV) boats. In both states, access to the ocean is limited to relatively few ports. Although not Council-managed, shellfish such as Dungeness crab and razor clams also provide popular and valuable recreational harvest opportunities in the northern CCE. In terms of Council managed species, Chinook and coho salmon see major recreational effort in estuaries and rivers.

In Washington, most all anglers access Council-managed waters from just four ports: Ilwaco, Westport, La Push, and Neah Bay. Washington Department of Fish and Wildlife's (WDFW's) Ocean Sampling Program tracks and estimates recreational catch and effort from these ports. The limited access points makes it possible for the Ocean Sampling Program to do direct counts of boats instead of needing to estimate effort using a phone survey. Catch and effort are tracked by two segments of the fishery: charter boats that bring members of the public out on the ocean for a fee and then those that fish from privately owned vessels (the "private boat" sector). Salmon and Pacific halibut have historically been the most popular targets. Salmon remain the most popular target in terms of trips taken ("angler trips"). Halibut has traditionally only been open for a limited number of days each year, and primarily in May, because of the limited quota available. With more harvest opportunity available, albacore tuna has represented the largest recreational catch by volume and black rockfish by numbers of fish. Black rockfish and other groundfish (a.k.a. "bottomfish") like lingcod and yellowtail rockfish (*Sebastes flavidus*) have provided the most consistent harvest opportunities for anglers, with longer seasons and relatively consistent harvest opportunity each year. Fishing in the ocean occurs March-October. Angler trips show a strong spike in July and August as weather and ocean conditions improve, the salmon season opens in June, and albacore's migration brings them within reach of Washington's ports. Data on Washington catch and effort is publicly available via RecFIN (https://reports.psmfc.org/). Catch and effort from the Council's management area can be found by selecting "OCEAN" as the "Water Area" in RecFIN's reports. In Washington, a 2017 survey estimated that angler trips in marine waters, including Puget Sound, contributed $262 million in gross domestic product to the state's economy (Lovell*, et al.* 2020). A study done for Washington's marine spatial plan based on 2014 data and focusing just on angler trips on the coast found that anglers expended $30.4 million in coastal communities and another $10.4 million elsewhere in the state (WDOE*, et al.* 2017). With the ports of Neah Bay and La Push located on the reservations of the Makah Tribe and Quileute Tribe, respectively, the economic activity created by recreational fishing for Council-managed species brings benefits to these tribal communities as well.

Each year sport recreational fishing in Oregon's marine waters contributes approximately $50-$70 million annually to the natural-resource-based economy of Oregon coastal communities (The Research Group 2015). Anglers make approximately 150,000 saltwater fishing trips annually in Oregon targeting groundfish, Pacific halibut, salmon (primarily Chinook and coho), and albacore.

The primary target of Oregon recreational anglers in most years is groundfish including rockfishes, lingcod, greenling, cabezon, and other bottom dwelling species (See Oregon Sport Bottomfish Season webpage for more information). Black rockfish are the backbone of the Oregon recreational groundfish fishery, making up approximately 75 percent of Oregon's annual recreational groundfish landings. Recreational fishing trips targeting groundfish are an important component of Oregon's charter-boat fleet offerings, because it provides consistent, year-round opportunity for charter-boat customers. The offshore longleader fishery supplements the traditional recreational groundfish fishery, which operates inside the 40 fathom regulatory line using traditional hook-and-line gear, is. The offshore longleader fishery is open year round to target midwater rockfishes, outside of the 40 fathom regulatory line using a modified hook-and-line longleader gear in order to avoid restricted bottom dwelling species such as yelloweye rockfish.

When salmon fishing is good, it is the biggest fishing draw on the Oregon coast. Seasons usually run between late-June and September. In recent years, coho seasons have taken a two-tiered approach with both a selective (hatchery fin-clipped only) season early in the summer and a non-selective (both hatchery and wild) season in September.

Starting in the mid-1990s, Pacific halibut has become a prized target of recreational anglers, becoming especially popular with private boat anglers since 2004. Seasons are set in most of Oregon with a nearshore (shoreward of the 40 fathom regulatory line) component and an all-depth component (see Oregon Sport Halibut webpage for additional information). The more popular all-depth seasons are open limited days per week to spread opportunities from May through September or October and to limit bycatch of yelloweye rockfish. Most years there are approximately 18,000 trips targeting Pacific halibut, with some halibut also caught on trips targeting salmon, groundfish, and even tuna, as regulations allow.

Each year the number of anglers pursuing albacore tuna off the Oregon coast grows (see Oregon Recreational Albacore Information). Access to albacore for recreational vessels off Oregon can be highly variable, depending on weather conditions and distance offshore to the fish. Temperatures in 2019 were notably different, with a large and dense bulk of warm water approaching the coast through June and July, and "coming ashore" in mid-July. The weather was generally good throughout August and September, and the fish stayed close to shore the entire season, allowing for record-breaking 2019 recreational harvest in Oregon.

Non-finfish species targeted by recreational anglers include Dungeness crab and razor clams. Dungeness crab receives the most effort from sport shellfishers. Crabbing in Oregon is a year-round activity and like the commercial Dungeness crab fishery, the sport fishery is managed by the state. Razor clams are another popular recreational shellfish fishery in Oregon. Razor clams are found throughout Oregon's ocean beaches. Periodically, razor clams and Dungeness crab become contaminated with biological toxins produced by naturally occurring algal blooms. If levels become high enough, these pose a health risk and harvest closures can occur. Closure can last months or years depending upon the levels. The two main bio-toxins are Domoic Acid and Paralytic Shellfish Toxin.

**California -- the Central and Southern CCE**

While fishing in marine waters off northern California targets some of the same species as fisheries off Oregon and Washington, there is a more diverse array of species available to marine recreational fisheries off the full length of California's coast. Recreational fishing in ocean waters includes boat-based modes (occurring aboard private and charter vessels) in addition to a significant shore-based component. Beyond Council-managed finfish, Californians also participate in valuable recreational fisheries of state-managed species, such as California halibut and several basses (*Paralabrax*), surfperches (family *Embiotocidae*), Dungeness crab, and California spiny lobster (*Panulirus interruptus*) , see California Department of Fish and Wildlife's (CDFW) Marine Species Portal.

Primary targets along the central California coast include Chinook salmon, lingcod, albacore, nearshore and shelf rockfishes, Pacific sanddabs (*Citharichthys sordidus*), and California halibut. South of Point Conception, targets include Pacific bluefin tuna, yellowfin tuna, California scorpionfish (*Scorpaena guttata*), rockfishes, Pacific mackerel (*Scomber japonicas*), Pacific bonito, California halibut, the basses (*Paralabrax)*, yellowtail (*Seriola lalandi*), and Pacific barracuda (*Sphyraena argentea*).

Recreational ocean fishing occurs year-round in Southern California, where ocean and weather conditions are less extreme than in more northern waters, permitting anglers greater access to the resource in winter months. Calmer weather and a large human population combine to make Southern California Bight fisheries the largest component of angler effort and catch in the CCE. Fishery regulations are often the constraining factor that determines when and where most recreational fishing occurs, and regulations have become increasingly restrictive over the last thirty years. Peak fishing months are May through September.

Bottomfish – which include rockfish, ocean whitefish (*Caulolatilus princeps*), lingcod, basses (kelp bass, and barred sand bass (*Paralabrax nebulifer*)), and California scorpionfish – are a very popular target of saltwater sportfishing in California (California Department of Fish and Wildlife 2020 and prior). These species consistently make up a majority of California's boat-based sportfish landings in numbers of fish kept – see Figure 3-13 and Figure 3-14. Bottom Fishing is an important component to California's CPFV fleet because it provides consistent, year-round opportunity. Other popular recreational fishery targets are inshore fish, which include California halibut, spotted sand bass (*Paralabrax maculatofasciatus*), surfperch, croakers, leopard shark (*Triakis semifasciata*), jacksmelt (*Atherinopsis californiensis*), and Pacific herring (CDFW 2020 and prior). Much of the recreational fishing for these species occurs in the state's bays and harbors, although California halibut are also targeted in shallow waters along the open coast.

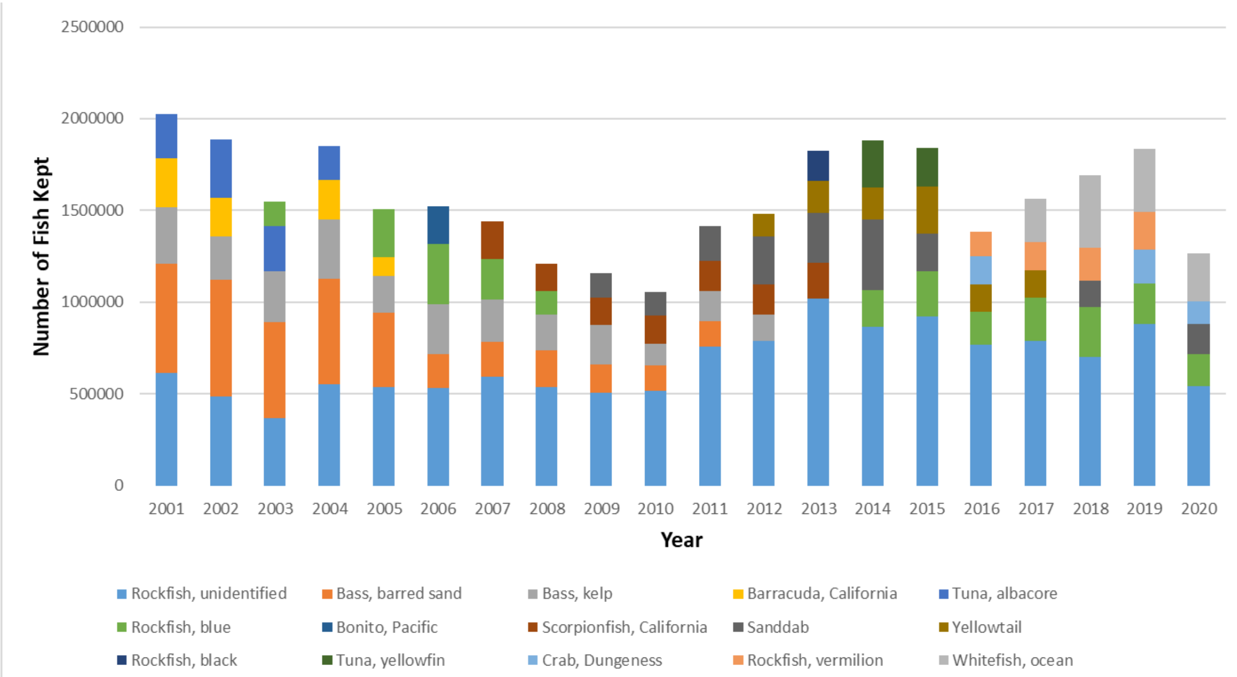


**Figure 3-13.Top five species kept by commercial passenger fishing vessels in California, 2001-2020.**

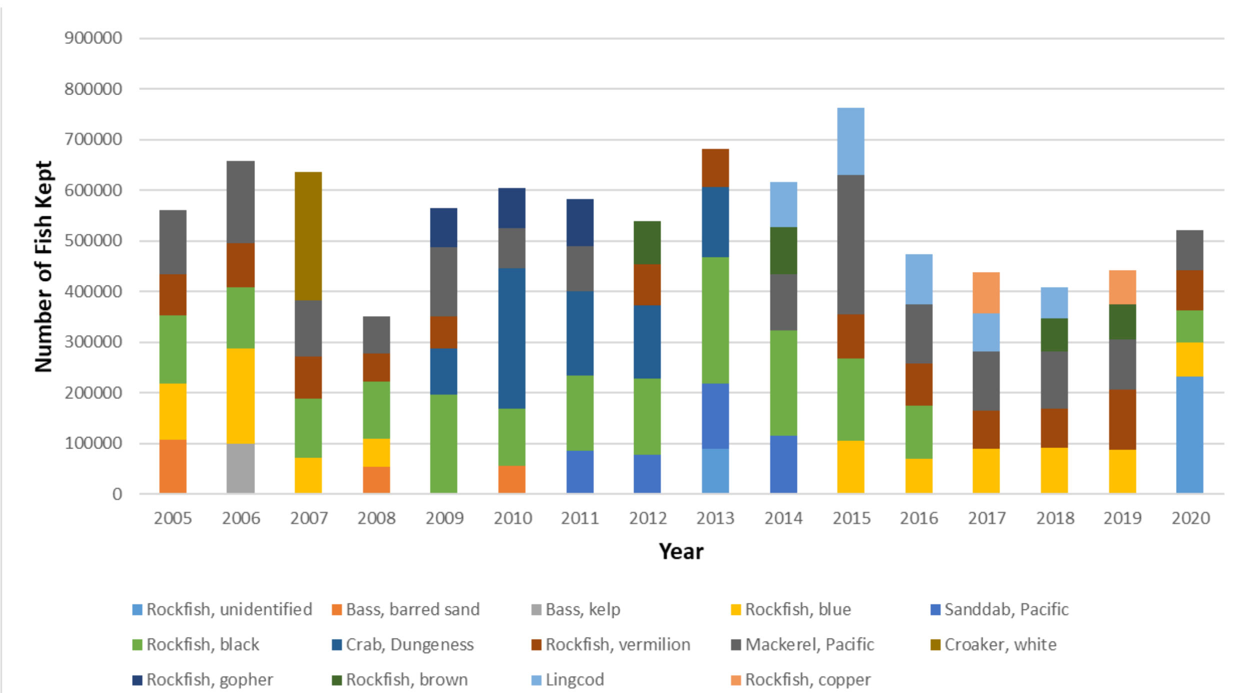


**Figure 3-14. Estimated top five species kept by private/rental boats in California, 2005-2020.**

Coastal migratory species include yellowtail, Pacific barracuda, Pacific bonito, and Pacific mackerel (California Department of Fish and Wildlife 2020 and prior). Although Pacific mackerel are one of the most frequently caught recreational fish, they have long been cast in the role of a nuisance fish by most recreational anglers, while the other species are popular targets of recreational fisheries based primarily in Southern California. The recreational fishery for ocean salmon in California is primarily for Chinook salmon (California Department of Fish and Wildlife 2020 and prior). Take or possession of coho salmon is prohibited in California. Primarily fished north of San Luis Obispo County, this popular fishery has seen its recreational fishing seasons curtailed in recent years due to poor stock forecasts.

HMS include yellowfin tuna, Pacific bluefin tuna, mahi-mahi, albacore tuna, skipjack tuna (*Katsuwonus pelamis*), thresher shark, and wahoo (*Acanthocybium solandri*) (California Department of Fish and Wildlife 2020 and prior). Historically, all of these species were encountered primarily by recreational fisheries in the southern half of the state. In recent years however, the albacore stock has shifted north, making them rare off California and most abundant off Oregon and Washington. Recreational catch of Pacific bluefin tuna in ocean waters off California, conversely, has increased in recent years, with recreational catches reported as far north as Washington.

Patterns in what species are targeted throughout the year are mostly dependent on regulations; however, there are a few fisheries where it is dependent on the species availability in a particular area (e.g., tuna, California halibut). During El Niño and marine heatwave years, ocean whitefish became dominant in the groundfish fishery. Recruitment of California halibut in San Francisco Bay and Humboldt Bay has been substantial and is still supporting this now very popular fishery, with the average size of fish continuing to increase with each passing year (M. Brown pers. com).

There is slightly more CPFV fishing effort than private/rental boat fishing effort in California, but it varies per fishery. For example, tuna catch is dominated by CPFVs, but California halibut catch is dominated by recreational fishing from private/rental boats (M. Brown pers. com). Noteworthy recreational fishing developments in California in recent years include the development of the California halibut fishery in San Francisco Bay and Humboldt Bay, and the continued Pacific bluefin tuna abundance in waters off California, which historically is a cyclic trend with a few years on and a few years off. Also, a new deep-drop recreational fishery for swordfish is gaining traction in the Southern California Bight (M. Brown pers. com).

#### 3.4.2.3 Tribal Fisheries

The marine ecosystems of the CCE support a wide variety of plant and animal species that tribes have depended on, and been stewards of, since time immemorial for food, medicine, tools, culture, ceremony, and commercial endeavors. Tribal fishers do not differentiate between recreational and commercial fisheries; instead, fisheries are a keystone of their cultural and spiritual identities. Shellfish (both mollusks and crustaceans) and various species of marine fishes are important for cultural purposes, social interactions, and health. Many types of nearshore species such as shorebirds, dune grasses, seaweed, and kelp are used for food and cultural activities. Marine mammals such as otters, seals, and whales have great cultural importance and have been traditionally harvested. As discussed in Section 3.5.4, many West Coast tribes entered treaties with the Federal government, ceding much of their land in exchange for the continued rights to gather, hunt, and fish in their usual and accustomed (U&A) fishing areas. These treaties have been upheld by the U.S. Supreme Court, and many West Coast tribes are now co-managers of the marine resources of the CCE.

#### 3.4.2.4 First Receivers and Processors

West Coast fish processors and receivers process fish and shellfish in a wide variety of forms for sale in domestic and international markets. Most Council-managed species are processed on land, although some species, such as Pacific whiting, may be processed at sea. Depending on the species and market preferences, fish may be sold live or processed into fresh, frozen, blast-frozen, canned or smoked forms, or converted to fish meal, oil, or surimi. Dungeness crab product, as an example, is sold live, or as fresh or frozen whole cooked crabs, as well as picked meat, legs, and sections. Fish landed or otherwise caught in West Coast tribal fisheries for commercial sale are routed through similar processing chains to those used by the non-tribal fisheries. Tribal fisheries also land fish for personal and cultural uses, which are usually processed locally into fresh, frozen, smoked or canned products and are typically banned by tribal regulation from entering commercial markets.

Delivery, purchase, and sale of fish are regulated primarily under state law, or when conducted on tribal lands, under tribal law. Federal rules can apply to certain activities as well. For example, those wishing to purchase fish harvested in the groundfish individual fishing quota program must be issued a first receiver site license from NMFS. The first landing of fish from a vessel into a port or other place of delivery is the core activity regulated and monitored by the states and tribes. Each state and tribal government requires deliveries to be recorded on a marine fish receiving ticket, or "fish ticket," that records species landed, the amount landed in weight or numbers of fish, and the price paid for each species or market category. The fish tickets provide an official record of landings on the coast and can be used for other purposes such as the assessment of general and special taxes and fees on fish landings.

Rules on the specific items that must be reported and the timing and method of that reporting can differ by state and by fishery, but also show similarities. Contrasting Oregon and California, Oregon requires fish tickets to be forwarded to Oregon Department of Fish and Wildlife (ODFW) in paper form or submitted electronically through the Pacific States Marine Fisheries Commission West Coast E-Ticket system within fishery specific timeframes. Electronic landings reporting became mandatory in California on July 1st, 2019.

The fisheries under Council management are an important source of economic activity in the West Coast seafood processing industry. However, the West Coast seafood industry as a whole also depends on harvest from shellfish operations and other fisheries not managed by the Council. For example, according to PacFIN data, shellfish accounted for 23 percent of total inflation adjusted landings revenue during the period 2015-2019. Dungeness crab fisheries, which are managed by the three states and several tribes individually, provide the most valuable source of landings in most years and 30 percent of inflation adjusted ex-vessel revenue 2015-2019. Descriptive statistics on the seafood processing industry may be found in the Fisheries Economics of the U.S. series.

Processors of fish and fishery products are required by the U.S. Food and Drug Administration to develop Hazard Analysis Critical Control Point plans to help identify potential hazards and develop control strategies and practices. Also for food safety purposes, state agencies like the Oregon Department of Agriculture require permits for: shellfish distributors, shippers, and wholesalers; shuckers and packers; shellfish growers; and commercial harvesters from shellfish growing areas.

Seafood products are marketed in many ways, ranging from traditional methods such as local fishermen selling off their boat directly to consumers, to web-based marketing and sophisticated product coding that links an individual fish product to its harvester. (For example, Pacific Fish Trax is an online information sharing system focused on West Coast fisheries. Its website provides viewers with tools to track seafood products, link customers and fishermen, and improve science, marketing, and management.)

Table 3-4 shows price per pound for the top 25 species ranked by total ex-vessel revenue in 2019 (out of a total of 252 species). Only five species in this list rank in the top 25 in terms of average price per pound. Many of the most valuable species on a price per pound basis are landed in relatively small quantities and include a variety of rockfishes, likely destined for live fish markets.

**Table 3-4. Top 25 species ranked by total ex-vessel revenue, 2019, showing average price per pound. (Source: PacFIN comprehensive_ft, 12/23/2020).***

| Management Group | Species | Price Per Pound | Total Ex-vessel Revenue ($1,000s) | Rank – Total Revenue | Rank - Price Per Pound |
|---|---|---|---|---|---|
| Crab | Dungeness Crab | $3.67 | $204,822 | 1 | 44 |
| Groundfish | Pacific Whiting | $0.09 | $29,624 | 2 | 235 |
| Salmon | Chinook Salmon | $4.91 | $29,208 | 3 | 26 |
| Shrimp | Pacific Pink Shrimp | $0.73 | $28,337 | 4 | 160 |
| HMS | Albacore | $1.66 | $27,832 | 5 | 99 |
| Groundfish | Sablefish | $1.94 | $20,807 | 6 | 89 |
| CPS | Market Squid | $0.50 | $16,373 | 7 | 181 |
| Other | California Spiny Lobster | $13.76 | $11,334 | 8 | 1 |
| Shrimp | Spot Prawn | $11.96 | $10,094 | 9 | 2 |
| Other | Pacific Halibut | $4.99 | $7,387 | 10 | 24 |
| Other | Red Sea Urchin | $2.12 | $6,965 | 11 | 84 |
| Groundfish | Petrale Sole | $1.20 | $6,767 | 12 | 120 |
| Groundfish | Widow Rockfish | $0.26 | $5,399 | 13 | 214 |
| Groundfish | Dover Sole | $0.42 | $5,343 | 14 | 195 |
| HMS | Bigeye Tuna | $3.44 | $4,243 | 15 | 48 |
| Other | Nom. Calif Halibut | $5.49 | $3,933 | 16 | 18 |
| Other | Unsp. Sea Cucumbers | $4.87 | $2,945 | 17 | 27 |
| Crab | Rock Crab | $1.79 | $2,570 | 18 | 96 |
| Salmon | Coho Salmon | $2.15 | $2,563 | 19 | 83 |
| HMS | Swordfish | $3.95 | $2,530 | 20 | 42 |
| Other | Unsp. Hagfish | $1.16 | $2,374 | 21 | 123 |
| Groundfish | Yellowtail Rockfish | $0.31 | $2,221 | 22 | 209 |
| Salmon | Chum Salmon | $0.84 | $2,169 | 23 | 153 |
| Groundfish | Lingcod | $1.30 | $1,919 | 24 | 112 |
| Groundfish | Nom. Shortspine Thornyhead | $5.12 | $1,773 | 25 | 23 |

*Average price per pound was obtained from the PacFIN database by dividing total ex-vessel revenue by total landed round weight in pounds. Species subject to confidentiality rules (less than three vessels or processors) are excluded.

### *3.4.3 Fishing Communities*

The MSA places highest priority on conservation of fish stocks for the achievement of optimum yield (OY). However, the MSA's National Standard 8 requires conservation objectives to be achieved in a manner that provides for the sustained participation of fishing communities in fisheries and minimizes adverse impacts on fishing communities to the extent practicable (16 U.S.C. 1851). National Standard 8 also requires the Council to use the best available scientific information when weighing impacts to fishing communities and fishing participation. Under the MSA, a "fishing community" is a community that is "substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and U.S. fish processors that are based in such community" (16 U.S.C. §1802).

To characterize West Coast fishing communities, the Northwest Fisheries Science Center Human Dimensions Team published a Community Profiles document in 2007 describing the history, geography, demography, infrastructure, and fisheries for 120 West Coast fishing communities. Subsequently, NMFS social scientists developed a composite Community Social Vulnerability Indicator (CSVI) based on metrics of social vulnerability, gentrification, and fisheries engagement and dependence (Jepson and Colburn 2013). These metrics may be accessed through the NMFS Social Indicator Mapping Tool. In addition, the CSVI is plotted against a fishing reliance metric for selected West Coast fishing communities in section 6.1 of the annual ESR (e.g., Harvey*, et al.* 2020b).

There are many ways to think about and characterize human communities, and fisheries management usually has only a small influence on human well-being in any particular community, although fisheries management actions can have notable effects on the particular individuals, families, and businesses that participate in fisheries. Breslow (2017) conducted a review and analysis of indicators that might be used in the CCIEA to understand the effects of environmental change and fisheries management on human well-being. That analysis takes broad ideas around general human well-being, as understood by the Millennium Ecosystem Assessment (2005, MEA) and other international institutions, and focuses specifically on the connections humans have to the marine environment, fish stocks, and fisheries. The two attributes of human well-being that Breslow, *et al*. (2017) focus on as useful to understanding connections between human communities and marine ecosystems are access to resources and self-determination. The CSVI metrics provide details related to those attributes by looking more closely at the degree to which fishing communities may depend on fishery resources for their self-determination.

Holland (2020) surveyed over 1,400 West Coast commercial vessel owners for their motivations for and non-monetary rewards from fishing, providing a close look at the well-being of the individuals who participate in West Coast fisheries. Because many West Coast fishing communities may host only a small number of vessels, these impressions of individual access to resources and self-determination help us see West Coast fisheries participants as part of a geographically-dispersed community of practice, not just as people who may live in a narrow geographic area. Interestingly, Holland, *et al*. (2020) found that many commercial fisheries participants derive notable social benefits from fishing beyond the more obvious economic benefits, such as enjoyment of the outdoors, continuation of family traditions, and support of the local economy and community. Recreational fisheries have long been studied for their social and cultural benefits (e.g., Fedler and Ditton 1994), but analyses of the effects of commercial fisheries management on the human environment have traditionally focused on potential revenue gains and losses.

This section summarizes the variation in West Coast fishing community characteristics across the three CCE regions described in Section 3.1, drawing on PacFIN data along with selected demographic characteristics derived from CSVI analyses to broadly describe regional variations in fisheries and community characteristics. For the discussions below, these metrics are only reported for fishing communities in each region, not the entire population of the region.

Figure 3-15 through Figure 3-17 provide a coastwide comparison of: (a) landings, (b) ex-vessel revenue, and (c) vessel participation across the CCE regions by fishery. Most landings and related ex-vessel revenue occur in the Northern CCE, where groundfish dominate landings volume. In terms of ex-vessel revenue, crab (primarily Dungeness crab) is the major contributor in both the Northern and Central CCE. CPS, primarily market squid, often account for the biggest proportion of landings and revenue in the Southern CCE. State-managed species, principally spiny lobster, also account for a large share of ex-vessel revenue in this region. These figures illustrate the access fishing communities have to different species by geographic area, the fishing effort levels available in different communities, and the investments fishing businesses have made in those communities

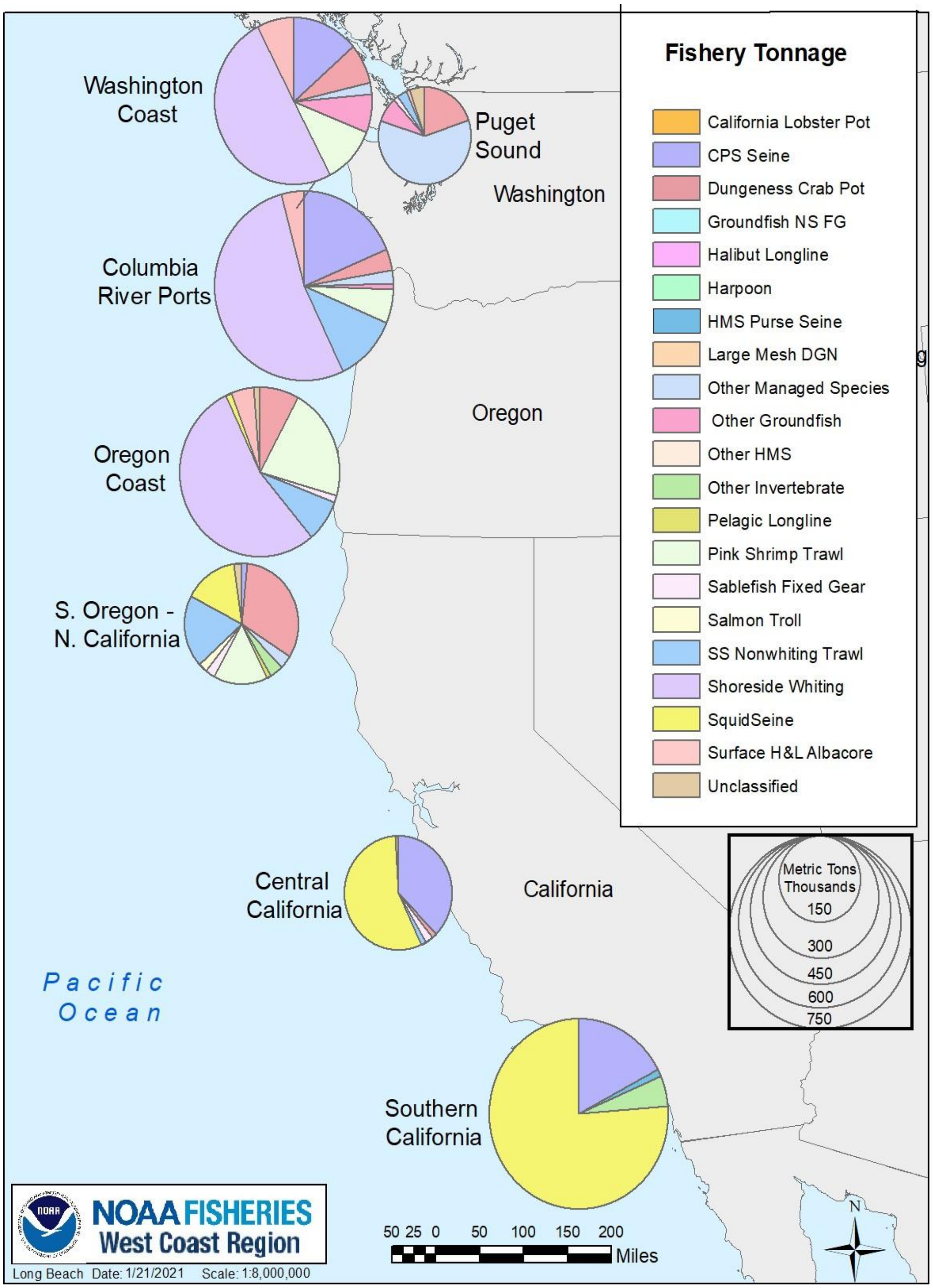


**Figure 3-15. Proportion of landings (mt) by fishery and West Coast regions, 2010-2019. (Source: PacFIN comprehensive_ft table.)**

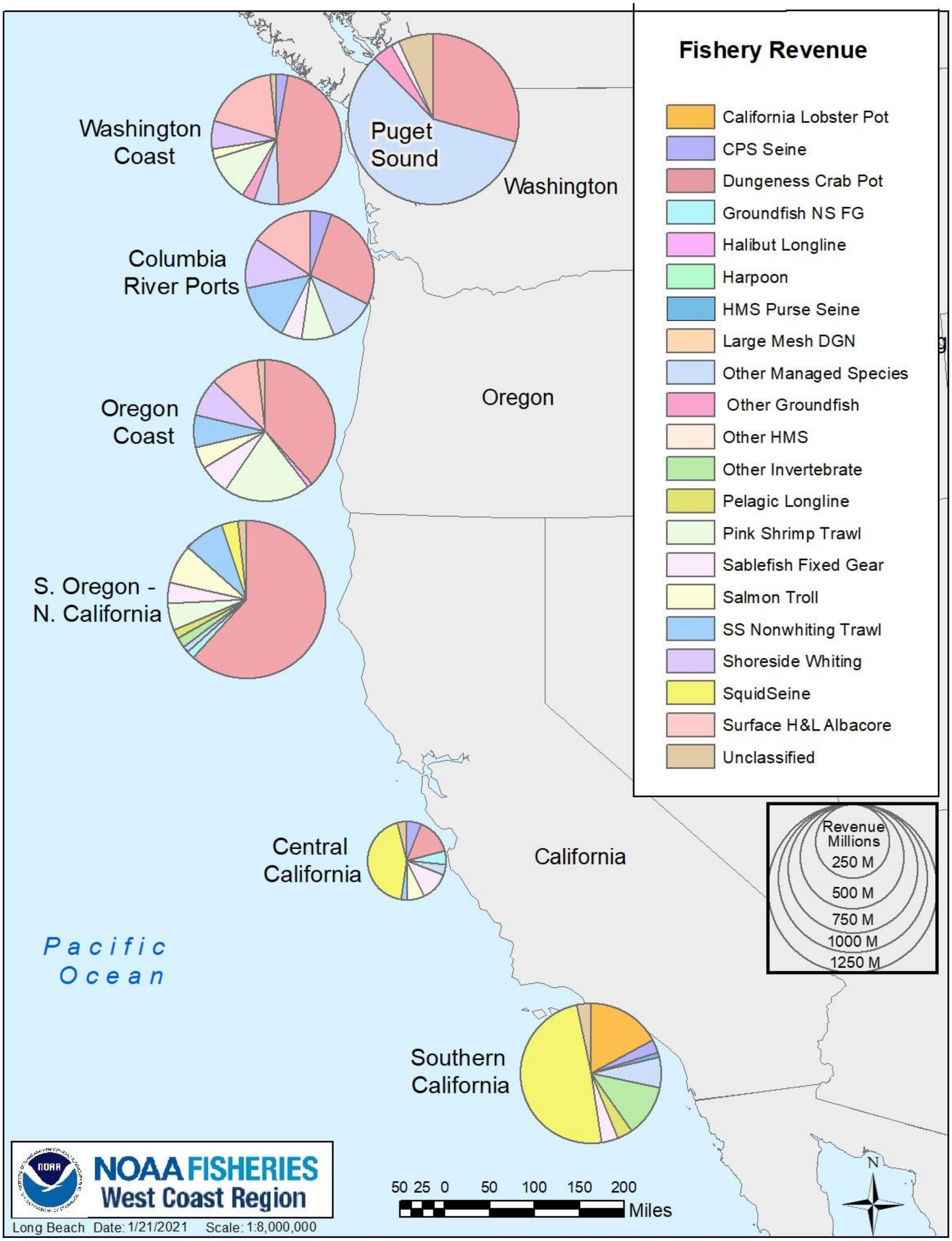


**Figure 3-16. Proportion of inflation-adjusted ex-vessel revenue by fishery and West Coast regions, 2010-2019. (Source: PacFIN comprehensive_ft table.)**

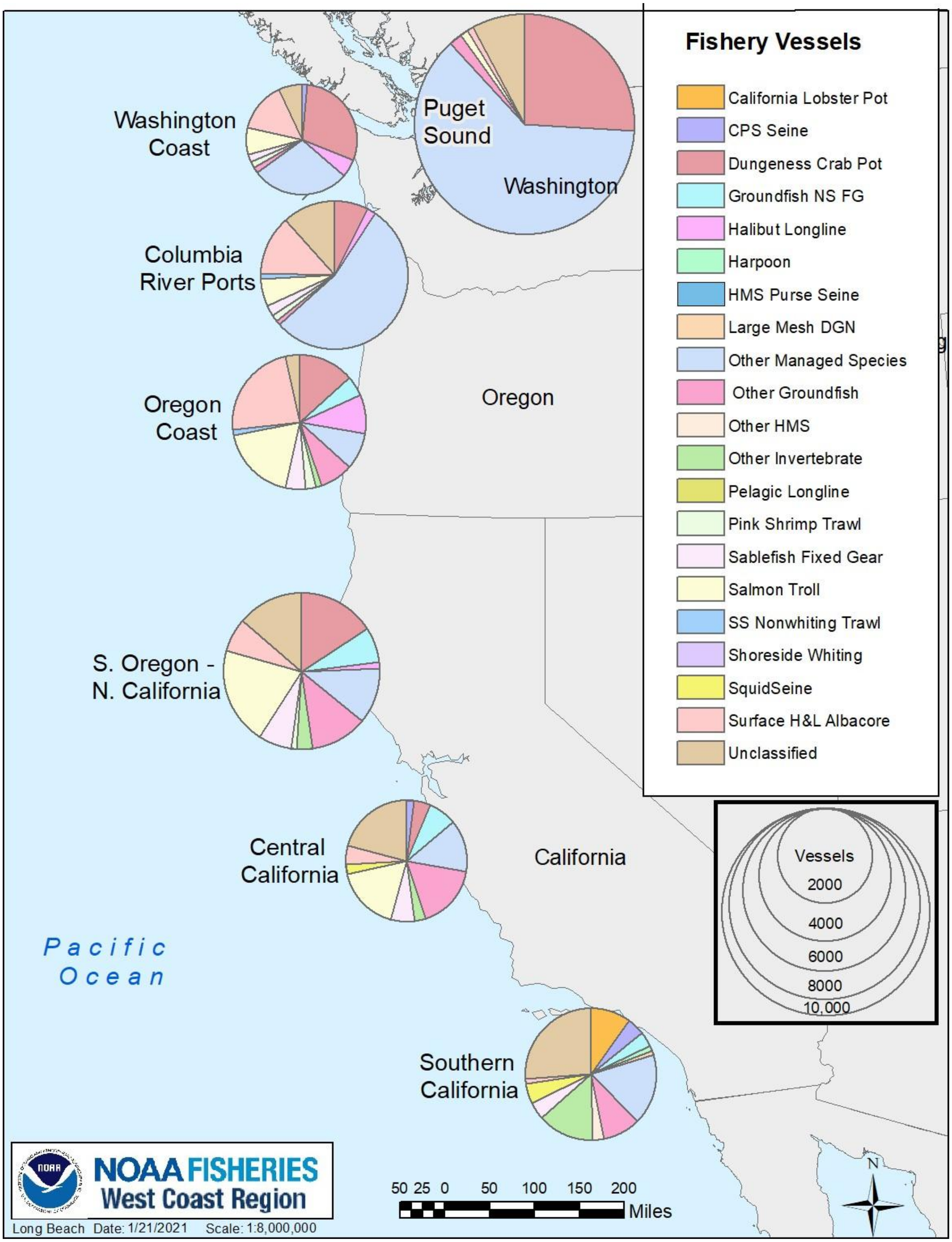


**Figure 3-17. Proportion of vessels making landings by fishery and region, 2010-2019. (Source: PacFIN comprehensive_ft table.)**

### 3.4.3.1 Fishery Characteristics

Fishing revenue associated with different CCE species and fisheries reflects the species that are geographically available to vessels operating in the northern, central, and southern subregions. Coastwide revenues of particular species may fluctuate from year to year, but those fluctuations are more noticeable in the ports and areas that rely most heavily on those species.

In the U.S. EEZ, the Northern CCE stretches from Cape Flattery in the north to a terminus at Cape Blanco in southern Oregon. This large region includes Puget Sound and the Strait of Juan de Fuca, the Washington Coast, the Columbia River area, and the Oregon Coast south of the Columbia River communities and extending to Cape Blanco. There are 74 places where landings have been made in the Northern CCE during the past decade according to the PacFIN database. The largest commercial fishery ports by landings value are Westport, Washington (16 percent of total ex-vessel revenue in the region); Newport, Oregon (14 percent); Astoria, Oregon (12 percent); and Coos Bay, Oregon (9 percent).

Figure 3-13 shows ex-vessel revenue by fishery in the Northern CCE. As noted previously, the Dungeness crab, albacore troll, and pink shrimp fisheries are important contributors, accounting for just over half of ex-vessel revenue in the region. The highest value landings occur in the Puget Sound region, which accounts for the largest share of revenue (35 percent) but has the smallest landings volume (9 percent). Columbia River ports (principally Ilwaco, Washington and Astoria-Warrenton, Oregon) exhibit the opposite pattern: the largest share of landings volume (35 percent) and smallest revenue share (20 percent). This is because Ilwaco, Washington and Astoria, Oregon are major ports of landing for Pacific whiting, a high volume, low value species.

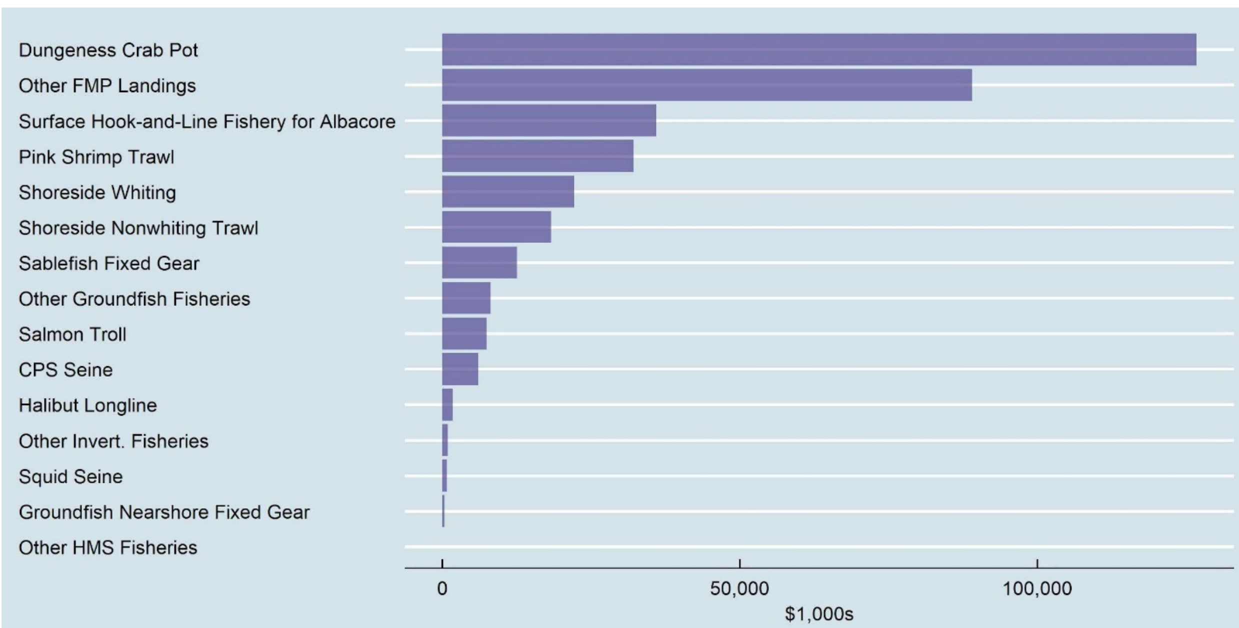


**Figure 3-18. Annual average inflation-adjusted ex-vessel revenue (2020 dollars) by fishery in the Northern CCE, 2010-2019.**

In the Central CCE, which extends from Cape Blanco in southern Oregon to Point Conception in California, there are 73 places where landings have been made during the past decade according to the PacFIN database. The largest commercial fishery ports by landings value are Crescent City (14 percent of total ex-vessel revenue in the region), San Francisco (13 percent), and Eureka (11 percent).

Figure 3-14 shows ex-vessel revenue by fishery in the Central CCE. Like the Northern CCE, the Dungeness crab fishery dominates in terms of ex-vessel revenue (52 percent of the region total) followed by the purse seine fishery for market squid (11 percent) and salmon troll fishery (8 percent). By value, ports between Cape Blanco and San Francisco dominate, accounting for 80 percent of ex-vessel revenue due primarily to the Dungeness crab fishery, while the market squid fishery is more important in the southern portion of the region.

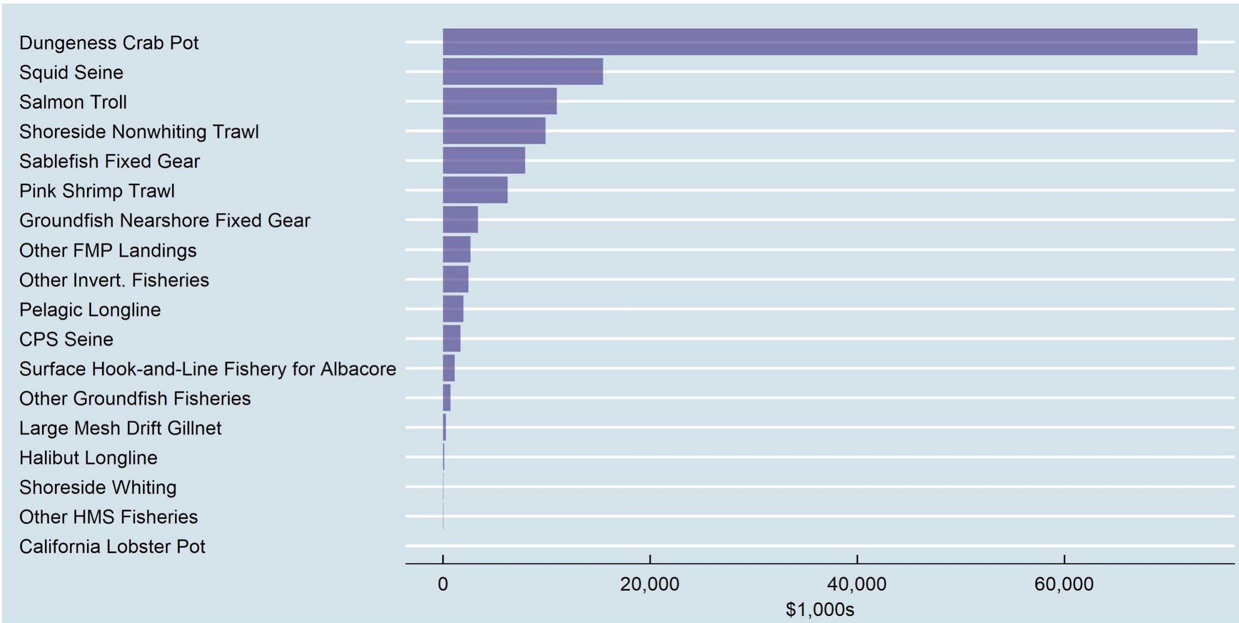


**Figure 3-19. Annual average inflation-adjusted ex-vessel revenue (2020 dollars) by fishery in the Central CCE, 2010-2019.**

The Southern CCE is coincident with the ecologically diverse Southern California Bight, where there are 48 places where landings have been made during the past decade according to the PacFIN database. The market squid purse seine fishery dominates in terms of ex-vessel revenue in this region (48 percent of the total for the region), followed by the pot fishery for California lobster (17 percent). The largest commercial fishery ports by landings value are Ventura (20 percent of the total), Terminal Island at the Port of Los Angeles/Long Beach (16 percent), and nearby San Pedro (15 percent).

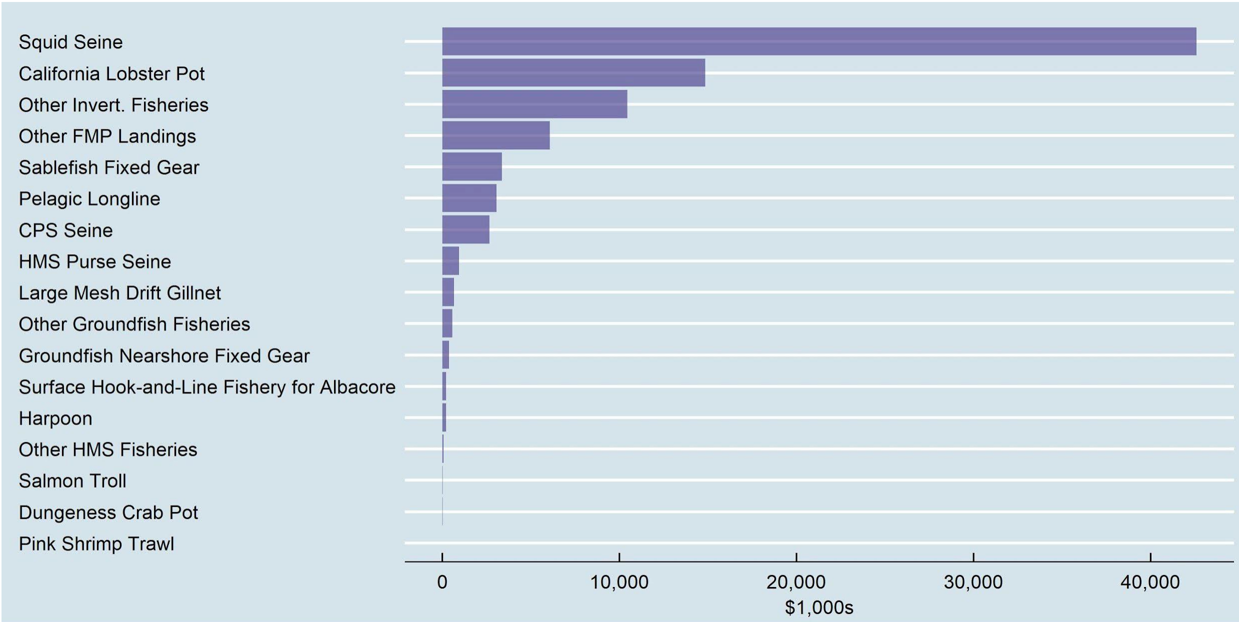


**Figure 3-20. Annual average inflation-adjusted ex-vessel revenue (2020 dollars) by fishery in the Southern CCE, 2010-2019.**

### 3.4.3.2 Fishing Reliance and Community Social Vulnerability

Assessing a community's social vulnerability asks how resilient that community is to major changes, which can include environmental shifts, economic changes, or cultural shifts. NMFS' CSVI relies on general social science principles around human and community well-being, but have been tuned to issues specific to coastal and fishing communities, asking questions about issues like dependence on fisheries income, vulnerability to sea level rise, and community gentrification (Jepson and Colburn 2013).

Figure 3-21 plots the CSVI against the fishing reliance metric for West Coast fishing communities in the Northern, Central, and Southern CCE regions. Each of the regions includes a variety of levels of social vulnerability (vertical axes); however, there are relatively few communities that are strongly reliant on fisheries income (horizontal axes). Fisheries should not be viewed as unimportant to these communities. Rather, fisheries are an integral part of West Coast communities, linked into diverse coastal economies that provide residents and visitors with a range of fisheries-associated ecosystem services, including recreational charter services and commercial fisheries processing, cuisine that ranges from fish-and-chips to fine dining, and recreational activities like beach-combing, bird watching, and boating.

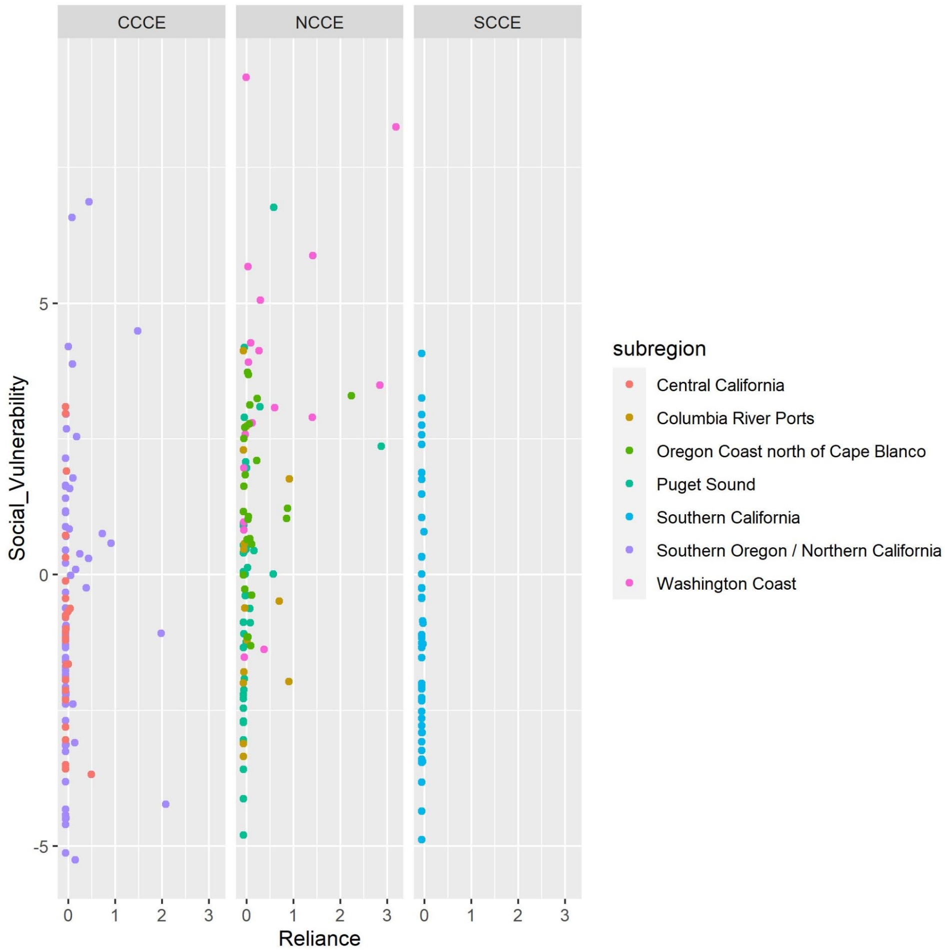


**Figure 3-21. Community Social Vulnerability Index (CSVI) plotted against the Fishing Reliance Index for West Coast fishing communities by region.**

The annual ESR identifies those communities with the greatest engagement in fisheries, and Figure O.1. from the 2021 ESR's supplemental materials is reproduced here as Figure 3-22. Unsurprisingly, higher fishing engagement is seen in some of the more remote coastal communities, particularly for Washington and Oregon, where dense urban areas are farther from the coast. California cities like San Francisco and San Diego, however, also have concentrated pockets of fisheries engagement that place those cities at relatively high levels of engagement for their regions.

Figure 3-23 plots data from the U.S. Census Bureau's American Community Survey to illustrate regional population, income, and poverty levels for fishing communities included in the CSVI. The major subregions along the U.S. West Coast are economically diverse; therefore, little information may be gleaned from these highly generalized data about the specific income and poverty levels of fishing communities. However, it can be seen from these plots that subregions with more, and larger, metropolitan areas exhibit higher median household income for the included communities. This includes the Puget Sound, Central California, and Southern California subregions. Subregions on the more isolated coasts of Washington and Oregon tend to exhibit a lower median household income for included communities. As discussed in Section 4.5, poverty in human communities is considered to be in opposition to well-being (MEA 2005); thus higher poverty levels in some regions can indicate lower general levels of human well-being in those regions.

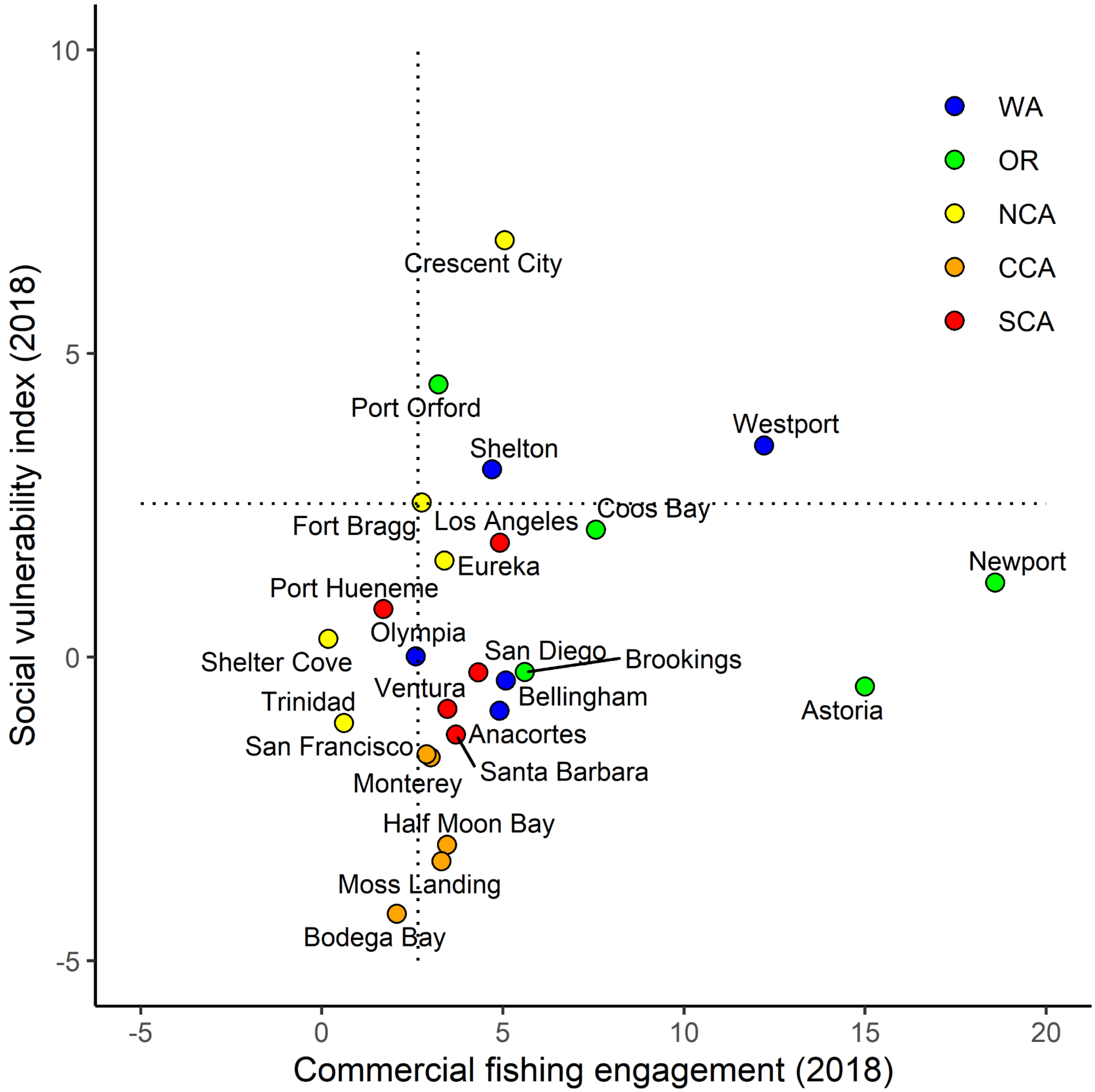


**Figure 3-22. Commercial fishing engagement and social vulnerability scores as of 2018, from five regions of the California Current. The top five highest scoring communities for fishing engagement were selected from each region. Black dotted lines denote one s.d. above the mean for communities with landings data. (Reproduced from Appendix O of the 2021 ESR.)**

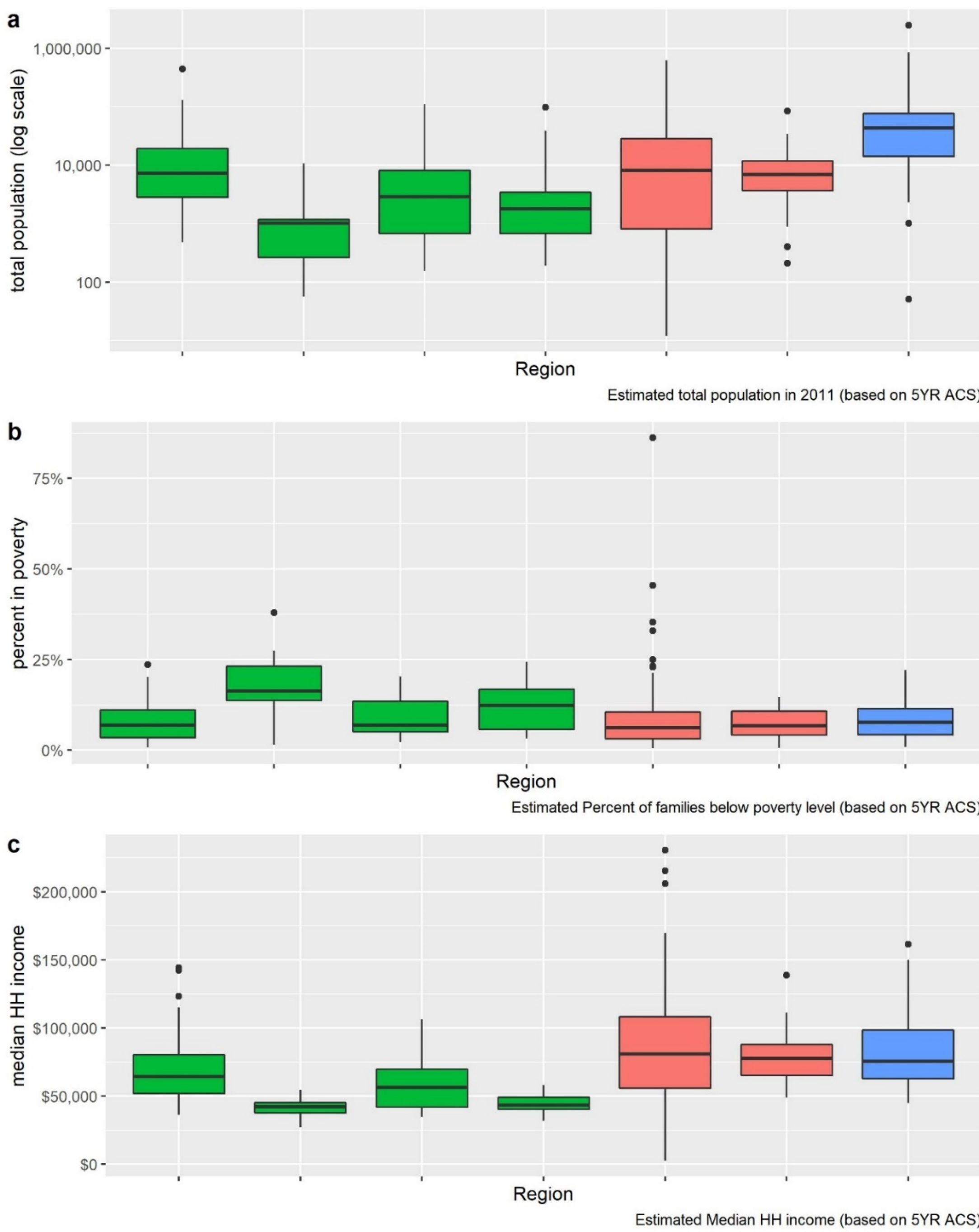


**Figure 3-23. Demographic characteristics for fishing communities in CCE subregions: a) total population, b) percent of families below the poverty line, c) median household income. Subregions from left to right are Puget Sound, Washington Coast, Columbia River Ports, Oregon Coast north of Cape Blanco, Southern Oregon/Northern California, Central California, Southern California. Fill colors indicate CCE regions: Northern CCE, green; Central CCE, red; Southern CCE, blue. Boxplots summarize the distribution of values. The box encloses the range from the 25th to 75th quartiles with the thick horizontal line indicating the median. The whiskers above and below the box represent an extension of the inter-quartile range with any values outside that represented by points. (Data from U.S. Census American Community Survey 5-year estimates. Population, 2011 ACS; other demographic metrics, 2018 ACS.)**

### 3.5 Fisheries and Natural Resource Management in the CCE

Many CCE fisheries are under the Council's jurisdiction, but the Council also shares jurisdiction over or management responsibilities for the species it manages with other entities or institutions. While the states and tribes participate in the Council process, they also have separate management processes linked to and informing the Council's work. Beyond the EEZ, management processes for several Council species include multi-national processes with their own priorities and institutions. Figure 3-24 provides a general overview of the state/tribal/Federal management process: the states, tribal, and Federal government together organize and implement fisheries monitoring, data gathering, and research programs; scientific information is reviewed through the Council's SSC; management measures and programs are developed through the Council's advisory bodies and associated public processes; scientific analyses are again reviewed through the SSC for their utility within the management process; the Council uses the SSC recommendations and advice from its advisory bodies and the public to recommend harvest levels and other management measures; Council recommendations are then reviewed and partially or wholly implemented through Federal, and then tribal and state, regulatory processes.

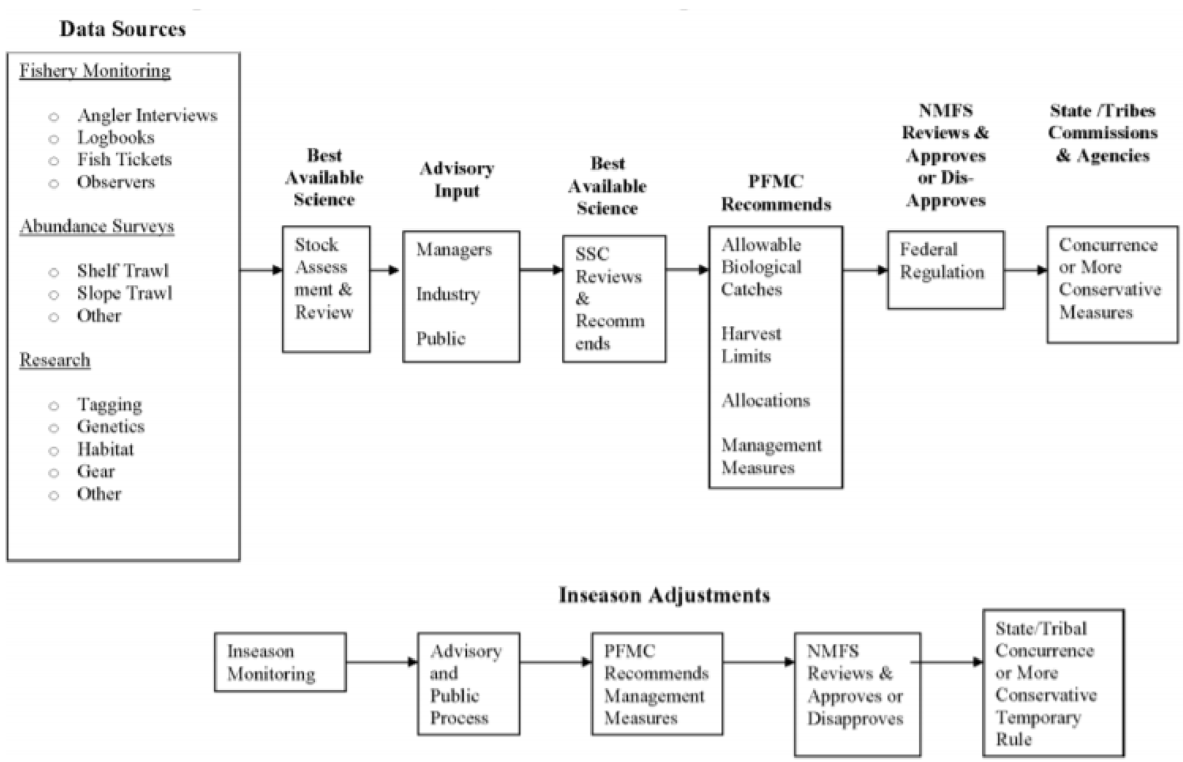


**Figure 3-24. State/Tribal/Federal management process overview.**

#### 3.5.1 Council Fisheries Management

Fishery management councils were first authorized by the Fishery Conservation and Management Act of 1976 (Pub. L. No. 94-265). That Act also established an ocean fishery conservation zone (later, the EEZ) beyond state marine waters out to 200 nautical miles offshore of U.S. coastlines, and gave fishery management councils areas of authority within the zone. The first 20 years of council management was a period of development and maturation of management frameworks, particularly including efforts to "Americanize" the fisheries occurring within the EEZ. During this period, the Pacific Council adopted fishery management plans for salmon (1978), groundfish (1982), and northern anchovy (1978). The Council also assumed a role in allocating the West Coast catch limit for Pacific halibut, established through an international body, the International Pacific Halibut Commission. Procedures to periodically adjust catch levels in relation to stock status were established under both the Salmon and Groundfish FMPs during this period. One of the objectives of the 1976 Act was to shift harvests in the EEZ from foreign to domestic vessels. Off the West Coast, this meant domestication of the large trawl fishery for Pacific whiting and other groundfish species, with all foreign fishing ending in the early 1990s. Full domestic management fostered a realization that many stocks were fully utilized, or had been overexploited by the offshore foreign fisheries of the mid-century. For groundfish fisheries, full utilization sparked a call in the late 1980s for a Federal limited access permit program, ultimately adopted in 1992. Beginning in the late 1980s, the listing of salmon stocks under the ESA also necessitated increasingly precautionary management, accompanied by a steady long-term decline in catch.

The 1996 Sustainable Fisheries Act (SFA), one of a series of amendments and reauthorizations to the original MSA, ushered in an era of more precautionary management. The SFA triggered a more robust framework for determining stock status, ending overfishing, rebuilding overfished stocks, minimizing bycatch, and taking into account the effects of fisheries management on fishing communities. Another new provision directed councils to identify EFH for federally-managed stocks and to consider measures to reduce the effects of fishing on such habitat. Playing out over the subsequent decade, these provisions ushered in substantial changes in management to deal with newly declared overfished stocks and consideration of a broader range of environmental concerns.

In 2000, the Northern Anchovy FMP became the CPS FMP, which includes Pacific sardine, market squid, and other, similar species. This expansion of Federal authority over new coastal species marked a steady increase in Council interest in a variety of species and issues. The Council subsequently developed its HMS FMP to address West Coast EEZ harvest of a suite of internationally-managed tuna and shark species, adopting that FMP in 2004. The Council's groundfish management efforts have increased significantly since the turn of the 21st century with measures to rebuild overfished species (largely accomplished) and minimize bycatch; a catch share program for groundfish trawl fisheries (individual fishing quotas and co-ops) has transformed management of those sectors.

Other initiatives the Council has embarked on in the first two decades of this century include: a prohibition on krill harvest through the CPS FMP, successful rebuilding of all but one of the West Coast groundfish species declared overfished around the turn of the century, grappling with multiple salmon fishery disasters resulting from climate variability and change, and contending with the precipitous decline in the Pacific sardine stock and attendant fishery closure. The breadth of issues considered by the Council has continued to expand along with the desire to take a more holistic view of fishery management signaled by the adoption of this FEP in 2013.

While the FEP does not directly trigger management actions, the regular status reporting and ecosystem initiative development process resulting from it give the Council opportunities to widen its view of the effects of its fishery management actions. The FEP also served as a platform for developing ecosystem-based management measures implemented in the FMPs, including the coastwide prohibition on the development of fisheries for unfished forage species implemented in 2016 (see Section 2.2) and a wholesale look at how the Council may facilitate adaptation to the effects of climate change. In the third decade of the 21st century, marine spatial planning could become a preoccupation if the push to decarbonize energy systems leads to massive development of offshore wind farms. Along with potential expansion of marine aquaculture and other initiatives to combat climate change (such as the expansion of marine protected areas), the space available to fisheries could be at a premium.

### 3.5.2 Ecosystem-Based Management Measures within FMPs

This section identifies ecosystem-based principles and related management measures already embedded in Pacific Council FMPs, particularly management measures that mitigate the impact of fishing on the environment or ecosystem or account for the effects of the biophysical environment on managed species. Other protective management measures have also been promulgated under the ESA and MMPA. For each measure listed under the FMPs, we indicate in brackets the FMP species groups or protected species that may benefit from the measure listed. The following lists, separated by FMP, are current through February 2021.

#### 3.5.2.1 CPS FMP

**Harvest Management**

Conservative and Ecologically Driven Management Strategy: The Council has demonstrated a consistently conservative approach to CPS harvest management in response to their ecological role as forage and importance to West Coast fisheries, as well as the inherent variability in their population levels resulting from prevalent ocean conditions. The CPS FMP includes ecosystem considerations as part of its OY-based harvest control rules (HCRs). The FMP also allows the Council to consider ecosystem needs when setting annual catch limits, targets, or guidelines. In the late 1990s, the Council chose the most conservative HCR for Pacific sardine when presented with a wide range of FMP harvest policies. The rationale for this harvest policy, like the other HCRs in the FMP, favors maximizing biomass over maximizing catch. Because of this, the harvest levels that result from the rule, which are used for annual management, never exceed 12 percent of the estimated biomass for that year.

Environmental Indicators: To respond to changing environmental conditions, the Pacific sardine HCR includes an environmental parameter. However, this environmental parameter is one of the Council's priority research needs.

Cutoff Parameters: HCRs for Pacific sardine and Pacific mackerel have long used a "cutoff" parameter to protect a core spawning population and to prevent stocks from becoming overfished. Once biomass falls below the cutoff, directed harvest is prohibited. Cutoff values are set at or above the overfished threshold and have the effect of automatically reducing harvest rates as biomass levels decline. This mechanism serves to preserve the spawning stock. For Pacific sardine, the cutoff value is 150,000 mt or three times the overfished threshold and for Pacific mackerel the cutoff value, set at the overfished threshold, is 18,200 mt. [HMS, groundfish, salmon, CPS, marine mammals, birds]

The Council frequently reviews new science in support of stock assessments and management strategies, and conducts stock assessments annually or biennially for Pacific sardine and Pacific mackerel, respectively, due to fishery interest and harvest and the annual variability that can occur in the biomass of CPS. For other CPS finfish stocks that are not subject to intense fishery interest or harvest, and therefore are not assessed frequently, the harvest ABC control rule consists of a 75 percent reduction from the stock's overfishing limit to determine the catch limit. This precautionary management approach for these stocks accounts for variability in population biomass for these stocks over time. [HMS, groundfish, salmon, CPS, marine mammals, birds]

**Habitat Conservation**

EFH for CPS finfish species is temperature-based. The east-west geographic boundary of EFH for CPS is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10 to 26° C. The southern boundary is the U.S.-Mexico maritime boundary. The northern boundary is more dynamic and is defined as the position of the 10° C isotherm, which varies seasonally and annually. Defining EFH in this dynamic way, based on changes in the ecosystem itself over time, is by definition a form of ecosystem-based management. [CPS] Although the CPS FMP does not identify or apply management measures to mitigate fishing gear impacts to CPS EFH, NMFS is required to conduct consultations on any Federal activities that may adversely affect CPS EFH, as well as any other EFH designated under Council FMPs.

**Bycatch Mitigation**

Ecosystem component (EC) species: The CPS FMP incorporates Pacific herring, jacksmelt, and a suite of lower trophic level species shared across all FMPs (Shared EC Species). Of these shared EC species, bycatch and incidental catch of jacksmelt in addition to Pacific herring in CPS fisheries is specifically monitored and reported along with all other non-EC species bycatch/incidental catch annually in the CPS SAFE document.

Krill harvest prohibition: The CPS FMP prohibits harvest of all species of euphausiids (krill) that occur within the U.S. West Coast EEZ to help maintain important predator-prey relationships and the long-term health and productivity of the CCE. These ecosystem conservation principles ensure that fisheries will not develop that could put krill stocks and the other living marine resources that depend on krill at risk. [HMS, groundfish, salmon, CPS, marine mammals, birds]

Other bycatch provisions: Incidental catch provisions are often included in annual management recommendations. These provisions include small allowances for other CPS and non-CPS fisheries of incidental catch of specific CPS for which the directed fishery may be closed to reduce or prevent discard. Salmon species may not be retained in non-tribal CPS directed fisheries and to the extent practicable must be released immediately with a minimum of injury. Pacific halibut may not be retained in non-tribal CPS directed fisheries. [CPS, salmon, Pacific halibut]

ESA incidental take protections: CPS fishing boat operators and crew are prohibited from deploying their nets if a southern sea otter is observed within the area that would be encircled by the purse seine. [otters]

**Ecosystem Information**

The annual SAFE document for CPS includes an ‘Ecosystem Considerations’ chapter that provides a summary of oceanographic trends and ecological indicators being tracked by NMFS in the CCE and the ongoing work examining their potential effects on CPS stocks. [CPS]

### 3.5.2.2 Groundfish FMP

**Harvest Management**

Weak stock management to curtail allowable harvest of more abundant species in order to reduce opportunities for incidental catch of less abundant, co-occurring species. Harvest levels for species managed via an overfished species rebuilding plan are usually set at a fraction of $F_{MSY}$ harvest rate. [Groundfish, salmon]

Precautionary harvest policies: For less abundant stocks and stocks with little scientific information, harvest policies become increasingly precautionary. [Groundfish]

Allowable harvest of shortbelly rockfish, an abundant species with high prey value to the CCE, had been set to extremely low to accommodate incidental catch while discouraging any fishery development, to ensure that it retains its role as prey for other (non-human) predator species. In 2017, incidental catches of shortbelly reached unprecedented levels beginning in 2017 based on a boom and shift north in the population. In June 2020, the Council recommended designating the stock as an EC species while identifying a clear trigger for revisiting the need for active bycatch management. [Groundfish, HMS, salmon, marine mammals, seabirds]

Stock assessments include literature review and discussion of relevant ecological, biological, social, and economic factors and the interactions between them, to allow the SSC and Council to weigh impacts of those factors under different potential harvest scenarios. [Groundfish]

Stock-wide management: For whiting, participation in a U.S.-Canada bilateral treaty organization to jointly manage and conserve Pacific whiting to ensure that harvest of the cross-boundary resource remains within sustainable parameters. [Groundfish, marine mammals, seabirds]

**Habitat Conservation**

EFH Conservation Areas: extensive, coastwide, long-term closed areas to protect groundfish EFH from bottom contact gear, particularly in rocky reef areas; extensive, coastwide, long-term closed area to freeze the footprint of West Coast trawl gear use to inshore of 700 fm depth contour. [Groundfish, salmon (particularly Chinook), marine mammals, seabirds]

Gear Restrictions: Trawl gear regulations to constrain habitat damage through a small footrope requirement shoreward of the rockfish conservation areas (RCAs), and minimize catch of juveniles through a minimum mesh size requirement. Fixed gear regulations to prevent lost gear from ghost fishing through a gear attendance requirement and, for pots, a biodegradable escape panel requirement. [Groundfish, salmon (particularly Chinook), marine mammals, seabirds]

**Bycatch Mitigation**

RCAs: coastwide, seasonally-variable closed areas to minimize bycatch in all groundfish fisheries of rebuilding groundfish species. For cowcod and yelloweye rockfish, species-specific closed areas off the southern (cowcod) and northern (yelloweye) U.S. West Coast. [Groundfish, salmon (particularly Chinook), marine mammals, seabirds]

Salmon Conservation Zones: mid-coast, estuary-plume-focused closed areas near the mouths of the Columbia and Klamath Rivers to minimize bycatch in whiting fisheries of endangered and threatened salmon stocks. [Salmon, CPS, green sturgeon, marine mammals, seabirds]

Seabird bycatch minimization and mitigation measures: bottom longline gear vessels that set gear between dawn and dusk are required to deploy bird-scaring streamer lines north of 36° N. latitude to limit bird attraction to gear, and are subject to equipment and handling requirements for bringing incidentally-caught short-tailed albatross onboard, and resuscitating and releasing when possible. [Seabirds]

Bycatch Monitoring: Regulations require fishery participants in non-maximized retention fisheries to sort catch, both at-sea discard and landings, by FMP species or grouping as appropriate, ensuring continued high quality, long-term data on the hugely varied groundfish species catch, discards at sea, and landings. [Groundfish]

Individual fishing quotas: Implementation of the trawl rationalization program, including individual fishing quota management, has demonstrated reduced bycatch of non-target species such as halibut and overfished species of concern since its inception in January 2011. [Groundfish, Halibut]

**Fishery Monitoring**

Vessel monitoring system (VMS): Commercial fishery VMS requirements to better-enforce closed areas and other regulations. [Groundfish, salmon, marine mammals, seabirds]

Observers: Coastwide, mandatory observer program to gather total catch data from commercial fisheries. [All FMP species, all protected species taken as bycatch]

#### 3.5.2.3 HMS FMP

**Habitat Conservation**

FMP designates EFH for each species within the FMP, with sub-designations for the different life stages of those species. EFH designations for some HMS' life stages are temperature-based, recognizing those species' habits of associating with certain temperature ranges, regardless of where those temperatures may occur in any given season or year. [HMS]

**Bycatch Mitigation**

Environmentally-based time-and-area closures to minimize and mitigate sea turtle, shark, and marine mammal bycatch: NMFS-trained observers on vessels. Sea turtle protections include swordfish pelagic shallow-set longline fishery prohibited; prohibition on light stick possession for pelagic longline vessels operating west of 150° W. longitude; seasonal area closures for large-mesh drift gillnet (the Pacific Leatherback Conservation Area; Southern Loggerhead closure during El Niño events); equipment and requirements for the safe handling and release of incidentally-caught turtles; mandatory sea turtle and marine mammal training for skipper and crew in the large-mesh drift gillnet gear. Marine mammal protections: Pacific Offshore Cetacean Take Reduction Plan requires gear modifications on large-mesh drift gillnet gear (pinger and gear depth requirements). Mainland area closures include a complete closure of the fishery off California February 1-April 30, within 75 nm May 1-August 14, and within 25 nm December 15-January 31 the following year to mitigate shark bycatch; east of a line approximating 1,000 fm off of Oregon; and other discrete area closures along the California coast, as well as around the Channel Islands. State regulations to reduce marine mammal bycatch using time/area closures. [Sea turtles, marine mammals]

Seabird bycatch minimization and mitigation measures: pelagic longline gear configuration and setting requirements, offal discharge requirements, equipment and handling requirements for bringing incidentally-caught short-tailed albatross onboard, and resuscitating and releasing when possible. [Seabirds]

Bycatch limitations for HMS taken with non-HMS gear. [HMS]

Nationwide shark-finning prohibition. [Sharks]

Participation in international regional fishery management organizations to develop and implement multinational conservation measures, such as restricting fishing around fish aggregating devices for tropical tunas, and area closures to minimize bycatch of mammals and turtles. [HMS, marine mammals, sea turtles]

**Fishery Monitoring**

HMS permitting and record-keeping requirements for U.S. vessels operating in the EEZ and on the high-seas and landing HMS in U.S. ports. [HMS]

Selected commercial fishery VMS requirements to better enforce closed areas and other regulations. [HMS]

Mandatory observer program to gather catch data from commercial fisheries. [HMS, salmon, CPS, groundfish]

Nationwide marine mammal bycatch mitigation standards for imports. [Marine mammals]

#### 3.5.2.4 Salmon FMP

**Harvest Management**

Geographic control zones that may be opened or closed to fishing on an annual basis, depending on a particular year's management objectives and run forecasts, used to constrain the catch of salmon from less-abundant runs caught in common with salmon from more abundant runs. [Salmon]

Adaptive management process that allows swift inseason regulation changes to respond as catch information becomes available. That same process also includes an annual retrospective analysis of the effectiveness of modeling and management, ensuring an ongoing refinement of predictive and monitoring methodologies. [Salmon]

Oregon coastal natural and Columbia River coho harvest matrices that use juvenile salmon ocean survival as a predictor of ocean conditions, ultimately providing allowable total fishery impacts rates based on the return of jacks (sub-adults) to spawning streams. Also for Oregon coastal natural coho, the Council's SSC has recommended a new predictor methodology that blends multiple parameters, including sea surface temperature and copepod assemblage abundance. [Salmon]

Participation in international regional fishery management organizations to ensure cooperation on both North American and high-seas multinational conservation measures to prevent overharvest. [Salmon]

Provisional closed areas and restrictive harvest limits in years when Chinook harvest abundance is estimated to fall below a low Chinook abundance threshold, so as to provide adequate Chinook forage for Southern Resident Killer Whales.

**Habitat Conservation**

FMP designates EFH from the ocean extent of the EEZ to the shore, and inland up to all freshwater bodies occupied or historically accessible to salmon in Washington, Oregon, Idaho, and California, with exceptions for dammed streams, recognizing the long-term potential for managed stocks to recover in historically-used areas. [Salmon, and in marine waters, groundfish and CPS where EFH for those species intersects with salmon EFH]

**Bycatch Mitigation**

Yelloweye RCA off Washington state to minimize bycatch of an overfished rockfish species in the salmon troll fisheries. Regulations restricting groundfish and halibut retention, coupled with inseason management to adjust those as needed. [Groundfish, halibut]

Prohibition on the use of nets to fish for salmon within the EEZ to allow for live release of undersized salmon and to prevent bycatch of non-target species. [Salmon, HMS, groundfish]

### *3.5.3 CCE Species Managed Under the ESA, MMPA, and MBTA*

Recovering ESA-listed endangered and threatened anadromous and marine species within the U.S. portion of the CCE is a joint effort between U.S. citizens and Federal, states' and tribes' science and management agencies. NMFS has jurisdiction over recovery and protection of most marine and anadromous fish and mammal species of the U.S. CCE, including most marine mammals, sea turtles, marine fishes, invertebrates, and plants. Sea otter recovery is under the jurisdiction of the United States Fish and Wildlife Service (USFWS). The USFWS also has jurisdiction over recovery of CCE seabird species. The Council's FMPs include a variety of fishery management measures intended to minimize fisheries interactions with ESA-listed species. These measures are often the result of consultations on the FMPs required by the ESA. As the agency implementing FMPs, NMFS must ensure that all Federal fisheries comply with the ESA, and that actions authorized by the FMPs do not jeopardize listed species or adversely modify or destroy designated critical habitat. To meet this requirement, all FMPs have gone through ESA section 7 consultation with NMFS and with USFWS. Biological opinions, the outcomes of the consultations, have been completed for all Federal fisheries.

The laws that are used to manage the different species of the EEZ do not necessarily reflect their ecosystem interactions, but instead often address their abundance levels as individual stocks, or as DPSs or evolutionarily significant units (ESUs) of fish or other animals. Under the ESA, species considered for ESA protection include "any subspecies of fish or wildlife or plants, and any DPS of any species of vertebrate fish or wildlife which interbreeds when mature." For marine species with vast migratory ranges, a distinct population of a particular species may occur off the U.S. West Coast, while other distinct populations of that same species may occur elsewhere within the North Pacific or beyond. For example, Steller sea lions (*Eumetopias jubatus*) range across the entire North Pacific Ocean from coastal Japan and Korea to the U.S. West Coast. The portion of the Steller sea lion population off the U.S. West Coast is considered a DPS, known as the eastern DPS. The Steller sea lion's U.S. western DPS, generally found off Alaska and farther north, remains listed as endangered under the ESA, while the eastern DPS has been recovered and removed from ESA listing (78 FR 66140, November 3, 2013).

Designating a salmonid population as a DPS is based on whether that population may be considered an ESU for the species, meaning that it "must be substantially reproductively isolated from other nonspecific populations units, and it must represent an important component in the evolutionary legacy of the species" (56 FR 58612, November 20, 1991). For example, a spring-run Chinook for a particular river may be genetically similar to a fall-run Chinook for that same river, but those fish cannot breed with each other because they are not in the same breeding place at the same time, making them distinct ESUs. The complex salmon-linked ecologies of North American rivers that drain to the Pacific Ocean require government agencies and the public to see salmon runs for their very particular roles in small geographic areas like individual streams, and for their ecosystem-wide roles linking North America to the Pacific Ocean. Salmon also serve as an important prey item for ESA-listed endangered Southern Resident Killer Whales (*Orcinus orca*).

As shown in Table 3-5, ESA-listed marine or anadromous species that, in some or at all times of the year, may occur within the U.S. West Coast EEZ include marine mammals, sea turtles, fish, and invertebrates.

**Table 3-5. ESA-listed species that may occur in U.S. West Coast EEZ.**

| Species | Status |
|---|---|
| **Marine Mammals** | |

| Species | | Status |
|---|---|---|
| Blue whale *(Baleaenoptera musculus)* | | Endangered |
| Fin whale *(Baleranoptera physalus)* | | Endangered |
| Humpback whale (*Megaptera novaeangliae*) | | Endangered |
| Sei whale (*Balaenoptera borealis*) | | Endangered |
| Sperm whale (*Physeter macrocephalus*) | | Endangered |
| Killer whales, southern resident DPS (*Orcinus orca*) | | Endangered |
| North Pacific Right whale (*Eubalaena japonica*) | | Endangered |
| Southern sea otter (*Enhydra lutris nereis*) | | Threatened |
| Guadalupe fur seal (*Arctocephalus townsendi*) | | Threatened |
| **Birds** | | |
| Short-tailed albatross (*Phoebastria albatrus*) | | Endangered |
| Marbled murrelet *(Brachyramphus marmoratus marmoratus)* | | Endangered |
| California least-tern *(Sternum antillarum browni)* | | Endangered |
| **Sea turtles** | | |
| Leatherback turtle (*Dermochelys coriacea*) | | Endangered |
| Loggerhead turtle, North Pacific Ocean DPS (*Caretta caretta*) | | Endangered/Threatened |
| Olive Ridley (*Lepidochelys olivacea*) | | Endangered/Threatened |
| Green Sea Turtle (*Chelonia mydas*) | | Endangered/Threatened |
| **Marine invertebrates** | | |
| White abalone (*Haliotis sorenseni*) | | Endangered |
| Black abalone (*Haliotis crachereodii*) | | Endangered |
| **Fish** | | |
| Green Sturgeon, southern DPS (*Acipenser medirostris*) | | Threatened |
| Gulf grouper (*Mycteroperca jordani*) | | Endangered |
| Scalloped Hammerhead Shark (*Sphyrna lewini*) | | Endangered |
| Bocaccio, Puget Sound/Georgia Basin DPS (*Sebastes paucispinis*) | | Endangered |
| Yelloweye Rockfish, Puget Sound/Georgia Basin DPS (*S.ruberrimus*) | | Threatened |
| Oceanic Whitetip Shark (*Carcharhinus longimanus*) | | Threatened |
| Pacific eulachon, southern DPS (*Thaleichthys pacificus*) | | Threatened |
| **Salmonids** | | |
| Chinook (*Oncorhynchus tshawytscha*) | Sacramento River winter ESU | Endangered |
| | Upper Columbia River Spring ESU | Endangered |
| | California Coastal ESU | Threatened |
| | Central Valley Spring ESU | Threatened |

| Species | | Status |
|---|---|---|
| | Lower Columbia River ESU | Threatened |
| | Puget Sound ESU | Threatened |
| | Snake River Fall ESU | Threatened |
| | Snake River Spring/Summer ESU | Threatened |
| | Upper Willamette River ESU | Threatened |
| Chum (*Oncorhynchus keta*) | Hood Canal Summer Run ESU | Threatened |
| | Columbia River ESU | Threatened |
| Coho (*Oncorhynchus kistuch*) | Central California Coastal ESU | Endangered |
| | S. Oregon/N. CA Coastal ESU | Threatened |
| | Oregon Coast ESU | Threatened |
| | Lower Columbia River ESU | Threatened |
| Sockeye (*Oncorhynchus nerka*) | Snake River ESU | Endangered |
| | Ozette Lake ESU | Threatened |
| Steelhead (*Oncorhynchus mykiss*) | Southern California DPS | Endangered |
| | South-Central California DPS | Threatened |
| | Central California Coast DPS | Threatened |
| | California Central Valley DPS | Threatened |
| | Northern California DPS | Threatened |
| | Upper Columbia River DPS | Endangered |
| | Snake River Basin DPS | Threatened |
| | Lower Columbia River DPS | Threatened |
| | Upper Willamette River DPS | Threatened |
| | Middle Columbia River DPS | Threatened |
| | Puget Sound DPS | Threatened |

Marine mammals are protected under the MMPA, regardless of whether their populations are depleted enough to warrant listing as threatened or endangered under the ESA. Marine mammals that may, during some or at all times of the year, occur within the CCE are shown in Table 3-6.

**Table 3-6. Marine mammal species that may occur in U.S. West Coast EEZ.**

| Species | Stocks | ESA-listed? |
|---|---|---|
| **Odontocetes** | | |
| Harbor porpoise (*Phocoena phocoena*) | Various | |
| Dall's porpoise (*Phocoenoides dalli*) | CA/OR/WA stock | |
| Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) | North Pacific stock; CA/OR/WA stock | |

| Species | Stocks | ESA-listed? |
|---|---|---|
| Risso's dolphin (*Grampus griseus*) | CA/OR/WA stock | |
| Bottlenose dolphin (*Tursiops truncatus*) | California coastal stock | |
| Bottlenose dolphin (*Tursiops truncatus*) | CA/OR/WA offshore stock | |
| Short-beaked common dolphin (*Delphinus delphis)* | CA/OR/WA stock | |
| Long-beaked common dolphin (*Delphinus capensis)* | California stock | |
| Northern right whale dolphin (*Lissodelphis borealis*) | CA/OR/WA stock | |
| Striped dolphin (*Stenella coeruleoalba*) | CA/OR/WA stock | |
| Short-finned pilot whale (*Globicephala macrorhynchus*) | CA/OR/WA stock | |
| Sperm whale (*Physeter macrocephalus*) | CA/OR/WA stock | Endangered |
| Dwarf sperm whale (*Kogia sima*) | CA/OR/WA stock | |
| Pygmy sperm whale (*Kogia breviceps*) | CA/OR/WA stock | |
| Killer whale (*Orcinus orca*) | Eastern North Pacific southern resident stock | Endangered |
| Killer whale (*Orcinus orca*) | Eastern North Pacific offshore stock | |
| Killer whale (*Orcinus orca*) | West Coast transient stock | |
| Mesoplodont beaked whales (*Mesoplodon* spp.) - (Hubbs' beaked whales, Gingko -toothed whale, Stejneger's beaked whale, Blainville's beaked whale, Pygmy beaked whale or Lesser beaked whale, Perrin's beaked whale) | CA/OR/WA stocks | |
| Cuvier's beaked whale (*Ziphius cavirostris*) | CA/OR/WA stock | |
| Baird's beaked whale (*Berardius bairdii*) | CA/OR/WA stock | |
| **Mysticetes** | | |
| Blue whale (*Balaenoptera musculus)* | Eastern North Pacific stock | Endangered |
| Fin whale (*Balaenoptera physalus)* | CA/OR/WA stock | Endangered |
| Humpback whale (*Megaptera novaeangliae*) | CA/OR/WA stock | Endangered |
| North Pacific right whale (*Eubalaena japonica*) | Eastern North Pacific stock | Endangered |
| Sei whale (*Balaenoptera borealis)* | Eastern North Pacific stock | Endangered |
| Minke whale (*Balaenoptera acutorostrata*) | CA/OR/WA stock | |
| Gray whale (*Eschrichtius robustus*) | Eastern North Pacific stock | |
| | Western North Pacific | Endangered |
| **Pinnipeds** | | |
| California sea lion (*Zalophus californianus californianus*) | U.S. stock | |
| Harbor seal (*Phoca vitulina richardsi*) | CA stock and OR & WA coastal stock | |
| Northern elephant seal (*Mirounga angustirostris*) | CA Breeding Stock | |
| Guadalupe fur seal (*Arctocephalus townsendi*) | | Threatened |

| Species | Stocks | ESA-listed? |
|---|---|---|
| Northern fur seal (*Callorhinus ursinus*) | San Miguel Island stock | |
| | Eastern North Pacific | |
| Steller sea lion (*Eumetopias jubatus*) | Eastern Pacific stock (U.S.) | |
| **Mustelids** | | |
| Southern sea otter (*Enhydra lutris nereis*) | CA stock | Threatened |

Seabirds are protected under the MBTA, regardless of whether their populations are depleted enough to warrant listing as threatened or endangered under the ESA. Seabirds that may, during some or at all times of the year, occur within the CCE are shown in Table 3-7.

**Table 3-7. Seabird species that may occur in U.S. West Coast EEZ.**

| Species | Pacific Distribution | ESA-listed or Bird of Conservation Concern? |
|---|---|---|
| **Procelliformes** | | |
| Fork-tailed storm-petrel (*Oceanodroma furcata*) | North Pacific | |
| Leach's storm-petrel (*O. leucorhoa*) | Northern Hemipshere | |
| Ashy storm-petrel (*O. homochroa*) | CCE | BCC |
| Black storm-petrel (*O. melania*) | Channel Islands, CA, Baja California | |
| Black-footed albatross (*Phoebastria nigripes*) | Central Pacific, ranging into CCE | BCC |
| Laysan albatross (*P. immutabilis*) | Central Pacific, ranging into CCE | BCC |
| Short-tailed albatross (*P. albatrus*) | North Pacific | Endangered |
| Black-vented shearwater (*Puffinus opisthomelas*) | West Coast of Baja California breeder, migrates into CCE | BCC |
| Buller's shearwater (*P. bulleri*) | Southern Pacific breeder, migrates throughout Pacific Ocean | |
| Pink-footed shearwater (*P. creatopus*) | Southeastern Pacific breeder, migrates throughout Pacific Ocean | BCC |
| Short-tailed shearwater (*P. tenuirostris*) | Southern Pacific breeder, migrates throughout Pacific and Indian Oceans | |
| Sooty shearwater (*P. griseus*) | Southern Pacific breeder, migrates throughout Pacific Ocean | |
| Northern fulmar (*Fulmarus glacialis*) | Arctic circumpolar, south to central CA | |
| **Pelecaniformes** | | |
| Brown pelican (*Pelecanus occidentalis*) | Temperate and tropical Americas | |
| Double-crested cormorant (*Phalacrocorax auritus*) | Western subspecies (*P.a. albociliatus*), throughout CCE | |
| Brandt's cormorant (*P. penicillatus*) | West Coast of North America | |

| Species | Pacific Distribution | ESA-listed or Bird of Conservation Concern? |
|---|---|---|
| Pelagic cormorant (*P. pelagicus*) | North Pacific | BCC |
| **Charadriiformes** | | |
| Ring-billed gull (*Larus delawarensis*) | Off western N. America, CCE | |
| California gull (*Larus californicus*) | Off western N. America, CCE | |
| Western gull (*L. occidentalis*), | Off western N. America, CCE | |
| Glaucous gull (*L. hyperboreus*) | Northern Alaska to OR coast | |
| Glaucous-winged gull (*L. glaucescens*) | Northern and northeastern Pacific | |
| Heerman's gull (*L. heermanni*) | CCE south to Central America | |
| Mew gull (*L. canus*) | Northwest Alaska south to Baja California | |
| Bonaparte's gull (*Chroicocephalus Philadelphia*) | Western Alaska south to CCE | |
| Black-legged kittiwake (*Rissa tridactyla*) | Northwest Alaska to southern CA | |
| Gull-billed tern (*Sterna nilotica*) | Southern CA, northern Mexico | BCC |
| Caspian tern (*S. caspia*), | Off western N. America, CCE | BCC |
| Royal tern (*S. maxima*), | Subspecies (*S.m. maxima*), southern CA, northern Mexico | |
| Elegant tern (*S. elegans*), | Southern CA, northern Mexico | |
| Arctic tern (*S. paradisaea*), | Arctic circumpolar, south to WA coast | BCC |
| Forster's tern (*S. forsteri*), | Central and southern CA | |
| Least tern (*Sterna antillarum)* | Subspecies (*S.A. browni*), central CA to Baja California | Endangered |
| Black skimmer (*Rynchops niger*) | California south to southern South America | BCC |
| Common murre (*Uria aalge*) | Arctic circumpolar, south to central CA | |
| Pigeon guillemot (*Cepphus Columba*) | North Pacific | |
| Marbled murrelet (*Brachyramphus marmoratus*) | Northeastern North Pacific | Threatened, BCC |
| Scripps's murrelet (*Synthliboramphus scrippsi*) | Southern CA, northern Mexico | BCC |
| Guadalupe murrelet (*Synthliboramphus hypoleucus*) | Southern CA, northern Mexico | BCC |
| Ancient murrelet (*S. antiquus)* | Northern North Pacific, south to WA coast | |
| Craveri's murrelet (*S. craveri*) | Southern CA to Baja California | |
| Cassin's auklet (*Ptychoramphus aleuticus*) | Northeastern North Pacific | BCC |
| Rhinoceros auklet (*Cerorhinca monocerata*) | Northern North Pacific, south to southern CA | |

| Species | Pacific Distribution | ESA-listed or Bird of Conservation Concern? |
|---|---|---|
| Tufted puffin (*Fraterculata cirrhata*) | Northern North Pacific, south to Farallon Islands | |

### *3.5.4 Tribal and State Fisheries Management*

#### 3.5.4.1 Northwest Tribes' Fisheries Management

The Treaty Tribes of Oregon and Washington (Tribes) have both exclusive and shared authority to manage a wide variety of fisheries and natural resources affected by both current and future actions of the Council and by biophysical conditions within the CCE. The Tribes manage and harvest marine species covered by the Council's FMPs as well as other species governed by the Tribes' own exclusive authorities or by co-management agreements with the states of Oregon and Washington. The Tribes also retain property interests in species they do not currently manage or harvest but may choose to do so at a future time.

Tribal fisheries have ancient roots and their harvests are used for commercial, personal use, and cultural purposes. Authorities to plan, conduct and regulate fisheries; manage natural resources; and enter into cooperative relationships with state and Federal entities are held independently by each of the Tribes based on their own codes of law, policies, and regulations. The independent sovereign authorities of each Tribe were Federally recognized initially in a series of treaties negotiated and signed during 1854-1855: (Treaty with the Tribes of Middle Oregon (1855); Treaty with the Walla Walla, Cayuse, and Umatilla Tribes (1855); Treaty with the Yakama (1855); Treaty with the Nez Perce (1855); Treaty of Medicine Creek (1854); Treaty of Neah Bay (1855); Treaty of Olympia (1855); Treaty of Point Elliot (1855); and Treaty of Point No Point (1855). These treaties have been reaffirmed by judicial review, e.g., U.S. v. Oregon (SoHappy v. Smith) 302 Supp.899 (D. Oregon, 1969) and U.S. v. Washington 384 F. Supp. 312 (W. Dist. Wash., 1974), and administrative policies (e.g., Executive Order 13175 and Secretarial Order 3206).

Each Treaty Tribe exercises its management authorities within specific areas commonly referred to as U&A fishing locations. These areas have been adjudicated within the Federal court system or confirmed by Federal administrative procedures. The restriction of treaty-right fisheries to specific geographic boundaries creates place-based reliance on local resource abundance and limits the Tribes' latitude for response to variations in ecosystem processes, species distributions, or fisheries management effects.

Each Tribe has established sets of laws and policies to achieve sustainable fisheries production through traditional and science-based management. Regulations to control the conduct of each fishery (time, place, gear, etc.) are set through governmental procedures, and performance is monitored to ensure objectives are met. The Tribes participate as full partners with Federal and state entities to ensure their criteria for resource conservation and sustainable fisheries are compatible. For example, the Tribes participate in the annual Pacific Salmon Commission process to preserve fishing opportunities on healthy salmon stocks and ensure conservation of depressed stocks of Chinook, chum (*O. keta),* and coho salmon. Tribes also participate in the North of Falcon process with the State of Washington to achieve an annual set of co-management plans for salmon fisheries within the EEZ, state marine waters, inside marine waters, and terminal areas for Council action.

The Tribes' combined regions of management interest and authority include areas outside the EEZ and the physical boundaries of the California Current. However, many of the species managed and harvested in these areas are affected by Council management and by conditions within the CCE. For example, Treaty salmon fisheries in the Columbia River watershed, inside marine waters (Strait of Juan de Fuca, Puget

Sound and their watersheds), and coastal waters of Washington are significantly affected by salmon harvest quotas and schedules in the EEZ and by general marine conditions for growth and survival. All of the Tribes hold a vested interest in, and participate in, the Council's processes because salmon, other anadromous fishes (e.g., sturgeon spp., lamprey spp., smelt spp., trout and char spp.), and many migratory species of interest (e.g., marine mammals, herring, halibut) traverse and/or are affected by actions and activities within the EEZ and the California Current.

The four coastal Treaty Tribes (Coastal Tribes) of Washington (Makah Nation, Quileute Indian Tribe, Hoh Indian Tribe, and Quinault Indian Nation) have broad interests in the CCE and more complex relationships with Council processes and decisions. The U&As of the Coastal Tribes overlap with the EEZ and they have active ocean fisheries operating under the Council's current FMPs (Table 3-8).

Harvests in the Coastal Tribes commercial fisheries (Table 3-8) provide important employment and entrepreneurial opportunities for their remote communities, and make significant contributions to the coastal economy of Washington.

**Table 3-8. Coastal Treaty Tribes commercial fisheries.**

| Fishery | Species | FMP | Tribes |
|---|---|---|---|
| Longline | Blackcod, Pacific halibut | Groundfish | Makah, Quileute, Hoh, Quinault |
| Bottom trawl | Groundfish | Groundfish | Makah |
| Midwater trawl | Whiting, yellowtail rockfish | Groundfish | Makah, Quileute |
| Troll | Salmon | Salmon | Makah, Quileute, Hoh, Quinault |
| Purse seine | Sardine | CPS | Quinault |
| Pot | Dungeness crab | | Makah, Quileute, Hoh, Quinault |
| Manual intertidal | Razor clam | | Quinault |

### 3.5.4.2 California Tribes in the Council Process

Fisheries have been important to California tribes since time immemorial for cultural purposes, subsistence, and commerce-related activities. The primary stock co-managed by the Council, California, and the Hoopa Valley and Yurok Tribes is fall Chinook of the Klamath and Trinity River basins, which is an indicator stock for the Southern Oregon and Northern California complex of the Salmon FMP. Klamath Basin spring Chinook are considered a component of the Southern Oregon and Northern California complex; however, co-managers have not yet identified conservation objectives or coordinated regional management for this stock.

The Yurok Tribal fishery occurs within the lower 44 miles of the Klamath River and within a portion of the Trinity River below the boundary of the Hoopa Valley Reservation. The Hoopa Tribal fishery occurs in the Trinity River from approximately one mile above the confluence with the Klamath River to the upstream boundary of the Hoopa Valley Indian Reservation, approximately 12 river miles. The primary gear type used is gillnets; however, a small portion of the Chinook harvest is taken by dip nets and hook- and-line. Fall Chinook are typically harvested from early August through mid-December, with peak harvest in the Klamath River estuary occurring during late-August through mid-September, and in the Trinity River during late-September to early-October.

In 1993, the Interior Department Solicitor issued a legal opinion that concluded that the Yurok and Hoopa Valley Tribes of the Klamath Basin have a federally-protected reserved right to 50 percent of the available harvest of Klamath Basin salmon. Under the Council's annual salmon management process, half of the annual allowable catch of Klamath River fall Chinook has been reserved for these tribal fisheries since 1994. Federal courts affirmed this decision in Parravano v. Masten, 70 F. 3d 539 (9th Cir. 1995), cert. denied, 116 S. Ct. 2546 (1996). Tribal fisheries with recognized Federal fishing rights occur on the Yurok and Hoopa Valley Indian reservations located on the Lower Klamath and Trinity Rivers, respectively. These fisheries are regulated by their respective governments.

The Yurok Tribal Council regulates the fall and spring Chinook fishery via annual Harvest Management Plans, which are based upon the tribal allocation and subsequent regulations regarding sub-area quotas, conservation measures, and potential commercial fisheries. When the Tribal Council allows a portion of the allocation to go to commercial fishing, then most harvest is taken in the estuary where commercial fisheries are held. Subsistence fisheries are spread throughout the reservation.

The Hoopa Tribal Fishery is conducted in accordance with the Hoopa Valley Tribe's Fishing Ordinance. Fishing by tribal members occurs within the exterior boundaries of the Hoopa Valley Indian Reservation. The Hoopa Valley Tribal Council is the sole authority responsible for the conduct of the tribe's fishery, enforces the fishing ordinance, and ensures collection of harvest statistics through its Fisheries Department. The tribal fisheries normally set aside a small (unquantified) number of fish for ceremonial purposes. Subsistence needs are the next highest priority use of Klamath River fall Chinook by the Tribes. The subsistence catch has been as high as 32,000 fish since 1987, when separate tribal use accounting was implemented.

Commercial sales from the Yurok and Hoopa Valley Reservation Indian spring gillnet fisheries occurred in 1987-1989, 1996, 1999-2004, and 2007-2013, with an average annual commercial catch during years when the fishery was open of ~1,100 fish (PFMC 2021). Fall commercial Chinook gillnet fisheries occurred in 1987-1989, 1996, 1999-2004, 2007-2015, and 2019, with an average annual catch during years when the fishery was open of 21,200 fish, most of which were taken in the estuary. Detailed Klamath Basin tribal fishery data can be found in the Council's annual SAFE Document: Review of Ocean Salmon Fisheries.

#### 3.5.4.3 Washington Fisheries Management

**Legislative Mandate and Management Areas**

WDFW was created in 1994 when the Washington State Legislature merged the Department of Wildlife and the Department of Fisheries. WDFW's mandate is to "preserve, protect, perpetuate, and manage the wildlife and food fish, game fish, and shellfish in state waters and offshore waters" (Revised Code of Washington (RCW) 77.04.012). This legislative mandate also instructs WDFW to conserve fish and wildlife "in a manner that does not impair" the resources while:

- seeking to "maintain the economic well-being and stability of the fishing industry in the state";
- promoting "orderly fisheries"; and
- enhancing and improving the recreational and commercial fishing in the state.

In furtherance of this mission, WDFW identifies a set of Conservation Principles intended to advance ecosystem-based management through cross-disciplinary and collaborative work that embraces science; adaptive management; and integrates ecological, social, economic, and institutional perspectives into agency decision-making (WDFW 2019). The goal of the Conservation Principles is "conservation by managing, protecting, and restoring ecosystems for the long-term benefit of people, and for fish wildlife, and their habitat." WDFW also crafted a 25-Year Strategic Plan to address the challenge of achieving its mission under a growing population, a changing climate, and changing public values and expectations in the state (WDFW 2020).

WDFW divides management of coastal fisheries from those occurring in inner waters. Inner waters begin at Cape Flattery and include the U.S. portions of the Strait of Juan de Fuca and Strait of Georgia, the San Juan Islands, Hood Canal, and Puget Sound. Marine areas on the coast and in inner waters include estuaries, with the transition to freshwater management areas occurring at the mouth of rivers and streams.

WDFW's Council-related activities focus mainly on the coastal region, although management activities for salmonids extend well into the inner marine and freshwater areas of the state. The Department's legislative mandate covers "offshore waters" in addition to state waters, which the State Legislature defined as the "marine waters of the Pacific Ocean outside the territorial boundaries of the state, including the marine waters of other states and countries" (RCW 77.08.010(33)). The state has direct authority to manage the offshore activities of state residents and vessels that are registered or licensed with the state. WDFW also pursues its mission in offshore waters through collaboration and coordination with Federal, state, and tribal partners; formal engagement in intergovernmental forums; and interjurisdictional enforcement of state, Federal, and international laws. WDFW's collaborative efforts also include the co-management relationship the state has with tribal governments that hold rights to fish and to manage the fishing activities of their members.

WDFW's management is, on the whole, highly integrated with Council-managed fisheries. As in Oregon and California, the state is responsible for tracking commercial landings and recreational catch from vessels landing into state ports.

**State Policy Process and Fisheries**

WDFW consists of the Director, responsible for general operation and management of the agency, and the Washington Fish and Wildlife Commission (WFWC), which establishes policy and provides direction and oversight over the agency's conservation and management activities. The WFWC consists of nine citizen members that are appointed by the Governor and subject to confirmation by the Washington State Senate.

The WFWC's policy role includes rulemaking over the time, place, and manner of fishing activities, although the authority to issue some rules has been delegated to the Director (RCW 77.12.047).

Regulations are issued through the process established by the states' Administrative Procedure Act, Regulatory Fairness Act, and State Environmental Policy Act. The WFWC takes input and deliberates on proposed policies and regulations in formal meetings and informal hearings that are open to the public and held throughout the state. More information on the WFWC and the state's rulemaking process can be found on the WFWC's website (WDFW 2021b, 2021c).

The WFWC Policy C-3603 guides WDFW's involvement in the Council process. Preservation, protection, and perpetuation of the living marine resources through coordinated management of fisheries is WDFW's guiding principle. Among other things, this policy instructs WDFW's representatives to:

- Support harvest strategies that promote optimum long-term sustainable harvest levels;
- Seek the views of the public, including those who represent consumptive and non-consumptive interest groups;
- Support initiatives and existing programs that more closely align the harvest capacity with the long-term sustained harvest quantities of marine resources, including individual quota programs and license and effort limitations programs;
- Support tribal fisheries that are consistent with the applicable Federal court orders while

recognizing the need for management flexibility to optimize fishing opportunity;
- Consider the social implications, impacts on fishing-dependent communities, net economic benefits to the state, and other factors when taking positions on resource allocation issues;
- Take a precautionary approach in the management of species where the supporting biological information is incomplete and/or the total fishery-related mortalities are unknown; and,
- Support consideration of the use of risk-averse management tools to protect the resources in the face of management uncertainty.

To facilitate integration between state rules and Council management, the WFWC has delegated rulemaking authority to the Director over rules pertaining to the harvest of fish and wildlife in the EEZ. WDFW incorporates many Federal regulations issued through the Council process into state rules.

Among other things, this allows for the enforcement of Council-recommended regulations in state courts. Other WFWC policies that are of relevance to WDFW's engagement on the Council include:

- Policy C-3012 – Forage Fish Management Policy, Goals and Plan
- Policy C-3601 – Management Policy for Pacific Halibut
- Policy C-3611 – Marine Fish Culture
- Policy C-3613 – Marine Protected Areas
- Policy C-3619 – Hatchery and Fishery Reform

The full set of policies can be viewed and tracked on the WFWC website (WDFW 2021a). The Hatchery and Fishery Reform policy (C-3619) is one of note that was under review and considerations for revision by the WFWC in 2021.

#### 3.5.4.4 Oregon Fisheries Management

ODFW manages all of the state's marine fishery resources. Some species are managed in conjunction with Federal, regional, and/or international partners, while others are entirely within state management. ODFW consists of the Oregon Fish and Wildlife Commission (Commission), made up of seven members appointed by the Governor to represent the public interest, a Commission-appointed director, and statewide staff. ODFW participates in the PFMC's development and recommendation of management measures to NMFS for species included in Federal fishery management plans such as groundfish, salmon, highly migratory species, coastal pelagic species, forage fish, and Pacific halibut. Additional measures to accomplish state-specific objectives for these species may be adopted by the Commission in state rule, as long as they do not conflict with Federal regulations. The state has primary jurisdiction in the territorial sea (from shore to three miles seaward), although regulations adopted by the Commission apply throughout the state's Fisheries Conservation Zone (from shore to 50 miles). Fisheries for species without Federal management, such as pink shrimp, Dungeness crab, and bay clams, are managed entirely by ODFW.

Several policies established by the Oregon Legislature guide fish and wildlife management throughout the state. The Wildlife Policy and Food Fish Management Policy provide overarching goals (see below) for conservation and use. The Commission is authorized by the Legislature to adopt regulations for the recreational and commercial take of wildlife, including fish and shellfish, with the exception of oysters.[1]

[1] Oyster production and commercial harvest is regulated by the Oregon Department of Agriculture, as are biotoxin monitoring and related public health regulations.

The Wildlife Policy (1973) (ORS §496.012) requires that wildlife are managed to prevent serious depletion of any indigenous species and to provide the optimum recreational and aesthetic benefits for present and future generations of the citizens of Oregon. It includes the following coequal goals:

- Maintain all species of wildlife at optimum levels.
- Develop and manage the lands and waters of this state in a manner that will enhance the production and public enjoyment of wildlife.
- Permit an orderly and equitable utilization of available wildlife.
- Develop and maintain public access to the lands and waters of the state and the wildlife resources thereon.
- Regulate wildlife populations and the public enjoyment of wildlife in a manner that is compatible with primary uses of the lands and waters of the state.
- Provide optimum recreational benefits.
- Make decisions that affect wildlife resources of the state for the benefit of the wildlife resources and make decisions that allow for the best social, economic, and recreational utilization of wildlife resources by all user groups.

The Food Fish Management Policy (1975) (ORS §506.109) is intended to provide for the optimum economic, commercial, recreational, and aesthetic benefits for present and future generations, and includes the following broad goals:

- Maintain all species of food fish at optimum levels in all suitable waters of the state and prevent the extinction of any indigenous species.
- Develop and manage the lands and waters of the state in a manner that will optimize the production, utilization, and public enjoyment of food fish.
- Permit an optimum and equitable utilization of available food fish.
- Develop and maintain access to the lands and waters of the state and the food fish resources thereon.
- Regulate food fish populations and the utilization and public enjoyment of food fish in a manner that is compatible with other uses of the lands and waters of the state and provides optimum commercial and public recreational benefits.
- Preserve the economic contribution of the sport and commercial fishing industries, in a manner consistent with sound food fish management practices.
- Develop and implement a program for optimizing the return of Oregon food fish for Oregon's recreational and commercial fisheries.

Several other state policies and plans guide Oregon's fisheries management, including the Native Fish Conservation Policy and associated Fish Conservation Plans, the Oregon Conservation Strategy/Nearshore Strategy, and the Climate and Ocean Change Policy.

The Native Fish Conservation Policy (2002, OAR 635-007-0502 through 635-007-0509) aims to provide a basis for managing hatcheries, fisheries, habitat, predators, competitors, and pathogens in balance with sustainable production of naturally-produced native fish. The policy has three areas of emphasis. The first is defensive to ensure the avoidance of serious depletion of native fish. The second is more proactive to restore and maintain native fish at levels providing ecological and societal benefits. The third ensures that, consistent with native fish conservation, opportunities for fisheries and other societal resource uses are not unnecessarily constrained. This approach allows Oregon to play a vital role in the recovery of ESA-listed species and the prevention of future listings.

Oregon's Marine Fisheries Management Plan Framework (Framework, 2015) was developed to complement the Native Fish Conservation Policy. Marine Fisheries Management Plans (MFMPs) provide a consistent approach for documenting information on marine resources and measures related to their conservation and use. MFMPs are intended to optimize commercial fisheries, recreational fisheries, new fisheries, and other harvest of marine resources while maintaining ecosystem integrity. The Framework describes policies and principles, entities, and processes relevant to fisheries management in Oregon, and specifies the goals and content that should be included in MFMPs. Current completed MFMPs maintain ecosystem integrity and optimize fisheries including commercial fisheries, recreational fisheries, new fisheries, and other harvest of marine resources. Current completed MFMPs include the Forage Fish and Pink Shrimp Fishery Management Plans. Oregon's Forage Fish Management Plan specifically complements Federal management efforts by incorporating policies to protect specific assemblages of forage fish identified in the PFMC's approved CEBA 1.

The Oregon Conservation Strategy is an overarching strategy for conserving fish and wildlife, as well as various other invertebrates, plants, and algae. It is not a management plan or a regulatory document; rather, it presents issues, opportunities, and recommended voluntary actions that citizens, landowners, organizations, and agencies can take to improve wildlife conservation in Oregon. It emphasizes proactively conserving declining species and habitats to reduce the possibility of future Federal or state ESA listings. The Nearshore Strategy is a component of the Oregon Conservation Strategy, focusing on marine fish and wildlife in Oregon's territorial sea. The Nearshore Strategy is intended to contribute to the marine resource science and management needs, including those related to Council-managed fisheries, by guiding research and monitoring, education and outreach, and other actions toward priority nearshore issues and areas that have not been the focus of other significant efforts.

The ODFW Climate and Ocean Change Policy (2020, 635–900–0001) is the framework under which the agency will evaluate the impacts of climate change on the resources under its stewardship, adopt management practices to safeguard those resources, and minimize the impacts to communities that depend on these resources. This is the first such policy to be adopted by a fish and wildlife agency in the country. Oregon is already experiencing changes that are consistent with changes observed and projected globally, such as increased average air and water temperatures, disrupted precipitation patterns, and increased ocean acidification and hypoxia. The purpose of this policy is to ensure that ODFW prepares for and responds appropriately to the impacts of a changing climate and ocean on fish, wildlife, their habitats, and their use and enjoyment by current and future Oregonians.

ODFW manages marine protected areas, including Marine Gardens, Marine Conservation Areas, and Marine Research Areas in the state's territorial sea. Marine Gardens are areas targeted for educational programs that allow visitors to enjoy and learn about intertidal resources. Marine Conservation Areas are specially protected areas where regulations are tailored to the site. Marine Research Areas are used for scientific study or research including baseline studies, monitoring, or applied research. In addition, several shellfish preserves are closed to clam harvesting. Five no-take marine reserves and associated marine protected areas were established by the state legislature in 2012 (ORS §196.540 through §196.555 and Oregon Senate Bill 1510). ODFW regulates fishing in the reserves and protected areas, and coordinates with several other state agencies with jurisdiction over submerged lands, and public beaches, state parks, and intertidal areas along the entire coast.

In addition to managing fisheries, ODFW conducts research and monitoring to understand the biology, distribution, abundance, and other characteristics of fish and wildlife and their habitats in nearshore marine and estuarine waters. ODFW is the state's expert on these resources, and advises other state agencies (i.e., Oregon Department of Land Conservation and Development (Coastal Zone Management agency), Department of Environmental Quality (Clean Water Act agency), and Oregon Department of Agriculture (oysters, biotoxins, etc.)) who have jurisdiction over other aspects of Oregon's natural resource management. As such, ODFW is responsible for overseeing scientific monitoring of Oregon's system of marine reserves.

The Oregon Coastal Management Program (OCMP), managed by Oregon's Department of Land Conservation and Development (DLCD), is the state's implementation of the national Coastal Zone Management Program. The OCMP includes enforceable policies that are drawn from statutes, administrative rules, statewide planning goals, and local comprehensive plans and land use regulations. It provides for review of certain Federal action to ensure consistency with Oregon's interests. ODFW's Wildlife Policy and Food Fish Management Policy, among others, are part of the state's enforceable policies under the Federal Coastal Zone Management Act. The DLCD reviews Federal fishery regulations, including those recommended by the Council, for Federal consistency.

The Oregon Territorial Sea Plan (1994), which consists of goals and policies that guide the management of resources within the territorial sea, is also managed by the Oregon DLCD. The Territorial Sea Plan provides an ocean management framework, and identifies the process for making resource use decisions. Notable elements include a rocky shores management strategy, and the identification of uses, including ocean energy, of the seafloor and the territorial sea. State agencies with jurisdiction over ocean activities implement policies in the Plan under their own regulatory and management programs.

#### 3.5.4.5 California Fisheries Management

California fisheries management is guided by laws established by the California Legislature in the Fish and Game Code as well as Public Resources Code. The Legislature also delegates some authority to the Fish and Game Commission (FGC) which establishes regulations in Title 14, California Code of Regulations. Established in 1870, The FGC is the oldest conservation agency in the United States, predating even the U.S. Commission of Fish and Fisheries. The FGC is composed of five commissioners appointed by the governor and confirmed by the Senate. The full FGC regularly meets six times per year to address resource issues and adopt management measures, and they may schedule additional special meetings to gain information on specific issues or take emergency actions. Within the California Natural Resources Agency, the California Department of Fish and Wildlife (CDFW) is the lead agency charged with implementing laws and regulations and ensuring sustainable use of fish and wildlife.

The California Marine Life Management Act (MLMA) of 1998 is California's primary fisheries management law. It introduced a new paradigm in the management and conservation of California's living marine resources. The MLMA was developed in part based on many of the tenets of the MSA. The MLMA's overriding goal is to ensure the conservation, sustainable use, and restoration of California's living marine resources, including the conservation of healthy and diverse marine ecosystems. Through the MLMA, the Legislature delegated greater management authority to the FGC and CDFW. Key features of the MLMA include:

- Application to entire ecosystems, rather than only to exploited marine resources, with an over-arching priority of resource sustainability.
- Recognizing the state's resources for their use benefits, aesthetic and recreational enjoyment, and value for scientific research and education.
- Shifting the burden of proof for needed action towards initially demonstrating that fisheries and other activities are sustainable, rather than requiring demonstration of harm to initiate action.
- Encouraging an ecosystem-based approach to management rather than focusing on single fisheries, and the development of FMPs as the framework for management – initially specifying development of FMPs for the nearshore fishery and white seabass.
- Requiring development of a master plan that prioritizes fisheries according to the need for comprehensive management through FMPs.
- Recognizing the importance of habitat by mandating its protection, maintenance, and restoration.
- Minimizing bycatch and rebuilding depleted stocks.

- Emphasizing science-based management developed in collaboration with all interested parties so that stakeholders are more involved in decision-making and all aspects of management.
- Recognizing the long-term interests of people dependent on fishing; adverse impacts of management measures on fishing communities are to be minimized.
- Annual reporting on the status of the state's resources and their management.

The MLMA directs CDFW to develop a Master Plan to guide its implementation. The original Master Plan, adopted in 2001, was updated in 2018 to reflect new priorities and emerging management strategies for achieving the MLMA's goals, and to better describe CDFW's inclusion of MLMA principles in management decisions (CDFW 2018). The 2018 Master Plan is both a roadmap and a toolbox for implementation, providing guidance and direction in the following areas:

- Prioritization of management efforts – The Master Plan includes an interim list of prioritized species for management action and describes a more comprehensive approach to prioritization within a framework for MLMA-based management.
- Meeting stock sustainability objectives – The Master Plan identifies tools and approaches available to help consider and identify the most appropriate management strategies for achieving sustainability.
- Meeting ecosystem objectives – The Master Plan provides a stepwise approach to consider and address these issues.
- Integrating marine protected areas (MPAs) into fisheries management – Consistent with California's Marine Life Protection Act of 1999, the Master Plan provides information to consider to account for MPAs when attempting to meet stock and ecosystem-related objectives.
- Adapting to climate change – The Master Plan identifies that climate change needs to be factored into species prioritization, scaled management, identification of appropriate management strategies, adaptive management structures, and understanding the effects of management on fishery economics and communities.
- Engaging stakeholders and collaborating with partners – The Master Plan provides guidance on considering and crafting potential public engagement and identifies a range of areas where collaboration may be beneficial and the conditions necessary to ensure collaborations are effective.
- Advancing socioeconomic and community objectives – The Master Plan describes key socioeconomic questions and identifies strategies for obtaining related information as part of Master Plan implementation.
- Making management adaptive – The Master Plan identifies a range of structures, strategies, and recommendations for meeting the MLMA's adaptive management policy.
- Using the best available scientific information - The Master Plan identifies tiers of potential scientific review and considerations for identifying when each may be appropriate.
- Enhancing and scaling MLMA-based management – While FMPs remain an important tool for achieving the objectives of the MLMA, other tools such as ESRs, targeted rulemakings, and more streamlined FMPs can also be used. The Master Plan describes a continuum of management to make more efficient and effective use of available tools and resources to implement the MLMA across a wider range of California's fisheries.
- Ensuring the Master Plan is an effective resource and guide – The Master Plan describes the use of a new, online, publicly-accessible and user-friendly "living" library for California's state-managed fisheries information and the policies and tools of the Master Plan called the California Marine Species Portal. The goal is to organize and share the considerable research and

management efforts of CDFW and its partners, provide management resources and tools, and implement the new strategies described in the Master Plan.

#### 3.5.4.6 Idaho Fisheries Management

Idaho formerly contained some of the Columbia River basin's most productive habitats for anadromous fishes, although it is landlocked (Mallett 1974; Waples*, et al.* 1991). Most of the watershed of the Snake River, the Columbia River's largest tributary, lies in Idaho. Anadromous fishes found in Idaho include Chinook Salmon (spring, summer, and fall runs), steelhead, sockeye salmon, coho salmon, Pacific lamprey, and white sturgeon. Dam building, overfishing, and habitat destruction have taken their toll on these fish populations. The Snake River fall Chinook run was about 72,000 in the 1940s and about 29,000 in the 1950s. Historically, the Snake River spring/summer Chinook run exceeded 1 million fish, but was reduced to near 100,000 fish by the mid-1950s (Mathews 1991). Further declines followed construction of hydroelectric dams in the Snake and Columbia rivers, although considerable high quality spawning and rearing habitat remains in Idaho. Coho salmon were declared extirpated in 1986. Sockeye salmon were listed as endangered under the ESA in 1991, followed by listings of threatened for Chinook salmon (1992) and steelhead (1997). These listings have prompted a number of management initiatives that affect Idaho and Columbia River fisheries.

Current anadromous fish management programs in Idaho (IDFG 2019) include hatchery programs intended to mitigate for dam construction, habitat restoration, and management of fisheries to minimize risk to ESA-listed fish. Idaho also works collaboratively with Federal regulatory agencies, tribes, and other states to seek management of rivers to improve migratory conditions. Idaho hatcheries support fisheries within Idaho and downstream to the mouth of the Columbia River. The Nez Perce Tribe reintroduced coho salmon to Idaho in 1995, accompanied more recently by translocated adult lamprey into selected Idaho streams. Over 50 percent of Idaho's streams inhabited by salmon and steelhead are located within roadless areas, designated wilderness, or Wild and Scenic Rivers; therefore, habitat restoration has focused on selected areas impacted by agricultural or forestry practices.

Annual abundance of anadromous fishes in Idaho during recent years varies widely due to a combination of ocean and migratory conditions. Runs of naturally reproducing salmon and steelhead in Idaho have generally improved since historic low abundances experienced in the mid-1990s, but they are still much lower than the 1960s and early 1970s. In the last 20 years, most hatchery programs in Idaho have matured in terms of their smolt releases. However, programs for fall Chinook, coho, and sockeye have begun producing larger returns. For all species, abundance has been dominated by returns of hatchery fish, which typically compose greater than 75 percent of the run.

Anadromous fisheries in Idaho have similarly fluctuated in recent years. The Idaho Department of Fish and Game manages sport fisheries for Chinook salmon and steelhead to minimize incidental take of ESA-listed wild fish and ensure adequate return of hatchery fish for brood stock needs. The Nez Perce and Shoshone-Bannock tribes also pursue these anadromous fishes within Idaho. With the exceptions of fall Chinook and coho salmon, sport fisheries are mark-selective; only fish without an adipose fin may be harvested in Idaho sport fisheries. Tribal fisheries are not mark-selective. After accounting for the number of spawners needed to fully seed hatcheries, the surplus production is allocated equally between sport and tribal fisheries. Steelhead are usually more stable in their abundance. There have been peaks in the 2001-2002, 2009-2010, and 2014-2015 run years. Idaho's adult steelhead generally leave the ocean between June and October and are caught in state and tribal fisheries in the lower Columbia River. They are caught in fisheries in Idaho from mid-July through April. Reaches open to fishing include the Snake River downstream of Hells Canyon Dam, the main stems of the Clearwater and Salmon Rivers, and a few selected tributaries. Statewide harvest has been >40,000 fish during 2001-2016. Beginning in 2017, harvest opportunities have been curtailed as run sizes have dropped precipitously.

Spring/summer Chinook are more variable than steelhead. There have been peaks in 2001, 2010, and 2015. Spring and summer Chinook from Idaho are rarely harvested in the CCE but are the focus of extensive fisheries from the Columbia River mouth and upstream. In Idaho, continuous reaches are open to fishing in the Snake River downstream of Hells Canyon, the Clearwater River and its major tributaries, the South Fork Clearwater, North Fork Clearwater, Middle Fork Clearwater, and Lochsa Rivers, because of the absence of ESA-listed fish. In the Salmon River drainage, fisheries are more restrictive to minimize impacts to ESA-listed fish. Portions of the Little Salmon and South Fork Salmon Rivers have been open to fishing. As abundances increased after 2001, portions of the lower and upper Salmon River have opened as well. Peak statewide harvest was greater than 40,000 fish in 2001; however, in some recent years harvest has been less than 1,000 fish.

Fall Chinook in the Snake River have increased after 2006. There have been peaks in 2010 and 2014. The main fisheries for Idaho-reared fall Chinook are in the ocean and lower Columbia River, with total exploitation rates of 40 percent to 50 percent (Ford*, et al.* 2010). In Idaho, fisheries targeting fall Chinook salmon have occurred annually since 2013. Fisheries have been held in the mainstem Clearwater, Snake, and lower Salmon rivers with a total of 176 km of river open to fishing from September 1 through October 31 each year. A small section of the Snake River near Hells Canyon Dam remains open each year until mid-November. Annual harvest from 2013-2019 averaged 1,161 fish (range: 470-2,700) and anglers spent an average of 75,597 hours (range: 40,974-119,868) fishing for fall Chinook salmon. In 2019, approval of the Fisheries Management and Evaluation Plan (FMEP) for fall Chinook salmon by NMFS allowed the harvest of unclipped adult fall Chinook and additional areas were opened to fishing, bringing the number of river kilometers open to fishing up to 313 km.

Coho salmon in the Snake River have also increased after 2006. More than 5,000 adults have passed Lower Granite Dam in 2011, 2014, 2017, and 2019. Coho salmon seasons have been intermittent but have occurred in 2014, 2017, and 2019. Coho fishing has been open in the mainstem Clearwater and North Fork Clearwater rivers. Seasons typically open in early October and usually last into mid-November.

Annual coho harvest ranged from 26 to 150 fish and anglers spent an average of 14,365 hours (range: 3,317-27,130) fishing for coho.

White sturgeon maintain landlocked populations in the Snake River downstream of Shoshone Falls and the Kootenai River. The Kootenai population is protected as endangered under the ESA. Two reaches of the Snake River maintain viable naturally reproducing populations: Bliss Dam to C.J. Strike Reservoir and Hells Canyon Dam to the Lower Granite Dam Reservoir. Sturgeon have been introduced in the Snake River above Shoshone Falls upstream to the city of Idaho Falls. The Snake River in Idaho waters supports a catch-and-release fishery with conservative regulations.

Anadromous fisheries are important to Idaho. Salmon and steelhead fisheries generate well over $100 million in spending in good years. Much of the spending occurs in rural areas of the state, where it can be significantly beneficial to local economies. The 2001 Chinook fishery, which was an exceptional return year, generated an estimated $90 million in a period of weeks. The City of Riggins received an estimated $10 million in spending, which comprised about 25 percent of the total spending in Riggins that year. According to a 2011 survey, anadromous fisheries can generate over $5 million in state and local tax revenue. These fiscal metrics illustrate that salmon and steelhead fisheries are consequential to the economic and social well-being of Idaho communities.

### *3.5.5 Multi-State, Multi-Tribe, and State-Tribe Entities*

In addition to the Council process, there are West Coast multi-state or state-tribal natural resource management processes that affect fisheries management within the CCE.

#### 3.5.5.1 Pacific States Marine Fisheries Commission

The Pacific States Marine Fisheries Commission (PSMFC) is an interstate compact agency that helps resource agencies and the fishing industry sustainably manage Pacific Ocean resources for its member states: California, Oregon, Washington, Idaho, and Alaska. PSMFC has no regulatory or management authority, but does provide for collective participation by member states on topics of mutual concern and offers a forum for discussion and consensus-building. Its primary purpose is to promote and support policies and actions to conserve, develop, and manage these fishery resources. It coordinates research activities, monitors fishing activities, and facilitates a wide variety of projects. PSMFC staff collect data and maintain databases on salmon, steelhead, and other marine fish for fishery managers and the fishing industry.

#### 3.5.5.2 North of Falcon Process

The "North of Falcon" process is an annual salmon management planning process involving representatives from salmon treaty tribes, the states of Washington and Oregon, and the Federal government. The process addresses salmon management north of Cape Falcon, Oregon, and supports the Council's annual salmon management process by providing a series of advance public discussions of alternatives for the coming year's salmon seasons. Early each calendar year, North of Falcon process participants review new science and management information from prior years' salmon fisheries. This process allows managers to both prepare for Council action in March and April to set the year's salmon season parameters, and to prepare for shifts in state- or tribe-specific regulations intended to keep the applicable fisheries within their allocations.

#### 3.5.5.3 Intertribal Fisheries Commissions

The Northwest treaty tribes of Washington and Oregon formed two commissions in the mid-1970s to pursue common objectives and provide coordinated services to their memberships. The Columbia River Inter-Tribal Fish Commission was formed by agreement among the Warm Springs, Yakama, Umatilla, and Nez Perce tribes in 1977. The Northwest Indian Fisheries Commission was formed in 1976 by its 21 member tribes (Lummi, Nooksack, Swinomish, Upper Skagit, Sauk-Suiattle, Stillaguamish, Tulalip, Muckleshoot, Puyallup, Nisqually, Squaxin Island, Skokomish, Suquamish, Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, Makah, Quileute, Hoh, and Quinault). The commissions are governed by their member tribes, which appoint commissioners to develop policy and guidance for their operations. All actions and policies created are by unanimous consent of the membership. The commissions do not possess inherent, sovereign authority and provide mostly coordinating, advisory, and technical services to support tribal natural resources management efforts.

### *3.5.6 International Science and Management Entities*

For FMP species, the U.S. is a party with Canada in three treaties addressing fisheries for transboundary stocks: Pacific salmon, Pacific whiting, and North Pacific albacore. The U.S. is also a party with Canada in the Pacific Halibut Convention. Pacific Halibut is not an FMP species, meaning that the Council does not have MSA-level authority over the Pacific halibut stock or fisheries. However, halibut is taken as bycatch in some FMP fisheries and the Council has a Catch Sharing Plan for Pacific halibut taken off the U.S. West Coast. In addition, the U.S. is a party to several multi-lateral treaties addressing fisheries for HMS FMP species, and is a party to several agreements to conserve marine resources worldwide.

Bilateral entities and agreements:

- International Pacific Halibut Commission, implementing the Pacific Halibut Convention between the U.S. and Canada;

- Pacific Salmon Commission, implementing the Pacific Salmon Convention between the U.S. and Canada;
- Agreement between the Government of the United States of America and the Government of Canada on Pacific Hake/Whiting;
- Treaty between the Government of Canada and the Government of the United States of America on Pacific Coast Albacore Tuna Vessels and Port Privileges.

Multilateral entities and conventions:

- North Pacific Anadromous Fish Commission, implementing the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean (Canada, Japan, Russia, and the U.S.);
- Inter-American Tropical Tuna Commission, implementing the Convention for the Establishment of an Inter-American Tropical Tuna Commission and the Antigua Convention (Belize, Canada, China, Colombia, Costa Rica, Ecuador, El Salvador, the European Union, France, Guatemala, Japan, Kiribati, Korea, Mexico, Nicaragua, Panama, Peru, Chinese Taipei, U.S., Vanuatu, and Venezuela, with the Cook Islands as a Cooperating Non-Member);
- Western and Central Pacific Fisheries Commission, implementing the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the western and central Pacific Ocean (Australia, China, Canada, Cook Islands, European Union, Federated States of Micronesia, Fiji, France, Japan, Kiribati, Korea, Republic of Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Chinese Taipei, Tonga, Tuvalu, U.S., and Vanuatu. American Samoa, Guam, French Polynesia, New Caledonia, Tokelau, Wallis, Futuna, and the Commonwealth of the Northern Mariana Islands are Participating Territories, with Belize, Indonesia, Panama, Senegal, Mexico, El Salvador, Ecuador, Thailand, and Vietnam as Cooperating Non-members;
- North Pacific Fisheries Commission, implementing the Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean (Canada, China, Chinese Taipei, Japan, South Korea, Russia, the U.S. and Vanuatu, with Panama as a Cooperating Non-member);
- North Pacific Marine Science Organization, implementing the Convention for a North Pacific Marine Science Organization (Canada, Japan, China, South Korea, Russia, and the U.S.);
- International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, scientific initiative to support international HMS management (Canada, China, Chinese Taipei, Japan, South Korea, Mexico, and the U.S.);
- Tri-National Sardine and Small Pelagics Forum, scientific initiative for ecosystem-wide stock assessments (Canada, Mexico, and the U.S.).

# Chapter 4 Environmental Change, Human Activities, and Social-Ecological Dynamics in the California Current Ecosystem Overview

This chapter broadly examines how human and environmental forces interact to affect living marine resources and fisheries communities. For those effects that can be addressed by fishery management measures, the Council can consider, improve, and integrate the information that supports decision-making across its FMPs. Ultimately, the Council could use this FEP chapter to inform fishery management measures that help buffer against uncertainties resulting from those effects, and that support adaptive management that promotes sustainable fisheries within the California Current and for its fishing communities.

Chapter 4 builds on Chapter 3, by considering the complex interactions within the CCE, including the physical environment, biological environment, and the social and economic environment. In this chapter, we examine the interacting effects of human and environmental forces through the lens of the FEP's Goals and Objectives, provided in Chapter 1. As detailed in Table 4-1, below, Sections 4.1 through 4.6 discuss the major components of the CCE interactions and their influences on each other in the same order as they were addressed in Chapter 3, from the physical environment, then the biological environment from lowest trophic levels to highest, to the social and economic environment, and then to the Council's administrative processes within the fisheries regulatory regime.

**Table 4-1. Cross-referencing Sections 4.1-4.6 to FEP Goals.**

| Chapter 4 Section | FEP Goal |
|---|---|
| Section 4.1, Effects of Climate Variability and Change on the CCE (physical ocean processes and environment) | Goal 6: Promote fishery management that is sufficiently adaptive to account for the effects of climate variability and change, ocean acidification, marine heat waves, harmful algal blooms, and hypoxia. |
| Section 4.2, Shifts in Species' Abundance and Distribution and their Ecological Relationships (fish stocks, biological environment) | Goal 2: Conserve and manage species' populations and the ecological relationships among them to realize long-term benefits from marine fisheries while avoiding irreversible or long-term adverse effects on fishery resources and the marine environment. |
| Section 4.3, Effects of Human Activities on Marine Habitats (physical environment and habitat) | Goal 4: Protect and restore marine habitat diversity and integrity to the extent practicable. |
| Section 4.4, Interactions between Fisheries and Protected Species (protected species, biological environment) | Goal 5: Manage fisheries to support goals for protected species' recovery. |
| Section 4.5, Effects of Fisheries Management on Ecosystem Services and the Well-being of West Coast Communities (communities, social and economic environment) | Goal 3: Implement fisheries management that ensures continued ecosystem services for the wellbeing of West Coast communities and the nation. |
| Section 4.6, Framework and Public Forum for Ecosystem Information used in Council | Goal 1: Provide a framework and public forum to improve and integrate ecosystem information for use in Council decision-making. |

| Chapter 4 Section | FEP Goal |
|---|---|
| Decision-Making (fisheries management process) | |

### 4.1 Effects of Climate Variability and Change on the CCE

The Council's interest in our changing environment is articulated in FEP Goal 6: *Promote fishery management that is sufficiently adaptive to account for the effects of climate variability and change, ocean acidification, marine heat waves, harmful algal blooms, and hypoxia.* Climate change caused by greenhouse gas emissions, and interactions between natural and human-altered climate variability and extreme events are affecting marine ecosystems, often in unpredictable ways (Checkley Jr.*, et al.* 2017; Wuebbles*, et al.* 2017). Novel ocean conditions can bring different species (Jacox*, et al.* 2020), new risks (Santora*, et al.* 2020), and new opportunities (Smith*, et al.* 2020) to the ecosystem. These changing ocean conditions will challenge the ability of species and fisheries to track and take advantage of changes in habitat, shifts in their prey, and target populations (Abrahms*, et al.* 2021). Consistent monitoring of and reporting on these trends will help the Council to meet FEP Objective 6a: *Improve monitoring of the ecosystem and climate variability.*

Average sea surface temperature in the CCE is predicted to increase by 0.36°C per decade in the 21st century, with the greatest increase occurring in summer and a slight shift in the seasonal warming cycle to later in the year. Water temperature along the west coast of North America displayed the highest 3-year average on record between 2014 and 2016 (Jacox*, et al.* 2018), and conditions similar to the recent marine heatwaves will become increasingly common in ensuing decades (Jacox*, et al.* 2020).

The CCE is also experiencing ocean acidification more rapidly than the global average, with the nearshore and northern/central regions experiencing the most severe and persistent acidification (Feely*, et al.* 2008; Osborne*, et al.* 2020). Direct effects of warming and ocean acidification on living habitats (see Section 4.3) used by Council-managed species, especially in their early life histories, may indirectly modify expectations for stock-recruitment functions.

Oxygen levels throughout the water column are projected to decline further from current levels, and hypoxia is a growing concern in parts of the CCE. Ocean warming; increased upwelling of nutrient-rich, low oxygen deep waters (particularly in the northern California Current); and increased stratification can all have synergistic effects (Christian and Ono 2019, and references therein). Hypoxic and anoxic conditions may affect how and where target species may be caught, with influences on catch per unit effort and the potential for local depletion.

These and other physical and biogeochemical changes will produce direct and indirect effects on species and food webs in the CCE (Ainsworth*, et al.* 2011; Marshall*, et al.* 2017). For example, warming events that directly benefit harmful algae will indirectly elevate the mortality rates of marine mammals like pinnipeds that bioaccumulate the biotoxins found in their prey. This food web impact could cause consequent reductions in mammal predation rates on Council-managed species, at least in the short term. In contrast, accumulation of warmer onshore water masses may directly influence the movement of HMS, increasing their availability to fisheries in the CCE. Tracking species' productivity and distribution responses to environmental shifts and expanding scientific work on food webs addresses aspects of Objectives 6b and 6c, respectively*: Incorporate climate and ecosystem data into stock assessments and forecasts when applicable*; and *Assess the effects of climate variability and change on the ecosystem's long term stability and recommend research needed to understand the effects of potential shifts in species' abundance and distribution*.

It is important to note that ecosystem responses to warming may be nuanced and unexpected (Checkley Jr., *et al.* 2017). The anchovy population increase during the 2014-2016 marine heatwave is a prime example. Anchovy were previously believed to thrive under cold conditions (Chavez, *et al.* 2003; Siple, *et al.* 2020), but this species displayed very high recruitment in 2015 and had historically high spawning stock biomass by 2018 (Thompson, *et al.* 2019). The high anchovy biomass resonated throughout the ecosystem, with increased survival and reproduction of marine predators that feed on anchovy (e.g., sea lions). Similarly, recruitment of several rockfish species was historically high during the 2014-2016 marine heatwave even though recruitment had been historically low under warm conditions (Schroeder, *et al.* 2018). Our understanding of species' responses to marine heatwave conditions is evolving, and the Council will need multiple avenues, including stock assessments and other forecast tools (Objective 6b) for learning about how the ecosystem is affected by novel environmental conditions and anticipating future responses.

Climate-driven shifts in marine species distributions (Objective 6c) are increasingly documented worldwide and are mainly attributed to changes in temperature, oxygen, and food availability (Pinsky, *et al.* 2020). These shifts are often manifested as a poleward expansion in a species' range, a latitudinal change in a population's mean location, or movement to deeper offshore waters. In the CCE, several studies have documented or developed projections of changes in species' spatial distributions in response to climate variability (e.g., sardines, Kaplan, *et al.* 2016; Pacific whiting, Malick, *et al.* 2020; Morley, *et al.* 2018; Navarro, *et al.* 2018; groundfish, Pinsky, *et al.* 2018; salmon, Shelton, *et al.* 2021; Thorson, *et al.* 2016), although to date this work has been limited to a small suite of stocks. Less is known about how marine fauna and fishery resources will respond to long-term directional changes in climate and ocean conditions (Hazen, *et al.* 2013), although the growing number of studies elucidating the impacts of the 2014-2016 marine heatwave on the CCE can help advance our understanding (Brodeur, *et al.* 2019a; Brodeur, *et al.* 2019b; Sanford, *et al.* 2019; Santora, *et al.* 2017b; Santora, *et al.* 2020; Thompson, *et al.* 2021; Thompson, *et al.* 2019). There are likely to be commercially fished species spending less time within the CCE but also new species that may interact with existing fisheries or provide new fishing opportunities in the future (Pinsky, *et al.* 2020).

To meet the objectives of FEP Goal 6, we will need to rely upon additional forward-looking tools, including but not limited to species distribution models, to consider climate-ready management approaches (Holsman, *et al.* 2017; Pinsky and Nathan 2014) that facilitate adaptation to both extreme events and long-term changes in the CCE. Climate vulnerability assessments provide an expert-based approach to identify species, populations, and fishing communities most at risk from climate variability and change (Colburn, *et al.* 2016; Crozier, *et al.* 2019; Hare, *et al.* 2016). Seasonal- to decadal-forecasts of ocean conditions in relation to the distributions of Council-managed species can provide pre-season guidance on where and how much to fish (Kaplan, *et al.* 2016; Tommasi, *et al.* 2017a; Tommasi, *et al.* 2017b). Climate-informed management strategy evaluation (MSE) approaches use climate variables to inform recruitment estimates for both scenario testing and quota setting, and have been used to develop climate-informed stock assessments (e.g., sablefish, Tolimieri, *et al.* 2018; petrale sole, Pacific whiting, ). Changes in environmental conditions may cause threshold changes in forecast performance for Council-managed salmon (Satterthwaite, *et al.* 2020), and this phenomenon may be common for other Council-managed species and stocks as well. These approaches and others will underpin efforts to assess ecosystem response to and recovery from climate stress, and to improve and integrate information that supports decision-making across Council FMPs by buffering against uncertainties and supporting greater long-term stability within the CCE for its fishing communities.

## 4.2 Species' Abundance and Distribution and their Ecological Relationships

Goal 2 of this FEP is to: *Conserve and manage species' populations and the ecological relationships among them to realize long-term benefits from marine fisheries while avoiding irreversible or long-term adverse* *effects on fishery resources and the marine environment*. Population dynamics are driven by changes in four demographic rates: births, deaths, immigration, and emigration. The balance of changes in these rates, and spatiotemporal variation in them, determine local abundance as well as relative abundance through space (distributions). Changes in demographic rates of fished species are affected by at least four major factors: 1) removals by fishing (targeted or incidental catch) and consequent changes in community structure and energy flow/predation within ecosystems; 2) removals or habitat loss from non-fishing activities, often with greater impacts in freshwater, estuarine, and nearshore systems; 3) species interactions (including predation, competition, parasitism, and disease); and 4) shifts in climate that lead to both direct and indirect changes in productivity, including indirect effects such as changes in the abundance of prey or predators. Any and all of these effects can have cascading and cumulative impacts on ecosystem structure and energy flow in marine ecosystems that could lead to unexpected changes or surprises with respect to marine resource and fisheries management activities. Consistent monitoring and reporting of species population dynamics and the associated drivers of these trends will help the Council to meet FEP Goal 2.

Shifts in species distributions and overlap can lead to reorganizations of ecological communities, resulting in broken and novel interactions (Carroll*, et al.* 2019; Gilman*, et al.* 2010). These reorganizations can occur regardless of the mechanism driving distribution shifts, and can cause cascading effects such as changes in predation and competition dynamics, prey switching, and ecological release. Taken together, all of these changes can alter the abundance of predator and prey populations (Carroll*, et al.* 2019 and references therein; Gilman*, et al.* 2010) and will affect fisheries operating within the ecosystem. Tracking and identifying drivers of trophic relationship change within the CCE will assist in achieving the FEP Objective 2a: *Map trophic energy flows and other ecological interactions within the CCE to better understand trophic relationships and the potential ecosystem effects of fishing, and to understand the effects of trends in marine mammal, seabird, and other protected species' populations and diets on fish stock abundance.*

Importantly, a unifying theme among studies that have examined ecosystem responses to climate and human pressures is that we should not expect ecological communities to remain the same over time and space, but rather anticipate and manage for constant change. This theme implies that the identities of target species in any one location may change, such that some fishing opportunities diminish while others flourish. Nonetheless, to meet FEP Goal 2, it is important that fishing and other human activities occur in a way that does not erode the resilience (i.e., ability to absorb disturbance and reorganize to retain similar structure and functions by persisting through or rebounding from the disturbance) of the CCE overall, and does not result in an undesirable state. Although climate variability and climate anomalies have had measurable effects on the CCE food web in recent years, historic patterns of fisheries harvest have also triggered ecosystem responses. Below, we offer four examples of the interaction between changing ecosystem conditions and fishery dynamics.

The Council's 21st century efforts to rebuild the CCE rockfish populations that occupy low trophic levels as juveniles and mid-to-high trophic levels as adults, have had effects throughout the ecosystem. In the CCE, juvenile rockfishes are a common offshore prey item of common murres; however, when rockfish are less available due to unfavorable ocean conditions, murres forage closer to shore for northern anchovies. This also leads to seabirds consuming higher quantities of the out-migrating juvenile Chinook salmon that also occupy nearshore waters, which in turn significantly affects salmon survival (Wells*, et al.* 2017). Such unintended consequences or ecological surprises are likely to arise with changing ocean conditions and may be exacerbated during extreme climate perturbations.

During the 2014-2016 marine heatwave (which coincided with a large El Niño event), CCE phytoplankton production was abnormally low and taxa were generally redistributed farther north than usual. Despite generally lower phytoplankton productivity and biomass during the 2014-2016 marine heatwave, diatoms in the genus *Pseudo-nitzschia*, which release toxic domoic acid, thrived along much of the west coast of North America. (Bates*, et al.* 2018). Zooplankton responded to warmer CCE waters with decreased abundance and smaller body sizes of common krill species (Brodeur, *et al.* 2019a; McClatchie, *et al.* 2016) and abundance of more tropical krill species increased in the southern CCE (Lavaniegos, *et al.* 2019; Peterson, *et al.* 2017). Also, higher abundances of market squid were observed off the coast of Oregon and Washington and the increase in market squid landings in Oregon during this time reflects the temperature-driven change in abundance, combined with the highly mobile and experienced squid fishing fleet (Chasco, *et al.* In Review).

Responses to the marine heatwave were less predictable at higher trophic levels. For example, overall larval abundances of forage fish were very high, the assemblage was largely made up of species that are typically found to the south and offshore, and species such as Pacific sardine (*Sardinops sagax*) were observed for the first time spawning in the winter off Oregon (Auth, *et al.* 2018). Atypically, northern anchovy (*Engraulis mordax*) (Thompson, *et al.* 2019) and multiple rockfishes (Schroeder, *et al.* 2018) that previously flourished under cold conditions had extremely high recruitment from 2014-2016, and adult abundances of anchovy rose to record highs in subsequent years (Thompson, *et al.* 2019). Although we typically think of increased forage availability as a positive environmental change for higher-order predators, even favorable changes in the environment can bring new challenges for natural resource management. When anchovy and sardine populations are larger, their distribution can be quite different from our more recent experiences with those populations (see section 4.3). These shifts in distribution and abundance of lower trophic level species often lead to shifts in distribution of higher trophic level species, with possible additional effects on timing and location of fisheries' catch and bycatch.

The recent surge in anchovy resonated with multiple marine predators. California sea lions (*Zalophus californianus*) fed copiously on anchovy beginning in 2015 and had much enhanced pup condition from 2015-2018 (Thompson, *et al.* 2019). Humpback whales (*Megaptera novaeangliae*) were closer to shore than usual, following shifts in anchovy (Santora, *et al.* 2020). Unfortunately, this caused an increase in reported and confirmed whale entanglement rates in Dungeness crab (*Metacarcinus magister*) fishing gear, which resulted in whale mortality and intermittent closures of the fishery (Santora, *et al.* 2020). Catch of Pacific bluefin tuna (*Thunnus orientalis*) by the commercial passenger fleet off California was very high during the marine heatwave while the tuna foraged on anchovy (Runcie, *et al.* 2019).

These shifts in fisheries' timing, location, and bycatch challenges are linked to Objective 2b of the FEP: *Assess variability in fisheries income and vessel participation rates to ascertain whether CCE fishing rates have affected long-term stability and well-being for fishing communities*. Rigorous analysis of the interplay between exploitation rates, changes in stock abundance, and feedback to fishing communities (such as has been conducted for Alaska salmon; Cline et al. 2010) is a monumental task and a priority research and data need (Anderson, *et al.* 2017b; Beaudreau, *et al.* 2019; Cline, *et al.* 2017; Schindler and Moore 2019). The FEP addresses fishing community well-being in Section 4.5 and discusses variability in fisheries income and vessel participation rates in Section 3.4. The Council receives regular reporting on fisheries income and vessel participation rates in SAFE documents for each FMP and in the ESR for West Coast fisheries combined.

## *4.3 Human Activities and Marine Habitats*

Goal 4 of this FEP addresses marine habitats: *Protect and restore marine habitat diversity and integrity to the extent practicable*. Under the MSA, the Council is responsible for identifying EFH, "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C.§1853(a)(7)). The Council is also responsible for ensuring that its FMPs include measures to mitigate the effects of fishing on EFH, and for making recommendations and comments on non-fishing activities affecting EFH to other state and Federal agencies authorizing such activities (16 U.S.C. §1855(b)(3)). Much of the Council's Habitat Committee's workload involves monitoring and commenting on non-fishing activities that may affect EFH – see Table 4-2.

Aside from the direct consequences of mortality to the target populations themselves, the effects of fishing gear on marine habitat, particularly benthic marine habitat, is thought to be among the most significant impacts of fishing on the marine environment (Barnett*, et al.* 2017b; Mazor*, et al.* 2021; McConnaughey*, et al.* 2020). Although virtually all fishing gear can affect the structure and biota of a given bottom habitat, the significance of the impact can be difficult to fully predict and quantify. There are natural background levels of disturbance to all types of benthic communities as a consequence of large-scale activities such as storms, wave action, tidal currents, and geological events, as well as smaller-scale actions such as bioturbation or predator feeding activities (Hall 1994; Kaiser*, et al.* 2002). Consequently, shallow habitats are typically subject to greater natural disturbance than deeper habitats, such that the biota in such habitats may be more resilient to certain levels of disturbance than those in deeper or less-disturbed habitats. For fishing activities to have ecologically significant impacts, the disturbance must exceed the baseline level and frequency of the natural disturbance regime (Kaiser*, et al.* 2002; Mazor*, et al.* 2021). Where fishing does exceed the baseline level of disturbance, the severity of fishing impacts mainly depend on the extent of the disturbance, the complexity of the habitat substrate, and the configuration and towing speed of the gears (Collie*, et al.* 2000). For example, depending upon the habitat type, intensive but spatially-localized disturbance may have relatively lower ecological impacts than more infrequent but widespread fishing disturbance (Kaiser 1996).

Many Council-managed species, especially groundfish and salmon, rely on nearshore living habitats such as kelp and eelgrass during critical portions of their life histories. For example, many juvenile rockfishes and salmon use kelp and eelgrass habitat to find food and shelter, long before they recruit to fisheries. Giant kelp is subject to commercial harvest in California, and both kelps and eelgrasses are influenced by a variety of coastal activities, from development of structures to nutrient pollution. Indeed, these habitats serve as a biophysical bridge between human activities on land and those at sea. Kelps and eelgrass vary substantially in areal extent and other characteristics. In some areas their abundance has seen a long-term decline (e.g., Harenčár*, et al.* 2018; Reed*, et al.* 2016), often in response to environmental perturbations such as marine heat waves and storms (e.g., Reed*, et al.* 2011; Rogers-Bennett and Catton 2019). Protection and restoration efforts for these living habitats are ever-evolving, and require an understanding of the role of climate, trophic interactions, fishing, and other human activities to be successful. More generally, these observations about dynamic pelagic and nearshore habitats underscore how a static concept of EFH is fraught; habitats are spatially and temporally dynamic and so protection measures subject to a set-it-and-forget-it approach will miss their mark.

Salmon are most vulnerable to climate change at the margins of their range (Southern and Central California, interior stocks, Crozier*, et al.* 2019) which may lead to range contraction. Current commercially important salmon stocks in CCE fisheries (coho and ocean-type Chinook) are fall-migrating; therefore, climate variability will most likely affect their juvenile phases. Some stock-specific redistribution in the ocean is possible as sea surface temperature changes (Shelton*, et al.* 2021). Other likely effects of climate change on CCE salmon populations include increasing synchrony among stocks (Dorner*, et al.* 2017; Kilduff*, et al.* 2015), shifts in ocean distributions (Shelton*, et al.* 2021), and potential loss of estuary rearing habitat as a result of sea level rise (Thorne*, et al.* 2018). Droughts may increase vulnerability at ocean entry because of reduced river flows (Friedman*, et al.* 2019).

The recovery rate for the return of the ecosystem to a state that existed before a disturbance is an important concern when considering the effects of human activities on habitat. In some instances, altered habitat may not return to its pre-disturbance state. Activities that disturb or kill structure-forming invertebrates or vegetation have the potential to either prevent those species from recovering within the affected area within their mean generation times, or reduce the known distribution of those species (Dunn*, et al.* 2021). Activities that alter the geological structure of the ocean floor can reduce the usability of those habitats for fish and other marine species. Pelagic species may rely less on particular ocean bottom characteristics and more on water masses that expand and contract and which are defined by characteristics like temperature and current movement. Activities that alter the chemical composition, turbidity, or temperature of seawater (like those that lead to climate change and ocean acidification) such that the habitat cannot recover to its pre-disturbance state affect the usability of the water column itself and can drive changes in species' abundance and harvest availability (Hodgson*, et al.* 2018; Magel*, et al.* 2020; Marshall*, et al.* 2017).

The FEP's Objective 4a is to: *Maintain a diverse portfolio of protected habitat types in a way that meets the needs of the ecosystem and fishing communities*. Taken together, the EFH of Council-managed species ranges from the salmon streams of Idaho to the outer boundary of the U.S. EEZ. EFH for Council-managed species also ranges from the near-surface waters used by CPS and HMS, through the midwater domain of salmon and some groundfish species, down to the diverse bottom habitats used by many groundfish species. To meet Goal 4, the Council can and does implement management measures that protect marine habitat from the effects of fishing gear, but the Council has no direct authority over nonfishing activities, including the many terrestrial activities that affect freshwater and nearshore marine EFH. Of the Council's four FMPs, only the groundfish fisheries use gear that is likely to come into contact with bottom habitat, although the groundfish fisheries' rates of annual bottom contact have declined over time (Harvey*, et al.* 2020b). Gear used in the CPS, HMS, and salmon fisheries is only likely to affect habitat if it is lost at sea; therefore, the Council focuses its habitat-protection fishery management measures on groundfish fishing gear and fisheries. Fishing gear that is lost at sea, however, may affect marine organisms and habitat (Keller et al. 2010, Watters et al. 2010). Marine debris, especially plastics, produces fragments that can be ingested by many marine organisms, resulting in mortality (Browne*, et al.* 2008; Derraik 2002; Gove*, et al.* 2019; Thompson*, et al.* 2004). Marine debris in the form of lost fishing gear continues to trap and kill fish, invertebrates, seabirds, and marine mammals (Good*, et al.* 2010; Kaiser 1996) and may affect populations behaviorally by concentrating individuals both at the water's surface (Aliani and Molcard 2003) and on the bottom (Stolk*, et al.* 2007).

The Council has reviewed the non-fishing activities that may affect the EFH of the species under each of its FMPs. These reviews are not limited to ocean habitat and often consider effects of non-fishing activities within state and freshwater habitats, particularly for salmonids. More information on the Council's priorities for Federal and state agencies analyzing or permitting non-fishing activities in the California Current Ecosystem can be found in the draft *Pacific Fishery Management Council Guidance on Agency Activities in the California Current Ecosystem*.

Federal agencies are required to consult with NOAA when undertaking or permitting activities that may have adverse effects on EFH. While the Council does not have the staff or committee capacity to comment on every action that may affect EFH, in the past it has often used its Habitat Committee to provide initial reviews of large-scale non-fishing projects of particular interest or concern to the Council. In November 2019, the Council and its Habitat Committee concurred on a group of priority non-fishing actions for focused Habitat Committee review (see Table 4-2 from Agenda Item G.1.a, Supplemental HC Report 1, November 2019). In June 2021, the Council created the Ad Hoc Marine Planning Committee to track and advise it on marine planning issues and their effects on Council managed fisheries, data collection surveys, habitat, and coastal communities. Taken together, the projects that particularly attract the Council's notice tend to be large-scale energy projects that have the potential to result in the installation of man-made structures within areas designated as EFH, or any other land-based activities or planning processes that the Council believes may result in a significant loss of freshwater habitat or of the flow of freshwater itself within West Coast salmon streams.

**Table 4-2. Priority Non-Fishing Actions for Habitat Committee Focus (Agenda Item G.1.a, Supplemental HC Report 1, November 2019).**

| **Large-Scale or Otherwise Substantial Actions or Activities** |
|---|
| ● Ocean energy development<br>● Seafloor cables or pipelines<br>● Navigation channel dredging<br>● Offshore dredge material disposal sites – new or expansions<br>● Artificial reefs<br>● Shorebased energy export/import facilities (including liquefied natural gas) located on water bodies identified as EFH<br>● Shoreline modifications that may affect EFH<br>● Proposed dams and/or hydropower actions, including:<br>○ Operations/flows/spill/water storage<br>○ Management/Operation Plans, including changes to related coordination programs and conservation plans<br>○ Relicensing/decommissioning<br>○ New dams or dam removals<br>● Riparian habitat modifications<br>● Port development projects<br>● Jetty or levee construction/maintenance (e.g., nationwide structural vegetation removal)<br>● Transportation projects that cross marine or estuarine waters or major river systems (e.g., the Columbia River or the Sacramento River, San Francisco Bay)<br>● Desalination facilities<br>● Marine and estuarine aquaculture with habitat impacts<br>● Offshore geologic and geothermal exploration or mining (including sand mining)<br>● Oil and gas development<br>● Discharges of pollutants to rivers, estuaries, and ocean (thermal, outfall pipes, acidic discharges, biocide use) |
| **Policy- or Precedent-Setting Activities** |
| ● Precedent-setting technologies that may affect EFH, including those that are beneficial to EFH<br>● Major policies/rule changes that may affect EFH, including those that are beneficial to EFH and including marine spatial planning, climate and ecosystem policies, and policies /rules that affect non-Council managed species with a nexus to EFH for managed species<br>● Major program-level changes that may affect EFH (e.g., Forest Plan amendments, Army Corps of Engineers Nationwide Permits, Coastal Zone Management Plans, Northwest Power and Conservation Council, Fishery Conservation Objectives)<br>● Large-scale conservation programs and partnerships (e.g., Wild and Scenic River designations, large-scale habitat restoration, Salmon Restoration Initiative) |

The FEP's Objective 4b is to: *Promote awareness of and encourage lost fishing gear recovery projects, the development of fishing gear recovery technology, and fishing gear recycling programs as a means of protecting habitat from derelict fishing gear and ghost fishing*. Since 2005, the California Lost Fishing Gear Recovery Project has encouraged ocean users to report the presence of lost gear, and hires experienced commercial SCUBA divers to remove gear and other marine debris from near-shore waters in a safe and environmentally sensitive manner. The project continues to help reduce the potential impact of lost fishing gear and marine debris on living marine resources and underwater habitat. Other state agencies offer various programs to incentivize removal of lost and abandoned fishing gear from the ocean. The CDFW's Trap

Gear Retrieval Program, the ODFW's Post-Season Derelict Gear Recovery Program, and the WDFW's Derelict Fishing Gear Removal Project are all examples of comprehensive government programs that encourage locating, reporting, and removing harmful derelict fishing gear from the ocean. The California Fishing Line Recycling Program encourages responsible disposal of fishing line. In recent years, new companies have offered their services for recycling commercial fishing gear, primarily nets (e.g., Bureo Inc, Net Your Problem LLC, and Skagit River Steel and Recycling).

### 4.4 Interactions between Fisheries and Protected Species

Fisheries have both direct and indirect effects on protected species. Direct effects include those that occur at the same time and place as fishing activities, such as incidental catch or bycatch (Dayton*, et al.* 1995; Savoca*, et al.* 2020). Indirect effects occur when there is some intermediate cause-and-effect between the fishing activity and the actual effect being evaluated, such as reductions in prey base that serve as forage (Hunsicker*, et al.* 2010; Pikitch 2012; Pikitch*, et al.* 2014; Smith 2011). U.S. laws and regulations differentiate incidental mortality of protected, nonfish species (marine mammals, sea turtles, seabirds) from targeted harvest of those species. In terms of the overall effects, however, the same question applies – What are the ultimate effects of successive, human-caused mortality over time?

Goal 5 of the FEP is to: *Manage fisheries to support goals for protected species' recovery*. For fisheries management, meeting this goal usually means minimizing the bycatch of protected species. However, the Council has also taken a more ecosystem-based approach to this goal by thinking about indirect ways to support protected species' recovery such as through the management of their prey. An early example of this is the explicit consideration of recovering seabirds, specifically the brown pelican, into the management of northern anchovy and then subsequently the other CPS stocks. In recent years, the Council has expanded this ecosystem-based approach to this goal by prohibiting the harvest of krill and unfished forage fish species, managing Federal groundfish fisheries to minimize the incidental catch of groundfish stocks that serve as forage for protected species, managing Federal salmon and groundfish fisheries to minimize the incidental catch of Chinook stocks that serve as forage for endangered Southern Resident Killer Whales, and proposing annual abundance criteria for Chinook salmon below which directed salmon fisheries would implement specific management restrictions for endangered Southern Resident Killer Whales.

The highly dynamic CCE makes sustainable fisheries management challenging, not least because the geographic distribution of both fished species and those protected from fishing under MSA, ESA, and MMPA frequently change. In recent years, Council FMPs have grappled with management decisions related to climatic influences on bycatch of finfish (e.g., of Chinook salmon, shortbelly rockfish) and protected non-fish species (e.g., whales) alike. New disruptions, attributable to climate change, have put a punctuation mark on this challenge. Each of the Council's FMPs and the MSA itself include some variation on FEP Objective 5b: *Manage and minimize bycatch and bycatch mortality of protected species within and across FMPs to the extent practicable*.

The continued recovery of many non-fished protected species suggests that navigating interactions with protected species is likely to be a challenge for sustainable fisheries management on the West Coast for the foreseeable future (Hilborn 2020). Objective 5a of the FEP is to*: Review the status and trends of protected species' populations to facilitate understanding their role in the ecosystem within and across FMPs*. Although the Council is commonly called upon to manage fisheries to minimize interactions with protected species, it is not responsible for reviewing the status and trends of protected species' populations. A regular review of population trends for those species, possibly as a supplement to the ESR, could help keep the Council abreast of potential near-term interactions between fisheries and protected species.

Changing and unprecedented environmental conditions fueled by climate change will continue to affect the ecosystem and successful conservation and management measures will have to address novel direct and indirect interactions between fisheries and protected species. These interactions will arise due to range shifts and changing migration patterns of targeted species, protected species, or both (Lewison*, et al.* 2015; Pinsky*, et al.* 2018), as well as increased consumptive demand of protected predatory species (Chasco*, et al.* 2017b; Wells*, et al.* 2017). Recent and existing concerns surrounding interactions between Council-managed fisheries include:

- Bycatch of species (mammals, birds, turtles, fishes) listed as threatened or endangered under the ESA in groundfish fisheries. Accidental entanglement of whales in fixed-gear fisheries, including the sablefish pot fishery, has grown due to increasing whale populations (Calambokidis and Barlow 2020), changes in the timing of migration, and distribution shifts (Santora*, et al.* 2020). Predictive models (WhaleWatch) for blue whales have been developed to reduce ship strike risk (Abrahms*, et al.* 2019; Hazen*, et al.* 2017) but are also being targeted for use in reducing pot-interactions under anomalous environmental conditions. Direct effects of Council-managed groundfish fisheries are captured by the Council's Groundfish ESA Workgroup, but indirect effects such as shifts in fishery participation to avoid entanglement issues related to State-managed fisheries such as Dungeness crab, are not.
- Bycatch of species that are protected under MSA-based regulations, but which are also harvested in limited quantities by directed fisheries. Examples include interactions of the Pacific whiting fisheries with Chinook salmon and shortbelly rockfish. Chinook salmon bycatch in the Pacific whiting fishery is an ongoing West Coast fisheries management challenge, exacerbated recently by the increased consumptive demand of pinnipeds and the needs of ESA-listed southern resident killer whales for Chinook salmon as prey at different life stages (Chasco*, et al.* 2017b; Ohlberger*, et al.* 2019).
- Bycatch of shortbelly rockfish in the Pacific whiting fishery during the 2014-2016 marine heatwave suddenly grew to the point where it exceeded the shortbelly rockfish annual catch limit. Shortbelly rockfish are a forage species for several Council-managed target species, which the Council manages with intentionally low harvest limits. The combination of record high Pacific whiting and shortbelly rockfish recruitment during 2013-2016, and shortbelly rockfish's range shift northward, created this predicament.
- The protected species that tend to interact with HMS fisheries are usually highly migratory themselves, ranging with tunas and sharks across the whole Pacific basin. The Council's HMS fisheries management includes a variety of measures to minimize bycatch, including: limits on gear depth, soak times, seasonal closures, and pingers to reduce bycatch of sea turtles, sharks, beaked whales and other toothed mammals (Barlow and Cameron 2003; Hanan*, et al.* 1993; Mason*, et al.* 2019). However, changing distributions of HMS alter both the catch potential and bycatch risk for West Coast HMS fisheries (e.g. Hahlbeck*, et al.* 2017; Smith*, et al.* 2020). Dynamic ocean management tools (e.g., EcoCast) have been developed for the CCE to predict the distribution and timing of protected species migrations (Eguchi*, et al.* 2017; Hazen*, et al.* 2019) which can be used to inform fishing activity to potentially reduce bycatch risk to protected species.

Importantly, these examples of interactions between Council-managed fisheries and protected species reflect those we know about today and can anticipate in the near future. However, there is widespread agreement that ecological surprises that amplify these concerns are on the horizon. Such concerns are reflected in the future scenarios developed by the Council's Climate and Communities Initiative. These expectations highlight the importance of timely bycatch syntheses (Savoca*, et al.* 2020) at a regional level that allow the Council to respond nimbly to changing conditions, as they did with shortbelly rockfish bycatch.

### *4.5 Fisheries Management, Ecosystem Services and the Well-being of West Coast Communities*

The United Nations' Millennium Ecosystem Assessment defines ecosystem services as the benefits people obtain from ecosystems, including: "provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits" (2005, MEA). This MEA definition provides some context for Goal 3 of the FEP: *Implement fisheries management that ensures continued ecosystem services for the wellbeing of West Coast communities and the nation*. From a global perspective, human health does not occur in a vacuum and is related to and part of animal, plant, and environmental health (MEA 2005). The MEA explains human well-being as being in opposition to poverty, and as including opportunities for security, access to resources to gain an income or livelihood, health (including food security, freedom from disease, clean air and drinking water, and energy) and good social relations (MEA 2005). This definition therefore implies that well-being is inclusive of, but not limited to, the delivery of ecosystem services in a region. Breslow, *et al*. (2017) describe well-being as including four major constituents: connections, capabilities, conditions (e.g., environmental and economic conditions), and cross-cutting considerations such as equity, justice, security, resilience, and sustainability (see also, Breslow*, et al.* 2017; Szymkowiak 2021). Acknowledging the intrinsic links between ecosystem services and human well-being, as well as the broader and deeper concepts of well-being, aligns this FEP with international thinking on best practices for sustainable natural resource management over multiple generations (Breslow*, et al.* 2017; Dasgupta 2021; Leong*, et al.* 2019; Szymkowiak 2021).

While the fisheries management process tends to focus on the food security and recreational benefits that humans derive from fisheries, our work is also deeply affected by and tied into climate and nutrient cycles, with the well-being of fishing communities linked to our ability to access the ocean and fish. The CCE ESR focuses not only on more direct ecosystem services like amounts of fish landed and revenues from fisheries, but also on regulating and supporting ecosystem services like annual snowpack in the mountains that water our rivers and ocean upwelling conditions that support primary productivity (Harvey*, et al.* 2019). However, as is the case in many regions, the ESR does not tackle the full "complexity of how humans interact with, derive value from, and respond to changes in their marine ecosystems" (Breslow*, et al.* 2017; Szymkowiak 2021), but should strive to move in this direction.

The FEP's Objective 3a is to: *Continue to provide for commercial, recreational, ceremonial, subsistence, and non-consumptive uses of the marine environment*. That objective essentially re-phrases and provides further details on Goal 3, while also invoking the MSA's definition of OY, which calls for fisheries to be managed so as to benefit the nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems along with any number of social and economic factors (Healey 1984). Notably, OY is often interpreted strictly in terms of a stock's biological status (is it overfished and is overfishing occurring?), but there are a wide variety of techniques available for defining OY at an ecosystem level (Link 2017) and including social considerations more directly (Healey 1984; Mangel and Dowling 2016; Voss*, et al.* 2018) so as to achieve triple bottom line outcomes across environmental, economic, and social (including cultural) dimensions (Marshall*, et al.* 2018). Objective 3a ties those national priorities to West Coast priorities to ensure that we continue to provide for ceremonial and subsistence fisheries, with the term "ceremonial" explicitly included to acknowledge the unique status that Council-managed species and their habitats may have for a variety of treaty fishing tribes (NWIFC 2016). It also encourages a broader focus on non-economic social benefits of fisheries, and how those benefits are distributed to different populations. A longstanding body of research has shown that these non-economic social benefits can include a connection to the water, family heritage, a sense of community, and identity, amongst other factors (Holland*, et al.* 2020; Szymkowiak 2021).

The MSA requires that conservation and management measures, consistent with conservation requirements, take into account the importance of fishery resources to fishing communities by using economic and social data in order to: "(A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities" (16 U.S.C. §1851(a)(8)). Meeting this requirement can be difficult. But it can be addressed through a deeper understanding of adaptive behaviors within fishing communities, including but not limited to income diversification via cross-fishery participation, understanding of the livelihood landscapes in which fisheries occur, and household utility and welfare more broadly in fishing communities. Fishing communities are primarily located in coastal areas, which serve a wide variety of marine and other industries – from regional shipping hubs, to destination tourism locations, to submarine cable landing stations. Council decisions affect how much of which species of fish are taken within larger-scale geographic areas, but do not control whether and how coastal municipalities maintain harbor facilities, coastal community investments in attracting industries other than fishing, transportation infrastructure between fish landing facilities and major fish markets, or myriad other factors that affect income generated and quality of life within fishing communities. Council decisions on fisheries management are only a small part of the sum of elements that make up well-being for any particular fishing community.

Objective 3b is to: *Continue to monitor and engage in opportunities to minimize and mitigate the effects of non-fishing activities on the ecosystem to better ensure that conservation benefits are not undermined by negative impacts of these activities*. As discussed in Section 4.3, the Council usually addresses the effects of non-fishing activities on the ecosystem through the work of the Habitat Committee on EFH. As part of the 2020-2022 FEP re-drafting process, the Council developed a separate guidance document to more broadly discuss the potential for non-fishing activities to affect the CCE: *Pacific Fishery Management Council Guidance on Agency Activities in the California Current Ecosystem.* As of June 2021, the Council has also appointed a new Ad Hoc Marine Planning Committee to begin working with the Bureau of Ocean Energy Management and other non-fisheries entities to provide feedback to these entities on the potential effects of their proposed activities on fish stocks, fisheries, and the marine environment.

Objective 3c is somewhat outside of the Council's usual responsibilities, except as it applies to Council process participants: *Support education efforts to promote understanding of CCE biophysical processes, how the ecosystem affects human well-being, and of the potential risks and benefits to ecosystem services from climate variability and change*. Since adopting the 2013 FEP, Council process participants have been exposed to significantly more information about how the CCE functions, have had more opportunities with each new ESR to understand the links within the social-ecological system, and have brought more ecosystem information into Council discussions and analyses. In addition to the FEP and the annual ESRs, the ecosystem initiatives offer new opportunities to promote understanding of the CCE. Both Initiative 2 (Coordinated Ecosystem Indicator Review) and Initiative 3 (Climate and Communities) began with a public education webinar series designed to help Council process participants understand the CCE itself, how we conduct science to better monitor and understand the CCE, and where scientific uncertainty may affect our understanding of the CCE.

### *4.6 Framework and Public Forum for Ecosystem Information used in Council Decision-Making*

Goal 1 of this FEP is process-oriented: *Provide a framework and public forum to improve and integrate ecosystem information for use in Council decision-making*. To date, the Council has been committed to meaningful public engagement, and has proactively used a variety of approaches to better understand the ecosystem and to use that understanding to inform its decisions. In Chapter 2, this FEP provides annual processes for identifying candidate ecosystem research topics for SSC review in support of revisions to the ESR, and for considering and developing new ecosystem initiatives. The ecosystem initiatives themselves are a Council invention, and are processes by which the Council can address issues and challenges that affect two or more Council FMPs or coordinate major Council policies across the FMPs. This administrative goal of maintaining a regular process for Council discussion of ecosystem issues has been part of the FEP since 2013, when the Council recognized that a commitment to regular discussion of ecosystem issues was key to implementing ecosystem-based management. The Council's efforts to meet that goal have significantly improved Council and public awareness of ecosystem states, of climate variability and anomalies, and of the interacting influences of the physical, biological, social, and economic components of the ecosystem on each other.

Through the ecosystem status report process laid out in Section 2.3, the Council meets FEP Objective 1a: *Provide annual and regular opportunities for the Council and its advisory bodies to consider physical, biological, social, and economic information on the CCE with an emphasis on environmental and climate conditions, climate change, habitat conditions, ecosystem interactions, and changing socio-economic drivers*. Ecosystem status reports are presented to the Council, its advisory bodies, and the public each March; new scientific information and analyses that could be of use to that report or to other Council work are reviewed through the SSC each September. However, in many cases it is difficult to trace a direct line between the ecosystem information received by the Council and its application to decision-making. Greater connection between ecosystem conditions and the quota-setting process could provide proactive approaches towards addressing shifting stocks in location or biomass.

Chapter 5 of this FEP, *Ecosystem Science in the Council Process*, SSC and Council work on Research and Data Needs, and the Council's annual processes detailed in Section 2.3 help the Council meet FEP Objective 1b: *Identify research and monitoring priorities to address knowledge gaps, including indicators and reference points to monitor trends and drivers in key ecosystem features*. While the annual SSC process to review new ecosystem science focuses on the annual ecosystem status report, that process also offers an opportunity for scientists to share new species-specific work (e.g., Haltuch*, et al.* 2020; Tolimieri*, et al.* 2018) and to look into changes in ecosystem modeling practices (Kaplan*, et al.* 2018; Punt*, et al.* 2016). Furthermore, individual FMPs have their own goals and objectives that can be informed by ecosystem considerations.

Objective 1c addresses the role of the Council within wider regional ocean management fora, and within international fisheries management organizations: *Provide a nexus to regional, national, and international ecosystem-based management endeavors*. Council members, scientists who participate in and support the Council process, and Council advisory body members also participate in the regional, nationwide, and international organizations and processes discussed in Sections 3.5.5 and 3.5.6. The Council's Habitat Committee ensures that the Council stays informed and comments on the wide variety of non-fishing activities that may affect EFH; the Council's FMP-specific advisory bodies track and share information and comments on regional and international science and management occurring in species- specific forums.

# Chapter 5 Ecosystem Science in the Council Process

The initial FEP development process over 2010-2012 spurred a lot of discussion about available and needed science in support of ecosystem-based management. Many of those ideas became part of the 2013 Research and Data Needs document (PFMC 2003). Beyond those specific research topics identified in 2013, the FEP also discussed plans for bringing more ecosystem information into stock assessments and plans for developing the CCE ESR.

Since 2013, stock assessment methodologies and processes nationwide have evolved, including those contributing to this Council process (Lynch*, et al.* 2018; PFMC 2020). The NMFS Next Generation Stock Assessment Improvement Plan (Lynch*, et al.* 2018) provides guidance on holistic and ecosystem-linked stock assessments, which are intended to incorporate ecosystem drivers of dynamic processes into stock assessment models and implement the NMFS ecosystem-based fisheries management policy and roadmap (National Marine Fisheries Service 2016; NMFS 2016). The Habitat Assessment Improvement Plan (NMFS 2010) and Thorson, *et al*. (2021) specified avenues for incorporating habitat information into stock assessments. To achieve a more holistic modeling approach, NMFS intends both ecosystem and socioeconomic drivers to be incorporated into stock assessments, where appropriate. There are also NMFS efforts towards improving climate-ready information for informing fisheries management, starting with the National Climate Science Strategy (Link*, et al.* 2015) and potentially advancing through national modeling efforts such as the Climate and Fisheries Initiative. Further discussion on using ecosystem information to provide context for stock assessments is provided in Section 5.1.

The Northwest and Southwest Fisheries Science Centers presented an initial ESR in November 2012 (National Marine Fisheries Service Northwest and Southwest Fisheries Science Centers 2012), and then later followed the FEP's schedule for ecosystem issues by presenting the ESR each March from 2014 to the present (e.g., Harvey*, et al.* 2020b). The 2013 FEP established an annual process where Center scientists consult with the SSC each September on potential new information and analyses to be incorporated into the next year's ESR, which ensures a regular review of the utility of the information in the ESRs. Council advisory bodies regularly provide guidance on information needed in the ESRs. For example, the 2020 ESR ((Harvey*, et al.* 2020a)) specified new habitat-based indicators for Sacramento fall Chinook salmon and Klamath fall Chinook salmon that the Habitat Committee had developed to address potential non-fishing impacts related to rebuilding plans. Under its second ecosystem initiative, a *Coordinated Ecosystem Indicator Review*, IEA scientists worked with each of the Council's advisory bodies to better understand which ESR indicators were more or less useful to the management process. Conversations under that initiative continue to shape ESR contents and provide ecosystem scientists with unusual insights into how ecosystem modeling might be used to address the unique fishery management challenges faced by this Council (Tommasi*, et al.* 2021). In this chapter we offer a forward-looking approach towards how the Council could continue to bring ecosystem science into the fishery management process.

## *5.1 Ecosystem Information in Support of Fisheries Management*

A key idea in ecosystem-based fisheries management is that fisheries are considered as whole systems consisting of interacting ecological, economic, social, and cultural components, and that management actions that account for the linkages among these components are likely to result in more productive and resilient fishery systems. Better understanding of ecosystem conditions that shape fishery systems and cut across fishery management plans could help support ecosystem-level management goals (Levin*, et al.* 2018; Link 2017; Link and Marshak 2019). Ecosystem considerations have the potential to be used along with single-species assessments, multispecies assessments, and can be used to develop ecological indicators in support of decision-making.

### 5.1.1 Ecosystem Considerations in Single Species Stock Assessments

On the U.S. West Coast, there have been many advances in the use of ecosystem information as the supporting context for stock assessments since the development of the original FEP. These include but are not limited to: the contextual information provided by biophysical and socioeconomic indicators reported in the annual ESR; process-based studies of relationships between oceanographic conditions and groundfish recruitment (petrale sole, Haltuch*, et al.* 2020; examples include sablefish, Tolimieri*, et al.* 2018; and Pacific whiting, Vestfals*, et al.* In Review); development of more robust ecosystem considerations sections in stock assessments ((e.g., sablefish Haltuch*, et al.* 2019b); identification of environmental thresholds associated with bias in population dynamics forecasts (e.g., salmon Satterthwaite*, et al.* 2020); climate vulnerability assessments (Crozier*, et al.* 2019); and an MSE to evaluate impacts of climate on sablefish stock dynamics in the ensuing decades (Haltuch*, et al.* 2019b). These types of information help meet recommendations in the NMFS Stock Assessment Improvement Plan.

Historically, the use of ecosystem or environmental variables in fisheries assessments were rare (Haltuch*, et al.* 2019b; Marshall*, et al.* 2019). Ecosystem and environmental indicators in stock assessments are often used not in the assessment itself, but to inform the analysis of data for use in an assessment, for use in an MSE or for ad hoc adjustment of acceptable biological catches or use in a HCR. These indicators often involve information related to predation levels on target species and the abundance of prey available to them (Dorn and Zador 2020; Thayer*, et al.* 2020). Marshall, *et al*. (2019) found that only 24 percent of all U.S. stock assessments included ecosystem information. More rare are those assessments that include ecosystem indicators for stock productivity; a review found that only 24 of 1,250 assessments worldwide directly incorporated environmental information into an assessment (Skern-Mauritzen*, et al.* 2016). Better mechanistic understanding of environmental variability as a driver of population dynamics (Haltuch*, et al.* 2019a; Haltuch*, et al.* 2020; Thayer*, et al.* 2020; Tolimieri*, et al.* 2018) can lead to improved stock forecasts and estimates of stock status by adjusting for changes in estimated unfished biomass, a biological reference point (Berger 2019). Ecosystem information can also support using dynamic reference points or define time periods that serve as reference points. In certain cases, it may be possible to integrate ecosystem information into harvest control rules, as is currently done for Pacific sardine within the PFMC. For example, future research to determine if the Habitat Compression Index, currently described in the ESR, can be linked to the availability of HMS and CPS stocks, which could in turn inform harvest decisions.

Furthermore, these ecosystem considerations need not be directly integrated into the population modeling that forms the core of a single species assessment. Rather, ecosystem considerations can be included in the stock assessment process at many points, including as auxiliary/companion information for review by stock assessment review panels and the Council, to frame thinking around harvest decision tables (Dorn and Zador 2020), in considering spatial harvest allocations, and more (see *Ecosystem indicators* section below). Once avenues for incorporating ecosystem information are identified (following Koehn*, et al.* 2020), we should prioritize objectives for incorporating ecosystem information in FMPs, develop operational objectives for the ecosystem information in the management process, and ultimately evaluate success of implementation of ecosystem information in the quota-setting process. Multiple pathways for ecosystem information could better address fisheries-specific needs to respond rapidly to changing climate and socio-ecological conditions.

### 5.1.2 Ecosystem considerations in multispecies stock assessments

Multispecies assessment models can allow predator-prey and competitive dynamics among Council-managed species to be incorporated into the stock assessment process (Holsman*, et al.* 2016), while providing a way to assess more than one stock simultaneously. In addition, multispecies production models can provide insight into how the total harvest across species interacts with environmental variability to affect potential production of biomass within or across an FMP (Fogarty*, et al.* 2012; Gaichas*, et al.* 2012;

Mueter and Megrey 2006). Like multispecies models, spatial stock assessment models (Berger*, et al.* 2017) can be usefully applied to species with population structure (e.g., lingcod Longo*, et al.* 2020) and/or those that experience shifts in distribution, especially in the context of harvest allocation decisions that are made in relation to geographic boundaries, both national and international (e.g., the U.S.-Canada border for Pacific whiting (JTC 2021). Notably, alternative assessment models need not replace the use of current single-species modeling approaches. Rather, results from multiple models can be considered individually as management advice or combined using ensemble modeling techniques (Anderson*, et al.* 2017a; Gårdmark*, et al.* 2013; Rosenberg*, et al.* 2018). The formal consideration of multiple model types (Drew*, et al.* 2021) would allow for an improved accounting of both structural uncertainty (how the population dynamics are conceived to occur, i.e., how is the model formulated) with the observation uncertainty that is commonly examined (via sensitivity analyses of parameter values, given a model).

### *5.1.3 Ecosystem information to guide management actions*

Ecological indicators are valuable for tracking changes in ecosystem functioning and evaluating those changes within the context of past system perturbations (Harvey*, et al.* 2020c). They can also be used within or alongside stock assessments to help inform management decisions. Many of the indicators currently used to assess the status of ecosystem condition and stocks are based on individual taxa. However, combining long-term monitoring surveys and data with modeling frameworks that summarize information across taxa to develop indicators of community or ecosystem state might help improve our ability to predict the recruitment and survival of managed and protected species. Moreover, synthesizing information across taxa that are known to respond quickly to environmental perturbations might also provide the earliest possible detection of an ecosystem shifting into a novel state (Hunsicker*, et al.* In Review; Litzow*, et al.* 2020b). Such information would provide invaluable support for ecosystem-based and climate-ready fisheries management strategies aimed at mitigating the potential ecological and socio-economic impacts of ecosystem shifts.

Inclusion of ecological indicators in decision tables can help inform management actions (Dorn and Zador 2020). Similarly, confidence in population forecasts can be augmented by examining how environmental variability affects bias, as there is potential for nonlinear and/or threshold distortions in model performance as environmental conditions change (Satterthwaite*, et al.* 2020). In a more qualitative sense, robust descriptions of ecosystem conditions, inclusive of social and economic considerations, can provide guidance around risk to stocks and the broader ecosystem (Shotwell 2018). Whether qualitative or quantitative, ecosystem considerations can be integrated into decision tables used to inform harvest advice (Dorn and Zador 2020; Thayer*, et al.* 2020).

## *5.2 Climate-Ready Fisheries and Fishing Communities*

The Council's Climate and Communities Initiative, the FEP's third ecosystem initiative, has been at the forefront of the Council's ecosystem-based management work over 2019-2021. Under the initiative, the Council, participating agencies, non-governmental organizations, and the public have engaged in a strategic planning project to discuss and plan for the potential effects of climate variability and change on West Coast fish stocks and fishing communities. Concurrent worldwide struggles to manage the economic challenges associated with the pandemic have revealed some of the vulnerabilities in fisheries management as part of the nation's food security network. Together, these challenges and planning processes can help the Council assess its near-future science needs for managing fisheries and targeted and protected species under climate change. In doing so, the Council will have the opportunity to consider planning further into the future than the time scope covered by a stock assessment or harvest-setting process.

Fish and wildlife management under climate change focuses on managing species, habitats, and people's local activities to adapt to climate change (National Fish 2012). Scientists and managers focusing on terrestrial ecosystems and species have recently discussed a Resist-Adapt-Direct framework for responding to climate change, suggesting that we ask ourselves whether it is possible for the populations we manage to resist the effects of climate change, if they might adapt to climate change, or if and how humans can direct the adaptation of ecosystems to climate change (Lynch*, et al.* 2021; Schuurman*, et al.* 2020). In marine ecosystems, fisheries management itself must adapt to climate change and its effects on targeted and protected species' abundance and distribution.

Recent climate perturbations in the CCE provide examples of the types of challenges associated with climate variability and change: the 2005 delayed upwelling resulted in loss of forage in the northern CCE and the invasion of a novel predator, Humboldt squid (Zeidberg and Robison 2007); the 2014-15 marine heatwave resulted in northward expansion of multiple species (Sanford*, et al.* 2019); and, other new human-wildlife conflicts that have challenged both fisheries and protected species (Santora et al. 2020, Feist et al. 2021). In some cases, biological responses to climate variability were entirely unexpected. For example, anchovy generally thrived under cold conditions from 1950-2000, but rose to exceptionally high levels during the 2014-2016 marine heatwave (Thompson*, et al.* 2019). Elucidating mechanistic drivers of fish stocks and protected species distribution and abundance with the backdrop of a changing climate will be critical to ecosystem-based fisheries management. New predictive models that can help us understand patterns in the CCE forage complex are under development for important forage species such as anchovy (Muhling*, et al.* 2020), sardine (Kaplan*, et al.* 2016), juvenile rockfish (Santora*, et al.* 2017a), and krill (Cimino*, et al.* 2020). Modeling efforts aimed at detecting and accounting for nonstationary relationships between climate indices and managed and protected species (Litzow*, et al.* 2018; Litzow*, et al.* 2020a), which can affect our forecasting abilities, are being applied to West Coast ecosystems. New studies aimed at identifying species and life stages in the CCE whose habitat and phenology are highly constrained in space and time, and thus less adaptable to climate changes, can provide criteria for establishing EFH and monitoring priorities. Risk analyses can also be used to hindcast the effects of management strategies on historically-observed environmental conditions (Samhouri*, et al.* In press; Thayer*, et al.* 2020). Risk approaches can also be used to explore real-time distributions of predators to avoid entanglement, ship-strike risk, and other stressors (Abrahms*, et al.* 2019), efforts that will be important in minimizing future conflict between fisheries and protected species.

Climate vulnerability assessments (CVAs) of fish stocks and fishing communities (Colburn*, et al.* 2016; Hare*, et al.* 2016) also examine species or population sensitivity and exposure to climate change stressors to assess vulnerability using an expert-elicitation-based approach (Morrison*, et al.* 2015). These are being conducted for salmon stocks on the West Coast (Crozier*, et al.* 2019), federally-managed finfish species (McClure*, et al. in prep.*), and protected non-fish species. It is still necessary, however, to link CVAs explicitly to social vulnerability and adaptive capacity of fishing communities (Dudley*, et al.* 2021). There have been recent strides in this direction for the CCE using approaches that do not require expert elicitation and that can be updated and automated (Koehn*, et al.* In review). Coupled socio-ecological CVAs that focus on fishing community response would be a valuable addition to these efforts (e.g., Fisher*, et al.* 2021). The discussion around climate-ready fisheries – those with management plans that are able to adapt to changes in ocean conditions, stock distributions, and interactions with protected species – needs to consider not just the natural resources but the readiness or resilience of the fishing communities (Fisher*, et al.* 2021). For example, a broader portfolio allows fishing communities to shift among species during harmful algal blooms or in response to species range shifts (Fisher*, et al.* 2021), with fisheries like albacore tuna serving as an increasingly important resource in the overall portfolio (Frawley*, et al.* 2021). Risk analyses and management strategy evaluations focused on ecosystem response to anomalous years through the CCIEA and other science planning and implementation programs will be critical to get a big picture view of the resources and fishing communities most threatened and most available to future harvest (Harvey*, et al.* 2020c; Williams*, et al.* 2021).

### 5.3 *Synthesis of Biophysical and Social Conditions across FMPs and Beyond*

Climate is only one of many ecosystem drivers that has cascading effects across multiple FMPs, fishery participants, fishing communities, and the broader CCE. In this section we consider ecosystem science to capture the biophysical and social dynamics of and interactions between FMPs and the ecosystem. This section also addresses research that considers longstanding and emerging dynamics within the CCE that have traditionally been beyond the Council purview, but nonetheless have important effects on Council actions and stakeholders.

The connectivity within the biophysical system has important implications for fishery systems. In some cases, that connectivity is better understood and is already being taken into consideration (e.g., how snowpack and plankton this year affect salmon returns in future years), while there is still much that is not understood about other ecosystem connections (e.g., how harvest of Pacific whiting affects krill distribution and abundance, with cumulative effects on the productivity of groundfish and other stocks; how shifts in the phenology of environmental and biological processes at lower trophic levels affect the production of higher trophic-level fish stocks). Connectivity within the social systems could also be better understood. For example, perturbations to the state-managed Dungeness crab fishery affect participation choices and harvest levels in Council-managed salmon, albacore, and groundfish fisheries. In the Council context, this is well understood but rarely receives formal scientific analysis. Overall, the connectivity across the biophysical and social systems is challenging to understand and articulate, but needs greater attention. New uses of the marine environment, such as expanded offshore energy and aquaculture, and long-standing issues such as coordination with state-managed fisheries, pollution, eutrophication, shipping traffic, and noise, have direct and indirect ecological and social impacts that affect dynamics of Council-managed species and constraints and opportunities for fisheries participants and communities (Richmond*, et al.* 2019).

There are many tools and approaches available to provide the underpinnings for strategic evaluation of the biophysical and social ecosystem drivers that most need to be at the forefront for Council decision-making. For example, much of the current ESR is focused on indicators that allow us to understand the connections between individual stocks or stock complexes and the physical, ecological, and social factors that affect its dynamics. Few indicators in the ESR track system-level conditions, with climate being an obvious exception, but other possibilities include indicators related to overall FMP-level and CCE-level rates (e.g., productivity, species' resilience/recovery), status (e.g., total biomass), and biodiversity (including but not limited to target species). To support that work, there is a wide literature on the value and selection of indicators of ecosystem status to support ecosystem-based management (Levin*, et al.* 2014; Link 2005; Link and Browman 2014; Samhouri*, et al.* 2014). Examples from other regions include the New England ESR and the Mid-Atlantic ESR. Ecosystem models are also a useful tool for quantitatively assessing social-ecological trade-offs of alternative management options under current and future scenarios. For example, Atlantis models have been used to evaluate the effects of changes in ocean acidification, spatial management, and fishing pressure on various ecological and fishery indicators (Olsen*, et al.* 2018).

In addition to ecological indicators, communication and coordination is a vital component of implementing ecosystem-based and climate-ready fisheries management measures. Ecological shifts in species geographical ranges as a result of changing ocean conditions requires resource managers to coordinate with international and regional counterparts. For example, transboundary HMS, which spend only a portion of their lives in the CCE, are managed through engagement with international counterparts. U.S. fishery management councils can help those regional fishery management organizations mitigate the potential impacts of ecosystem shifts on highly migratory populations that range throughout the Pacific basin. Effective coordination and collaboration between resource managers, fishery participants, and the general public is also needed to support regional EBFM in response to changing ocean conditions. For example, we will need to understand whether a stock that declines in some particular location is the result of range shifts, or stock-wide declines in abundance. The Council's second ecosystem initiative, the coordinated review of ESR indicators, improved communication and coordination on indicators between ecosystem scientists and the larger Council family, but also provided scientists with a wealth of insights into the Council's interests in ecosystem science and modeling needed to address future Council concerns (Tommasi*, et al.* 2021; Townsend*, et al.* 2019). Further evolution of ESRs could support more real-time updates to identify potential human-wildlife conflicts before they occur, or at least help address them with more timely ecosystem information.

Between climate variability, climate change, and new and emerging human uses of the CCE beyond fishing, it is time to consider not just how ecosystem science can fit into existing Council processes and decision contexts, but also what new Council processes and decision contexts are needed to meet the demands of the 21st century. The scenario planning process used in the Council's third ecosystem initiative is a good example of how to go about this in a structured way that engages the full Council community and stakeholders. The scenarios developed therein provide guideposts for considering the priorities and concerns of the fishing communities reliant upon the CCE. New management processes may be needed, such as initiatives to identify and evaluate spatially explicit emerging and fading fishing opportunities. New decision contexts may develop, such as how to determine harvest levels when the biomass of individual stocks within the fishing closed areas created by offshore energy or aquaculture development is unknown and unknowable. And, we will have to consider challenges like how to allocate target and bycatch quota spatially (across regional and international borders) in years with anomalous environmental conditions that massively shift the distributions of target species. Forward-looking, transdisciplinary science focused on managing toward future conditions will in turn support fisheries and fishing communities (Kleisner*, et al.* 2021). The new tools and approaches described in this chapter will need consideration in the Council process, and this FEP is intended to bring together the people and ideas that will move ecosystem-based management forward for the CCE.

## Chapter 6 References


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