

3.0 WEST COAST MARINE ECOSYSTEMS AND ESSENTIAL FISH HABITAT

3.1 Affected Environment

3.1.1 *West Coast Marine Ecosystems*

The term ecosystem is generally defined as a “functional unit of the environment” within which the basic processes of energy flow and cycling are identifiable and can be (relatively) localized. In this sense, marine ecosystems are extremely difficult to identify, as most are relatively open systems, with poorly defined boundaries and strong interactions across broad spatial scales. The California Current ecosystem, like other Eastern boundary current ecosystems, are especially difficult to define, as they are characterized by tremendous fluctuations in physical conditions and productivity over multiple time scales (Mann and Lazier 1996; Parrish, et al. 1981). Food webs tend to be structured around coastal pelagic species (CPS) that exhibit boom-bust cycles over decadal time scales (Bakun 1996; Schwartzlose, et al. 1999). Similarly, the top trophic levels of such ecosystems are often dominated by highly migratory species such as salmon, albacore tuna, sooty shearwaters, fur seals and baleen whales, whose dynamics may be partially or wholly driven by processes in entirely different ecosystems, even different hemispheres. For this analysis, the ecosystem is considered in terms of physical and biological oceanography, climate, biogeography, EFH, marine protected areas, and the role of depleted species’ rebuilding in the marine ecosystem.

3.1.2 *Physical and Biological Oceanography*

The California Current is essentially the eastern limb of the Central Pacific Gyre, and begins where the west wind drift (or the North Pacific Current) reaches the North American Continent. This occurs near the northern end of Vancouver Island, roughly between 45° and 50° N latitude and 130° to 150° W longitude (Ware and McFarlane 1989). A divergence in the prevailing wind patterns causes the west wind drift to split into two broad coastal currents, the California Current to the south and the Alaska Current to the north. As there are really several dominant currents in the region, all of which vary in geographical location, intensity, and direction with the seasons, this region is often referred to as the California Current System (Hickey 1979).

The California Current itself is a year-round feature consisting of a massive southward flow of the cool waters of the west wind drift. The current is best characterized as a shallow, wide, and slow-moving body of water, ranging from the shelf break to 1,000 km offshore, with the strongest flows at the sea surface, and in the summertime (Dodimead, et al. 1963; Hickey 1979; Lynn and Simpson 1987). This surface current is matched in the summer by the California Undercurrent, which moves water northward from the south in a deep yet narrow band of subtropical water typically found just off of the shelf break at depths of 100 to 300 m. The undercurrent flows from Baja California to Vancouver Island, transporting warmer, saltier southern water north along the coast (Hickey 1979). On average, the California Current flow volume reaches a maximum in spring and summer, when the flow moves inshore, closer to the shelf break. The California Undercurrent develops in late spring through early summer and persists into the fall. During late summer and fall, there is considerably more mesoscale variability in flow patterns, with fields of cyclonic and anticyclonic eddies and considerable mixing of water masses between shelf and offshore waters (Brink and Cowles 1991). Beginning in the fall, and through the winter, the northward flowing Davidson Current is the dominant feature over the shelf and beyond the shelf break (Hickey 1998).

Current dynamics over the continental shelf are generally forced by regional wind fields, which tend to be southerly in the spring and summer, and northerly in the winter. Spring and summer winds drive offshore Ekman transport of surface waters, which is balanced by the upwelling of deeper waters that tend to be cooler and nutrient rich. Between the Strait of Juan de Fuca and Cape Blanco, summer upwelling leads to the development of a southward flowing upwelling jet over the continental shelf (Barth, et al. 2000; Hickey 1998). The shelf narrows as it approaches Cape Blanco, intensifying the energy of the jet (Barth, et al. 2000; Batteen 1997). As this jet reaches Cape Blanco it turns sharply offshore, mixing the cool, nutrient rich waters of the jet with the warmer, less productive waters of the slow-moving California Current. These interactions lead to the development of eddy fields and mesoscale variability in primary and secondary productivity that distinguish the region south of Cape Blanco from that to the north (Strub, et al. 1991). All these currents, countercurrents, undercurrents, jets, and meanders transport water masses of different origins and characteristics, as well as the nutrients and organisms entrained within them, to the California Current System.

Wickett (1967) demonstrated that secondary productivity off southern California was influenced by the advection of northern water from the west wind drift, such that interannual differences in southern Ekman transport explained 50 to 60 percent of the variance in zooplankton biomass. Chelton, et al. (1982) followed up these observations by observing that when the bulk of the divergent flow is to the south, the California Current experiences greater southward transport, more productive source waters and higher secondary production in the region off of southern California. Fulton and LeBrasseur (1985) further demonstrated that the zooplankton biomass, and even the mean size of copepods, was greater in the northern portion of the California Current when transport was high. Ongoing research has continued to demonstrate that climate-driven changes in transport and ocean conditions dramatically affect both the species composition and productivity of zooplankton in the northern California Current (Mackas, et al. 2005; Peterson, et al. 2002; Peterson and Schwing 2003b). Thus, while local wind fields and coastal upwelling ultimately drive much of the primary production at the base of the food web, growing evidence suggests that large-scale physical processes and associated changes in the community composition of zooplankton is a significant factor in determining the overall productivity of the ecosystem (Feinberg and Peterson 2003; Peterson and Keister 2003; Swartman and Hickey 2003).

3.1.3 *Interannual and Interdecadal Climate Forcing*

The effects of climate on the biota of the California Current ecosystem have been recognized for some time. Hubbs (1948) believed so strongly in the correlation between water temperature and fish distributions that he felt “justified in drawing inferences, from the known data on fish distribution, regarding ocean temperatures of the past.” It is worth noting that Hubbs had already drawn distinctions between eras that seemed to be associated with the establishment of warm-water populations over long time periods, and the occasional warm years (generally associated with stronger El Niño events) that brought irregular tropical or subtropical fish much further north along the coast.

Currently, the El Niño/Southern Oscillation (ENSO) is widely recognized to be the dominant mode of interannual variability in the equatorial Pacific, with impacts throughout the rest of the Pacific basin and the globe (Mann and Lazier 1996). During the negative (El Niño) phase of the ENSO cycle, jet stream winds are typically diverted northward, often resulting in increased exposure of the West Coast of the U.S. to subtropical weather systems. Concurrently, coastally trapped waves propagate the equatorial ENSO signal northward along the West Coast of Central and North America as far as the subarctic, resulting in increased northern advection, warmer sea surface (and subsurface) temperatures, elevated coastal sea levels, and deepened thermoclines (Bakun 1996). The impacts of these events to the coastal ocean generally include reduced upwelling winds, deepening of the thermocline, intrusion of offshore (subtropical) waters, dramatic declines in primary and secondary production, poor recruitment, reduced

growth and survival of many resident species (such as salmon and groundfish), and northward extensions in the range of many tropical species (McGowan, et al. 1998; Pearcy 2002; Pearcy and Schoener 1987). There is reduced availability of many forage species, particularly market squid, and juvenile survival of most rockfish is extremely low. Concurrently, top predators such as seabirds and pinnipeds often exhibit reproductive failure.

In addition to interannual variability in ocean conditions, the North Pacific seems to exhibit substantial interdecadal variability. Mantua et al. (1997) first defined what is now commonly referred to as the Pacific (inter) Decadal Oscillation (PDO), which is defined as the leading principal component of North Pacific (above 20° N latitude) sea surface temperatures between 1900 and 1993, 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. Evidence suggests that there have been two full PDO cycles in the 20th century. Cool (negative PDO) regimes occurred between 1890 and 1924, and from 1947 to 1976, while warm (positive PDO) regimes from 1925 to 1946 and again from 1977 to 1999. Variation in the productivity of salmon stocks throughout the Northeast Pacific seems to track these changes in ocean temperature, such that positive PDO regimes are associated with increased productivity of salmon stocks from western Alaska to northern British Columbia, and negative regimes favor stocks from California to southern British Columbia (Hare, et al. 1999; Mantua, et al. 1997).

Although the precise mechanism for the PDO remains elusive, the pattern is clearly linked to variability in atmospheric conditions. The average wintertime Aleutian low both deepened and moved eastward in the post-1977 regime (Mantua, et al. 1997), resulting in considerably stronger eastward wind stress (Parrish, et al. 2001). This increase in wind stress has been tied to the observed cooling (and increased productivity) of the waters in the central North Pacific and Alaska Gyre (Brodeur and Ware 1992; Polovina, et al. 1995), and the consequent warming of coastal waters in the Gulf of Alaska and California Current (Mantua, et al. 1997). In a more recent effort to quantify the broad scale impacts of the PDO on Northeast Pacific ecosystems, Hare and Mantua (2000) compiled 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. They found that the dominant principal component of these 100 time series has the same trajectory as the PDO, consistent with anecdotal accounts of covariance between the PDO and many other physical and biological indices.

Growing evidence also suggests that the PDO may have shifted from a positive to negative regime since 1999, as the period between 1999 and 2002 was associated with a negative PDO signal, cool coastal ocean temperatures, high southward transport, and tremendous salmon productivity (Peterson and Schwing 2003b). However, since that period there has been considerable confusion with respect to whether a shift in the PDO did actually occur, or even whether the PDO remains a dominant mode of variability in North Pacific Climate (Bond, et al. 2003; Goericke, et al. 2005b; Goericke, et al. 2005a). The degree to which long-term warming is affecting the world's oceans and its ecosystems relative to other forms of variability is currently a major concern, and the consequent interactions between monotonic (global change), interdecadal (PDO) and interannual (ENSO) climate variability are difficult to disentangle. Although a great many processes drive changes in sea surface temperature trends over multiple time scales, there is growing consensus that the integrated heat content of the global oceans has been increasing, and can only be adequately accounted for by atmospheric forcing attributed to the accumulation of greenhouse gasses in the atmosphere (Barnett, et al. 2001; Barnett, et al. 2005; Levitus, et al. 2000).

Within the California Current itself, (Mendelsohn, et al. 2003) described long-term warming trends in the upper 50 to 75 m of the water column using subsurface temperature records in the California Current

over the past 50 years. McGowan, et al. (1998) attributed significant long term declines in zooplankton populations in the California Current over the same period to increased water temperatures that resulted in an intensification of stratification and a reduction of nutrient regeneration into surface waters. Recent paleoecological studies from marine sediments also indicate that 20th century warming trend in the California Current have exceeded natural variability in ocean temperatures over the last 1,400 years (Field, et al. 2006a). All of this evidence suggests that although the development of statistical indices of climate variability across multiple time scales have improved our understanding of how climate has affected North Pacific ecosystems and productivity in the past, the future remains subject to extremely poor predictability.

3.1.3 *Biogeography*

Biogeography describes spatial patterns of biological distribution. Along the U.S. West Coast within the California Current system, such patterns have been observed to be influenced by various factors including depth, ocean conditions, and latitude. Each are discussed in the remainder of this section.

At the scale of the ecosystem, the most widely recognized patterns are distinct zoogeographic provinces extending North and South of Point Conception, California, known as the Oregonian and San Diego Provinces. The Oregonian Province extends from the Straight of Juan de Fuca in the North to Point Conception in the South. The San Diego Province begins at Point Conception and runs south past the terminus of the EEZ (NMFS 2004a).

Patterns of adult groundfish distribution based on depth have been observed to occur between nearshore, continental shelf, and the continental slope and have been used to form discrete management units. This information is detailed in 4.1. Botsford and Lawrence (2002) showed considerable spatial and temporal synchrony in coho salmon and Dungeness crab catches among ports and regions in the California Current between 1950 and 1990; interestingly, they also found that Chinook landings did not have spatial coherence. Similarly, Field and Ralston (Field and Ralston 2005) showed that 51-72 percent of the year-to-year variability in recruitment for three winter spawning rockfish (yellowtail, widow and chilipepper) seems to be shared coastwide, over a spatial scale of 500-1,000 km. The major differences in recruitment strength seemed to be associated with Cape Blanco and/or Cape Mendocino, and some evidence suggests differences in relative year class strength north and south of Point Conception as well. With respect to genetic evidence for biogeographic boundaries, Hedgecock (1994) found that fish and invertebrates with planktonic larvae generally maintain low spatial genetic variance over large (500-2000 km) regions in the California Current. Analysis of a range of *Sebastes* species also suggests little genetic differentiation within the California Current region (McGauley and Mulligan 1995; Rocha-Olivares and Vetter 1999; Wishard, *et al.* 1980), although some nearshore species may exhibit greater spatial patterns of population substructure, particularly north and south of Cape Mendocino (Cope 2004).

Williams and Ralston (2002) found that Cape Mendocino (and the Mendocino Escarpment) was one of the most noteworthy barriers to the latitudinal distribution of rockfish species diversity. Most stock assessments for groundfish tend to be either coastwide assessments, or are relative to the stocks north or south of Cape Mendocino (occasionally Cape Blanco). Both Cape Mendocino and Point Conception are key management boundaries for the Council. In general, evidence suggests wide to very wide dispersal of larvae and juveniles for most groundfish, with modest to limited movement of adults (general on the scale of thousands of kilometers for most species, with limited examples of small numbers of some populations moving in the hundreds of kilometers). There are strong seasonal inshore and offshore migrations for many species, particularly flatfish, and some evidence for ontogenetic movement in some species by both/either depth and latitude. Pacific hake are the only confirmed highly migratory

groundfish species in the FMP, with a clear seasonal migration from southern spawning grounds off of northern Mexico and Southern California to northern foraging habitat off of Oregon, Washington, and British Columbia (Bailey, *et al.* 1982). There is an ontogenetic component to this migration, as juveniles tend to be found off of central and northern California, with larger, older fish tending to travel further north. Similarly, the distribution of hake tends to be more northerly in warm years (Dorn 1995; Swartman and Hickey 2003), reflecting interannual shifts in marine habitat conditions.

While the physical and bathymetric features associated with these general biogeographic boundaries are fixed in space, the physical characteristics of water masses and associated plankton communities are clearly highly dynamic in space and time (as discussed in Section 3.1.2). Fulton and LeBrasseur (1985) described a transport-driven shifting subarctic domain in the northern reaches of the California Current System, the margin of which was characterized by abrupt declines in zooplankton biomass south of the subarctic boundary. Although the physical dynamics are now thought to be more complex than their model, it is clear that climate driven changes in transport and ocean conditions dramatically alter both the species composition and productivity of zooplankton throughout the California Current to a considerably greater extent than static boundaries based on geography (Mackas, *et al.* 2005; McGowan, *et al.* 1998; Peterson, *et al.* 2002; Peterson and Schwing 2003b).

For example, in the late 1960s and early 1970s, the dominant copepod species in the Northern California Current during the summer tended to be subarctic (or boreal) types such as *Pseudocalanus mimus*, *Calanus marshallae* and *Arcatioa longiremis*; species that are commonly found over shelf waters throughout the Gulf of Alaska (Peterson and Miller 1977). Data suggest that northern species became relatively less abundant, while southern (subtropical) species such as *Paracalanus parvus* and *Calanus pacificus* were more abundant through the 1980s and early 1990s. These southern species were almost completely dominant during the 1997–98 El Niño, at which time standing biomass was near all time lows (Peterson, *et al.* 2002). Since 1999, northern species have again dominated numerically during spring and summer, and the standing biomass of zooplankton has been roughly double that observed prior to 1999 (Peterson and Schwing 2003b).

3.1.4 Essential Fish Habitat

EFH has been described within the project area for highly migratory species, CPS, salmon, and groundfish. The MSA defines EFH to mean “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (16 U.S.C. 1802 sec. 3(10)). Regulatory guidelines elaborate that the words “essential” and “necessary” mean EFH should be sufficient to “support a population adequate to maintain a sustainable fishery and the managed species’ contributions to a healthy ecosystem.” The regulatory guidelines also establish authority for Councils to designate Habitat Areas of Particular Concern (HAPC) based on the vulnerability and ecological value of specific habitat types. Councils are required to minimize to the extent practicable the adverse of fishing on EFH. NMFS works through a consultation process to minimize adverse effects of non-fishing activities (50 CFR 600 subpart J).

3.1.4.1 Coastal Pelagic Species

The CPS fishery includes four finfish (Pacific sardine, Pacific (chub) mackerel, northern anchovy, and jack mackerel) and market squid. CPS finfish generally live nearer to the surface than the sea floor. The definition of EFH for CPS is based on the temperature range where they are found, and on the geographic area where they occur at any life stage. This range varies widely according to ocean

temperatures. The EFH for CPS also takes into account where these species have been found in the past, and where they may be found in the future.

The east-west boundary of EFH for CPS includes all marine and estuary waters from the coasts of California, Oregon, and Washington to the limits of the EEZ (the 200-mile limit) and above the thermocline where sea surface temperatures range between 10 and 26 °C. (A thermocline is an area where water temperatures change rapidly, usually from colder at the bottom to warmer on top). The southern boundary is the U.S.-Mexico maritime boundary. The northern boundary is more changeable, and is defined as the position of the 10° C isotherm, which varies seasonally and annually. (The 10° C isotherm is a rough estimate of the lowest temperature where finfish are found, and thus represents their northern boundary.) In years with cold winter sea surface temperatures, the 10°C isotherm during February is around 43° N latitude offshore, and slightly further south along the coast. In August, this northern boundary moves up to Canada or Alaska. A more complete description of CPS and associated EFH is contained in the CPS FMP, which is incorporated herein by reference.

3.1.4.2 Salmon

Salmon range from more than 1,000 miles inland to thousands of miles out at sea. Although the waters off Canada are salmon habitat, they are also not included in the description of salmon EFH because they are outside of U.S. jurisdiction. However, waters off Alaska are included in the description.

In estuaries and marine areas, salmon habitat extends from the shoreline to the 200-mile limit of the EEZ and beyond. In freshwater, salmon EFH includes all the lakes, streams, ponds, rivers, wetlands, and other bodies of water that have been historically accessible to salmon. The description of EFH also includes areas above artificial barriers, except for certain barriers and dams that fish cannot pass. However, activities that occur above these barriers and that are likely to affect salmon below the barriers may be affected by court rulings from ongoing EFH-related litigation.

The Council is required to minimize the negative impacts of fishing activities on essential salmon habitat. The ocean activities that the Council is concerned with include the effects of fishing gear, removal of salmon prey by other fisheries, and the effect of salmon fishing on reducing nutrients in streams due to fewer salmon carcasses in the spawning grounds. The Council may use gear restrictions, time and area closures, and harvest limits to reduce negative impacts on salmon EFH.

The Council is also required to comment and make recommendations regarding other agencies' actions that may affect salmon EFH. This usually takes the form of endorsing an enhancement program or other type of program, requesting information and justification for actions that might affect salmon habitat, and promoting the needs of the salmon fisheries. The Council works with many other agencies to identify cumulative impacts on salmon habitat, to encourage conservation, and to take other actions to protect salmon habitat. A more complete description of salmon and associated EFH is contained in the salmon FMP, which is incorporated herein by reference.

3.1.4.3 Highly Migratory Species

These species (tuna, swordfish and sharks) range widely in the ocean, both in terms of area and depth. Highly migratory species (HMS) are usually not associated with the features that are typically considered fish habitat (such as seagrass beds, rocky bottoms, or estuaries). Their habitat may be defined by temperature ranges, salinity, oxygen levels, currents, shelf edges, and sea mounts. Little is known about why highly migratory species frequent particular areas. Nevertheless, these species may be affected by actions close to shore or on land, such as fishing, dredging, wastewater discharge, oil and

gas exploration and production, aquaculture, water withdrawals, release of hazardous materials, and coastal development. A more complete description of HMS and associated EFH is contained in the HMS FMP which is incorporated herein by reference.

3.1.4.4 Groundfish

The Council first identified groundfish EFH in 1998 via Amendment 11 to the FMP. Because information about each groundfish species' habitat was limited, EFH was defined as the whole West Coast EEZ. However, in 2000, based on the *American Oceans Campaign v. Daley* court case, the Council was directed to revisit the question of groundfish EFH. In 2001, NMFS Northwest Region staff began work on an EIS for groundfish EFH off Washington, Oregon, and California, which after several years of work was finalized in 2005. The Council's preferred alternative in the final EIS became Amendment 19 to the Groundfish Fishery Management Plan in 2006.

EFH for groundfish is described as all waters from the high tide line (and parts of estuaries) to 3,500 meters (1,914 fathoms) in depth. HAPCs are a subset of EFH used to focus management and restoration efforts. The current HAPC types are: estuaries, canopy kelp, seagrass, rocky reefs, and "areas of interest" (a variety of submarine features, such as banks, seamounts, and canyons, along with Washington State waters).

In addition to identifying EFH and describing HAPCs, the Council also adopted mitigation measures directed at the adverse impacts of fishing on groundfish EFH. Principal among these are closed areas to protect sensitive habitats. There are three types of closed areas: bottom trawl closed areas, bottom contact closed areas, and a bottom trawl footprint closure. The bottom trawl closed areas are closed to all types of bottom trawl fishing gear. The bottom trawl footprint closure closes areas in the EEZ between 1,280 m (700 fm) and 3,500 m (1,094 fm), which is the outer extent of groundfish EFH. The bottom contact closed areas are closed to all types of bottom contact gear intended to make contact with the bottom during fishing operations, which includes fixed gear such as longline and pots. A more complete description of groundfish and associated EFH is contained in the groundfish FMP, which is incorporated herein by reference.

3.1.5 Marine Protected Areas

In addition to the closed areas described above, there are marine protected areas distributed throughout the project area. The EIS for Pacific Coast Groundfish EFH contains a complete analysis of these sites and is incorporated here by reference. The following is a brief summary of these areas.

Federally Designated Marine Managed Areas

- Twenty-eight National Wildlife Refuges, covering approximately 89,000 ha. Regulations vary by refuge, but generally, commercial fishing is not allowed in most refuges.
- Seven National Parks, covering approximately 570,000 ha (although only a small fraction of this area is the marine portion of the parks). Regulations vary by park.
- Five National Marine Sanctuaries covering approximately 3,000,000 ha. Regulations vary by sanctuary, but in general, all types of fishing are allowed in Federal waters of the sanctuaries.
- Four National Estuarine Research Reserves (NERR), covering approximately 8,000 ha. All fishing and fishing gear are prohibited from the Tijuana River NERR and the Elkhorn Slough NERR (which doesn't include the Slough's main channel). All other NERR sites allow or do not address specific fishing regulations.

Other Federal Areas

These are some additional areas under Federal jurisdiction that may have restrictions to vessel access, rather than specific regulations having to do with fishing or fishing gear. These data were developed in 1998 by Al Didier for the Pacific States Marine Fisheries Commission (PSMFC), so the total number of areas may have changed since these data were compiled.

- Twenty-two Regulated Navigation Areas (33CFR165) cover approximately 17,000 ha, and are located generally in urban areas such as Puget Sound, Columbia River, San Francisco Bay, Los Angeles, and San Diego.
- Forty-nine Danger Zones and Restricted Areas (33CFR334) cover approximately 170,000 ha. These are located in Puget Sound, San Francisco Bay, Monterey Bay, between Morro Bay and Point Conception, off some of the Channel Islands, and a few additional southern California locations.
- Twenty-seven weather and scientific buoys. Two buoys are located off the Washington coast, one is located off the Oregon coast, and twenty buoys are located off the California coast, with six of these located off Monterey Bay. Four of these buoys are located outside the EEZ.

Fishing regulated areas established by the Council:

- RCA: These areas have changed over time, as well as having a seasonal component to their locations. In addition, there are specific areas for trawl gear and non-trawl gear. Not all of the historical RCA areas have been developed into GIS data, but most of the areas from 2003 are mapped as an example. A chronology of changing trawl and non-trawl RCAs for the year 2003 is included below.
- CCA: Sections of the CCA cover a total area of 1,372,447 ha.
- Darkblotched Conservation Area (DBCA): The Dark Blotched Conservation Area covered 1,029,415 ha.
- Yelloweye Rockfish Conservation Area (YRCA): This area encompasses 59,285 ha.
- Two National Marine Fisheries sites (Pacific Whiting Salmon Conservation Zones), covering approximately 44,000 ha. These two sites, one off the Columbia River and one off the Klamath River, prohibit fishing for Pacific Whiting with commercial mid-water trawl gear.

State Marine Protected Areas

California: Marine protected area (MPA) boundaries for sites in California were downloaded from the California Department of Fish and Game website. In these data, there are 79 sites covering approximately 59,000 ha. The California sites have been categorized into 13 designations. California is currently renaming and recategorizing these sites into three designations (marine reserve, marine park, and marine conservation area); however, the existing designations are used here for descriptive purposes.

- Ten State Marine Reserves: These areas are located adjacent to the Channel Islands. No commercial or recreational fishing is allowed in these areas.
- Two State Marine Conservation Areas: These areas are also located adjacent to the Channel Islands. Most commercial fishing, except for spiny lobster fishing, is prohibited in these areas.
- Seven State Parks: Five of these coastal state parks are located north of San Francisco, one is south of Monterey, and one is near Irvine. Fishing regulations vary by park.
- Four State Beaches: One is located north of San Francisco and the other three are south of Point Conception. Fishing regulations vary by site.
- One State Historic Park: This site is located north of San Francisco. There are no prohibitions on fishing gear of any type.

- Nine Reserves: Several areas in, near or north of San Francisco Bay. A few areas in southern California. Regulations are highly variable by site—some prohibit all fishing, and some allow all fishing.
- Twenty-two Ecological Reserves: These sites are located all along the coast. Regulations are highly variable by site—some are designated as no-take reserves, meaning all fishing is prohibited, and some are designated to prohibit certain type of fishing. Some allow all fishing, but prohibit take of other types of resources.
- Four MRPA Ecological Reserves: three sites are located along the central California coast, and one is north of San Francisco. Recreational and commercial fishing is prohibited at all sites.
- One Invertebrate Reserve: This site is located on the central coast. Recreational fishing is allowed for finfish. Commercial fishing is allowed for finfish, lobster, abalone and crab.
- One Natural Preserve: This site is located in northern California. No access allowed to the site.
- Three Clam Preserves: These sites are located on the central coast, just north of Point Conception. No clams may be taken, but all commercial and recreational fishing and fishing gear are allowed.
- One Marine Gardens Fish Refuge: This site is located in Monterey Bay. Most commercial fishing gear is prohibited, except nets. Recreational pot gear is prohibited, other recreational gear is allowed.
- Fourteen Marine Life Refuges: These sites are located primarily along the central and southern coast. Most commercial gear, except pot and “other” gear, is prohibited from these sites. All recreational gear types are allowed.

Oregon: MPA boundaries for three types of sites in Oregon were provided by Oregon Department of Fish and Wildlife. These are all small intertidal sites encompassing approximately 460 ha.

- Seven Marine Gardens: Generally, commercial and recreational pot gear is prohibited, other gear types not restricted.
- Six Research Reserves: Generally, commercial pot gear is prohibited.
- One Habitat Refuge: All commercial and recreational fishing activities are prohibited.

Washington: The Washington State GIS data for MPAs contain 68 individual sites covering approximately 28,000 ha. The areas are managed by one of the following organizations: Washington Department of Fish and Wildlife (WDFW), Washington Department of Natural Resources (WDNR), San Juan County Marine Resource Committee (MRC), Washington State Parks and Recreation Commission (WSPRC), or The Nature Conservancy (TNC). The total area figure is a bit of an overestimate because some of the areas, such as state parks and TNC areas, include the upland portions of the sites as well as the marine portions.

- Nine WDFW Marine Preserves: generally prohibit most types of commercial fishing gear.
- Two WDFW Wildlife Refuges: generally closed to all access.
- Nine WDFW Conservation Areas: most restrictive of fishing—all fishing and gear are prohibited from nearly all of these sites.
- Two WDFW Sea Cucumber Closures: closed to commercial harvest of sea cucumbers and urchins.
- Six WDNR Aquatic Reserves: no restrictions on commercial or recreational fishing.
- Seven WDNR Natural Areas Preserves: highest level of restriction—only allowable activities are scientific or education functions. Therefore, no commercial or recreational fishing allowed.
- Two WDNR Natural Resource Conservation Areas: no specific prohibition of fishing activities.
- Eight San Juan County MRC Bottomfish Recovery Zones: these are voluntary bottomfish no-take zones—no specific prohibition of fishing activities.

- Seven State Parks: prohibited to take non-game invertebrates and seaweed. No specific prohibition of fishing activities.
- Two TNC Conservation Easements.
- Fourteen TNC Nature Preserves: limitation on public access and all fishing activities.

3.1.6 *The Role of Rebuilding Species in the Marine Ecosystem*

Under Section 304 of the MSA (104-297), fishery management plans, plan amendments, or proposed regulations for overfished species must take into account status and biology of any overfished stocks of fish as well as the interaction of overfished stocks within the marine ecosystem. This section was developed to consider the relevant aspects of these stocks with respect to their interaction with other biotic elements of the ecosystem.¹³ The intent is not to replicate the evaluation of status, life history, and productivity of the stocks themselves, which is discussed in more detail in Chapters 2 and 4, but rather to focus on the role of these species in the environment, and to attempt to evaluate the relative impacts of alternative management decisions analyzed in this document with respect to the long-term consequences on other elements of the ecosystem (noting that the likely or expected impacts on the stocks themselves are discussed in detail in the stock-specific summaries in Chapter 4).

The rebuilding rockfish stocks, and indeed all rockfish more generally, occupy a broad range of ecological niches and trophic roles, and some analysis of their principal predators, prey, and competitors is an important consideration with respect to the impacts that rebuilding decisions may have on the larger ecosystem. Larval rockfish (and larval fish more generally), have been shown to play a minor role in the macrozooplankton community, which is dominated by a wide range of predators and competitors (McGowan and Miller 1980). However, both juvenile and adult rockfish are important prey items to a wide range of other rockfish, other piscivorous fishes, seabirds, and marine mammals. Most food habits studies do not reliably or consistently report rockfish to the species level. Therefore, a summary of key predators here is focused more generally the role of rockfish as prey, rather than the role of individual rebuilding species as prey. Although it is not possible to assess potential impacts to predators that may or may not result from the depletion of rockfish populations, particularly with respect to the level of depletion beyond target levels or the natural population variability exhibited by unfished species (Miller and Sydeman 2004; Moser, *et al.* 2000), it is clear that rockfish in general (particularly juveniles) represent a significant trophic linkage throughout the ecosystem.

For example, Merkel (1957) reported that juvenile rockfish were particularly important prey of Chinook salmon along the central California coast, representing on the order of 22 percent of prey by volume throughout the year, with most predation occurring between May and July, when pelagic juveniles move inshore to settle. Brodeur and Pearcy (1990) also found heavy predation on larval and juvenile rockfish by coho and Chinook salmon along the Oregon and southwest Washington coasts. The importance of rockfish as prey to piscivorous rockfish such as bocaccio, cowcod, and yelloweye is summarized below; many nearshore rockfish species also predate heavily on other rockfish, particularly juveniles (Hobson, *et al.* 2001; Lee 1997; Love, *et al.* 2002). Lingcod are among the most voracious predators of both juvenile and adult rockfish; Phillips (1959) reported that a 54 lb lingcod in Monterey, California had been found with a 12-inch starry rockfish and an 18½-inch canary rockfish in its stomach. Additional studies have confirmed that rockfish are important prey items for both California (Shaw and Hassler 1989) and Oregon lingcod (Steiner 1978). Sablefish are also significant predators of both juvenile and

¹³ Many marine organisms (such as many types of plankton, structure-forming invertebrates, and burrowing or bioturbating organisms) can and do interact with abiotic (physical and chemical) characteristics of an ecosystem that could have broader-scale impacts to marine communities and ecosystems. However, such interactions are neither known nor suspected for the rebuilding species evaluated in this section, and consequently are not explicitly considered here.

adult rockfish, with rockfish representing between 20 and 60 percent of sablefish prey by volume (Buckley, *et al.* 1999; Cailliet, *et al.* 1988; Laidig, *et al.* 1997). However, for most depth ranges sablefish prey primarily on longspine thornyheads. Although Pacific hake are known predators of juvenile rockfish, juvenile rockfish represent significantly less than 1 percent of their diet by both volume and frequency of occurrence. Pacific halibut, soupfin sharks, dogfish sharks, and albacore tuna are other known rockfish predators (Bonham 1949; Rankin 1915; Ripley 1946), and many other fish are likely to feed on rockfish (particularly juveniles) as well.

A wide range of seabirds also prey heavily on juvenile rockfish (Chu 1984; Wiens and Scott 1975). For many species, as much as 90 percent of their diet comprises juvenile rockfish during the late spring and early summer, which coincides with the breeding season for many resident species (Ainley, *et al.* 1993; Miller and Sydeman 2004). However, there is considerable interannual, and interdecadal variability in the frequency of rockfish in seabird diets, related primarily to the availability of juveniles to seabirds. While many studies have not attempted to identify juvenile *Sebastes* to species, for those that have (largely off of the central and southern California coasts) unexploited species such as shortbelly rockfish generally account for more than two-thirds of the juvenile rockfish identified (Ainley, *et al.* 1996; Merkel 1957; Miller and Sydeman 2004). Throughout the 1990s, declines in juvenile rockfish predation by central California seabirds occurred in both exploited and unexploited rockfish species (Miller and Sydeman 2004; Mills, *et al.* 2006; Sydeman, *et al.* 2001). It is reasonable to expect that fisheries removals have contributed to overall declines in juvenile production, with proportionately greater declines in production for stocks that have been historically overfished and are now rebuilding.

As seabirds have a success-failure breeding response, rather than a response that is proportional to food supply, there is a potential for seabird populations to be highly sensitive to changes in food abundance (Furness and M.L.Tasker 2000; MacCall 1984; Sydeman, *et al.* 2001). This may be particularly true for seabirds in which juvenile rockfish have been shown to be a preferred prey item. Research has shown that common murrens prefer to forage locally for juvenile rockfish during their breeding season (May-June, when juvenile rockfish are most abundant), since the close proximity to the breeding grounds reduces foraging trip duration. In years when juvenile rockfish are less abundant, murrens forage in coastal waters for northern anchovy and other forage fishes (1990; Miller and Sydeman 2004). Consequently, it is difficult to determine whether declines in overfished species could have had a notable impact on seabird reproductive success or other predators above and beyond that which has occurred as a result of fishing stocks to target levels and natural variability. These declines are coincident with the poor recruitment observed in many exploited species (described in Section 4.1), as well as poor reproductive performance for many seabird species that depend heavily on juvenile rockfish in the breeding season (Sydeman, *et al.* 2001). However, the observation that declines were observed in the consumption by seabirds of juveniles of both unexploited and exploited species suggests that ocean conditions were a major factor in the low abundance of juvenile rockfish.

Both juvenile and adult rockfish are typically a modest, but significant, component in the diets of most California Current pinnipeds and many cetaceans; however, rockfish prey are rarely identified to the species level (Morejohn, *et al.* 1978; Perez and Bigg 1986; Stroud, *et al.* 1981). Morejohn *et al.* (1978) did identify bocaccio rockfish to species in diets of harbor seals and elephant seals, but other rockfish were listed solely as *Sebastes sp.* Lowry and Carretta (Lowry and Carretta 1999) reported that shortbelly rockfish were among the most frequently encountered prey items for California sea lions at San Nicolas, San Clemente, and Santa Barbara Islands. Lowry *et al.* (1991) also suggested that California sea lion food habits tend to be temporally dynamic and related to the relative availability of prey. Off of central California, some rockfish taken in food habits studies have been identified using

otoliths, with those identified to species including shortbelly, bocaccio, splitnose, vermilion, and canary rockfish.¹⁴

Given that most marine mammal populations in the California Current exhibit either stable or increasing abundance trends over the last several decades, it seems unlikely that the depletion of overfished rockfish or any alteration to their expected recovery trajectories that might result from management decisions would have a negative impact on marine mammals. However, the converse situation, in which increasing marine mammal populations might slow or prevent the recovery of rebuilding species (a depensatory impact), may be plausible. For example, Bundy (2001) used a multispecies model of the Newfoundland-Labrador ecosystem to evaluate such potential interactions between harp seals and cod. Her results suggest that although the decline of cod was the result of overfishing, the recovery may be hindered by the increasing natural mortality rate associated with a nearly constant per capita consumption of cod by harp seals and concurrent increases in seal abundance. Such factors, which are known as depensatory processes that could complicate recovery efforts for some species, are difficult to quantify, and consequently are not explicitly considered in the analysis of rebuilding trajectories. However, since most rockfish are characterized by low growth, low metabolic rates, and low natural mortality rates, they are likely to be less tightly coupled with the dynamics of either their predators or their prey over most temporal and spatial scales.

With respect to the food habits of the depleted species themselves, accurate quantification of food habits is poor. Most rockfish are notoriously difficult to sample for food habits studies due to the eversion of their air bladder upon capture in sampling gear, usually resulting in regurgitation of any stomach contents. Thus, while several quantitative studies exist for widow, canary, yelloweye, and darkblotched rockfish, anecdotal accounts of food habits are the primary source of information for cowcod and bocaccio rockfish. For all of these species, general patterns of prey preferences are evident from the literature; however, prey preferences may also vary substantially over time (seasons, years), space (depth, latitude, habitat) and life history stage (most species tend to exhibit some ontogenetic shift in prey preferences with size).

Available food habits studies tend to confirm that POP, darkblotched, canary, and widow rockfish are primarily planktivorous, with the vast majority of the diets of the first three of these being euphausiids. For example, Brodeur and Pearcy (1984) found that euphausiids comprised 85 percent of prey by volume for POP, 92 percent by volume for Canary rockfish, and roughly 75 percent by volume (of identifiable remains) for a small number of darkblotched rockfish (for which most prey remains were unidentifiable). All three of these species also fed to some extent on smaller amounts of pelagic shrimp, cephalopods, mesopelagic fishes, and other prey. Lee (2002) also found that canary rockfish relied heavily on euphausiids, which accounted for over 98 percent of prey by volume. By contrast, widow rockfish have a more varied range of prey items, including a heavy reliance on gelatinous zooplankton. Phillips (1964) reported that widow rockfish, which tend to occupy semi-pelagic habitat, feed on macrozooplankton, particularly amphipods. Adams (1987b) found that widow rockfish diets in northern California were dominated by four key groups of prey items; salps and other gelatinous zooplankton, euphausiids, pelagic shrimp, and small fish (primarily mesopelagic fish, juvenile hake, and forage fish such as anchovy and smelt). Lee (2002) found that nearly 75 percent of the diet by volume of widow rockfish off of Oregon and Washington was composed of salps and other gelatinous predators, with smaller fractions of euphausiids, pelagic shrimps, and small fish.

Although quantitative food habits studies do not exist for either cowcod or bocaccio rockfish, both Phillips (1964) and Love, et al. (2002) described bocaccio rockfish as almost exclusively piscivorous.

¹⁴ M. Weise, University of California Santa Cruz, unpublished data, but see Weise and Harvey (Weise and Harvey 2005) for an overview of the study and methods.

Love, et al. (2002) include other rockfish, hake, sablefish, anchovy, mesopelagic fishes, and squid as the key prey for large juvenile and adult bocaccio, while cowcod are described by Love et al. (2002) as feeding on “anything that is not bolted down,” but primarily fish and cephalopods. Limited data is reported in the literature for yelloweye rockfish. Steiner (1978) reported on the stomach contents of 28 yelloweye caught on rocky reefs off of the central Oregon coast, which preyed primarily on benthic epifauna, flatfish, other rockfish, and shrimp. Rosenthal, et al. (Rosenthal, *et al.* 1988) found that yelloweye rockfish in southeast Alaska were primarily piscivorous, preying primarily on herring, other rockfish, and sand lance. Thus, the general patterns that emerge for these seven species are that three are higher trophic level piscivores that tend to be found on rocky or highly structured habitat (cowcod, bocaccio, and yelloweye rockfish), three are primarily planktivores associated with shelf and slope benthic habitat (POP, canary, and darkblotched rockfish) and one is an omnivorous species that occurs and feeds primarily in midwater, and primarily on gelatinous zooplankton (widow rockfish).

As higher trophic level predators, cowcod, bocaccio, and yelloweye rockfish have a greater potential to play a structuring role in the ecosystem, particularly over smaller spatial scales. Despite their overall rarity throughout the marine environment relative to more abundant omnivorous or planktivorous rockfish,¹⁵ submersible surveys have found that these piscivorous species can be found at relatively high levels of abundance in many rocky reef habitats isolated and presumably lightly fished reefs (Jagiello, *et al.* 2003; Yoklavich, *et al.* 2002; Yoklavich, *et al.* 2000). In surveys of reefs that had high piscivores density, the concentration of smaller, fast-growing and early maturing *Sebastes* species was considerably lower (such as greenstripe, rosethorn, splitnose, and pygmy rockfish). By contrast, in rocky reef habitats known or suspected to be subject to heavier fishing pressure, the abundance of such small, fast-growing, and early-maturing species was considerably greater. For example, Stein et al. (1992) found that reefs with small numbers of piscivorous rockfish (such as yelloweye) had very high numbers (as much as three orders of magnitude greater) of smaller species. Yet the scarcity of data on spatial patterns of abundance and fishing pressure, and a lack of all but qualitative food habits data for most these species, makes demonstrating and quantifying such interactions extremely challenging.

Additional empirical support for either intraguild competition or top-down impacts of fishing that may have resulted in either localized or large-scale community changes is presented in Levin, et al. (Levin, *et al.* 2006), who found some evidence for broad-scale changes in the taxonomic composition of benthic marine fishes in the California Current. Their analysis focused on 16 species of rockfish, eight species of flatfish, and seven species of cartilaginous fish that were sampled by bottom trawl surveys on the continental shelf between 1977 and 2001 (including all of the rebuilding species except for cowcod). For the species they included in their analysis, rockfish declined from over 60 percent of the catch in 1977 to less than 17 percent of the catch in 2001, with flatfish catches increasing by a similar magnitude. Additionally, populations of larger rockfish (including primarily the rebuilding species) had fallen at high rates (as reflected by stock assessments), while those of smaller species, particularly those associated with soft substrate, had generally increased in abundance. These authors also note that the potential for smaller species of rockfish to consume or outcompete recruiting juveniles of larger species highlights the potential that fishing could shift the community composition of the rockfish assemblage, or the benthic groundfish assemblage more generally, into an alternate state.

¹⁵ Estimates of unfished biomass (B_0) for cowcod and yelloweye are on the order of 3,000 and 7,500 mt respectively. By contrast, estimates of unfished biomass for bocaccio and widow and canary rockfish are on the order of 70,000, 90,000, and 230,000 mt respectively. Similarly, cowcod have always been among the rarest of *Sebastes* spp. larvae identifiable to species in the standard CalCOFI survey area (nearshore to offshore waters south of Point Piedras Blancas off California) between 1951 and 1998, with estimates of abundance as much as two orders of magnitude less than more abundant species (Moser, *et al.* 2000).

The potential for intraguild competition or top-down forcing, in both small-scale rocky reef systems and throughout the larger ecosystem, is also supported by theoretical considerations and simulation models. Walters and Kitchell (2001) as well as MacCall (2002a) have demonstrated the potential for strong interactions among the adults of higher trophic level piscivores and their prey, such that adults crop down forage species that may be potential predators or competitors of their own juveniles, with consequent negative impacts on higher trophic level predators when their populations are reduced by fishing (see also Swain and Sinclair 2000). Baskett, et al. (2006) have explored the potential for such interactions as well, with a community interactions model based on rocky reef habitat and juvenile and adult life history stages of rockfish parameterized to represent yelloweye and pygmy rockfish. Their model sought to evaluate interspecific dynamics among rocky reef rockfish within a marine reserve, and considered the interactions among fishing, population recovery following cessation of fishing mortality, juvenile predation and competition.

Without interspecific interactions, the model developed by Baskett, et al. (2006) predicted that larger piscivores would recover given minimal levels of dispersal and reserve size. However, when community interactions were taken into account, initial conditions such as the relative abundance of the piscivores and the size of the reserve became more important with respect to the ultimate stable state, and the models predicted that under some circumstances recovery could be unlikely. Due to lack of adequate information on abundance and plausible parameter values for many of the interactions, the model was simplistic in the sense of modeling a single predator (with two life history stages) and a single prey/competitor, with little evaluation of the complicating impacts of climate variation, variability in recruitment, multiple alternative prey items, and other factors. Despite this, their results were consistent with similar simulations of the potential consequences of community interactions in marine systems (MacCall 2002a; Mangel and Levin 2005; 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.

3.2 The Effects of Fishing on Habitat and the Marine Ecosystem

With regard to EFH, NMFS recently completed an EIS to comprehensively evaluate groundfish habitat and the effects of groundfish fishing on that habitat, in response to litigation (*American Oceans Campaign v. Daley et al.*, Civil Action No 99-982(GK)). The current action, authorizing harvest of groundfish within EFH, are within the scope of fishery management actions analyzed in the EIS for groundfish EFH. Those analyses are incorporated by reference. A Record of Decision for Pacific Coast Groundfish EFH was issued on March 8, 2006, and concluded that partial approval of Amendment 19 to the FMP would minimize to the extent practicable adverse impacts to EFH from fishing. Amendment 19, approved on March 8, 2006, provides for a comprehensive strategy to conserve EFH, including its identification, designation of HAPC, and the implementation of measures to minimize to the extent practicable adverse impacts to EFH from fishing. The final rule implementing Amendment 19 provides measures necessary to conserve EFH and no additional EFH recommendations are necessary for this proposed action. Based on the analyses in the EFH EIS (NMFS 2005) and the mitigation measures implemented as part of that action, NMFS concludes that the effects of 2007–08 harvest specifications will not be significant and are therefore not analyzed further.

The 2004–05 groundfish harvest specifications EIS pointed out there is currently insufficient information to predict the effects of fishing on the marine ecosystem in any precise way nor distinguish among the alternatives in terms of these types of effects. As noted in that EIS, NEPA regulations address this issue. When an agency is evaluating reasonably foreseeable significant adverse effects, there is incomplete or unavailable information, and the costs of obtaining it are exorbitant or the means unknown, the agency must, (1) so state, (2) describe the importance of the unavailable information to

the assessment, (3) summarize any existing scientific information, and (4) evaluate impacts based on generally accepted scientific principals (40 CFR Part 1502.22), which may accord with the best professional judgment of agency staff. NMFS acknowledges that the information necessary to fully evaluate impacts to EFH and marine ecosystems, as described in the preceding paragraph, cannot be reasonably obtained at this time, and impacts are generally unknown.

Furthermore, it is not possible to separate out the direct/indirect effects of the action on the ecosystem (fishery removals), which may be modest, and the cumulative effects of past and future groundfish fishing mortality (occurring as past or reasonably foreseeable future actions under the management framework). Therefore, the following sections summarize existing scientific information on two potential long-term effects of the depletion of stocks from unfished biomass: (1) potential effects to constituents of the food web as a result of depletion of groundfish species at different trophic levels and (2) broad-scale genetic and demographic changes in fish populations resulting from fishing. Section 3.3 assesses the effects of the proposed action in light of this discussion.

3.2.1 *Effects of Fishing on the Food Web*

The sections above provide a conceptual framework, based on trophic considerations and the basic structure and function of marine food webs, for considering the plausible impacts of the removal of both overfished (rebuilding) stocks as well as healthy stocks from the marine ecosystem. The impact associated with both the status quo and the action alternatives are the removals of these species from the ecosystem, at various levels depending upon the OY alternatives. Biogeography and EFH are presented for consideration of other elements of the ecosystem along with current measures to protect EFH.

Although far from conclusive, the empirical evidence and theoretical considerations discussed in Section 3.1.3 suggest some potential for top-down impacts or intraguild competition, as a result of declines in higher trophic level species such as cowcod, bocaccio, and yelloweye rockfish over small spatial scales. It is reasonable to expect that similar impacts could potentially be associated with fishery-induced declines in stocks of healthy species (those reduced from their equilibrium abundance, but not to levels below overfishing limits), such as sablefish, Pacific halibut, petrale sole, shortspine thornyhead, Pacific hake, and other piscivorous or higher trophic level species. Such impacts are often referred to as trophic cascades, in which declines of high trophic level species (keystone predators) have cascading impacts through food webs to the abundance, productivity, and species diversity of lower trophic levels. Empirical examples of trophic cascades tend to be more common for semi-enclosed ecosystems such as lakes, or highly structured (two dimensional) environments, such as intertidal or sub-tidal ecosystems (Paine 1966; Simenstad, *et al.* 1978; Tegner and Dayton 2000). As one ventures further from these environments, the evidence for top-down control, or trophic cascades, becomes considerably spottier, although (Van der Elst 1979) reported a classic example of top-down control of a coastal ecosystem off of the Natal coast in South Africa.¹⁶

However, in coastal upwelling ecosystems such as the California Current, most evidence suggest that the primary forcing factor for ecosystem productivity and structure over the scale of the entire system tends to be either “bottom-up” (based on the amount and variability of primary or secondary production) or “middle-out.” For example, (Ware and R.E.Thomson 2005) proposed that the carrying capacity of north Pacific coastal ecosystems was primarily determined by bottom-up control, based on correlations

¹⁶ In this case, increased mortality of large sharks resulted from the use of shark nets to protect bathers, which subsequently caused an apparent increase in the abundance of smaller dusky and milk sharks on which they preferentially fed. This increase of smaller sharks resulted in a substantial decline in catch per unit effort of several populations of teleost fishes that were both commercially and recreationally important to coastal communities in the region.

between latitudinal variability in primary production and commercial fisheries yields. Alternatively, bottom-up control in these ecosystems could be a function of secondary production, through variability in the productivity and species composition of the zooplankton community. As discussed in Section 3.1.2, the California Current seems to experience higher secondary production during periods of stronger southward transport and cooler sea surface temperatures. Zooplankton, particularly euphausiids, are the principal prey item for most of the mid-trophic level organisms in the California Current, including Pacific hake and most rockfish.

An alternative to bottom-up control is “middle-out” control, also referred to as “wasp-waist” control, in which a small number of key mid-trophic level species represent a bottleneck of energy flow between lower and higher trophic levels. It has long been noted that food webs in coastal upwelling ecosystems tend to be structured around CPS, such as krill, sardine, anchovy, and hake, that exhibit boom-bust cycles of abundance over decadal time scales (Bakun 1996; Parrish, *et al.* 1981; Schwartzlose, *et al.* 1999). Such dynamics have long been thought to be a consequence of the energetic and highly variable oceanographic processes that shape the physical environment and drive production throughout pelagic and benthic food webs in coastal upwelling ecosystems (such as the California Current system) over a range of time scales (Mann and Lazier 1996; Parrish, *et al.* 1981). The idea of wasp-waist control was first suggested by Rice (1995) and developed in greater detail in Cury *et al.* (2000). The premise is that the low species diversity often observed in the middle of many upwelling ecosystems results in a vast majority of the energy in the food web flowing through CPS such as sardine, anchovy, and mackerel. Many of these seem to feature “weak links” in their life cycles related to sensitivity to climate forcing, such that climate conditions determine the productivity of these stocks, and indirectly drive the dynamics of both higher and lower trophic levels.

Empirical evidence for any of these types of control is typically limited for large marine ecosystems (Hunt and McKinnell 2006). However, where trophic interactions among exploited species are documented or suspected, ecosystem modeling can provide a template to evaluate both the magnitude and consequences of removals of either predators or prey in the system of interest (Christensen and Walters 2004; Hollowed, *et al.* 2000). Although such models are unavoidably constrained by conceptual shortcomings and data limitations, most critical reviews of multispecies modeling approaches agree that ecosystem models can augment contemporary single species models by confronting an array of interactions and dynamics that are more difficult to address with single-species models, such as competition, predation and environmental variability (Fulton, *et al.* 2003; Hollowed, *et al.* 2000; Plagányi and Butterworth 2004). For example, Walters, *et al.* (2005) used the results from a number of existing ecosystem models to demonstrate that widespread application of contemporary (MSY proxy) single-species management approaches could lead to dramatic impacts on ecosystem structure, particularly where such approaches are applied to forage species. Their results add considerable weight to the perceived need to consider forage species as resources whose value is derived from their role as prey to commercially and recreationally important stocks, a consideration consistent with recent the Council determination to place a precautionary ban on krill (euphausiid) harvests throughout the West Coast EEZ.

Dynamic simulations of an ecosystem model of the Northern California Current were developed by Field, *et al.* (2006b), who modeled the continental shelf and slope ecosystem between Cape Mendocino and Cape Flattery between 1960 and 2004. The model was based on, and tuned to, biomass estimates from stock assessments and surveys, consumption and production rates estimated from empirical studies or the literature, historical estimates of landings and discard rates, and the limited food habits data that were available in this region. The model was run forward first under the assumption of a constant environment, then forced dynamically with several climate indices. They found that most of the variability observed in single species models and dynamics can be replicated with a multi-species modeling approach, despite significant changes in food web structure and the abundance of both

predators and prey in this ecosystem over time. In general, these results imply that over the macro-scale, there do not appear to be obvious changes in ecological structure that have resulted in strong interspecific interactions (predation, competition) between most of these species. One large exception to this generalization was Pacific hake, which by virtue of their large biomass and high consumption of forage species in the model were shown to have potential competitive interactions. Agostini (2005) found that most model components (particularly pandalid shrimp, rockfish, salmon, seabirds and marine mammals) benefited from a reduction in hake biomass, primarily as a result of increases in the availability of euphausiids, forage fish and other prey.

These results are consistent with what is known of the life histories for many of the rockfish, roundfish and longer-lived flatfish in the California Current, where low mortality rates are indicative of low predation rates and presumably weakly coupled trophic interactions. In other words, species with a low natural mortality rate are unlikely to be a “key prey species” for higher trophic level predators, and are consequently less likely to effect significant bottom-up control in the energy flow or structure of the ecosystem. Consequently, the effects of severe declines in the overfished species that were explicitly included in this model (canary rockfish, widow rockfish, and POP) to other elements of the ecosystem appear to be minimal. The model found considerably stronger interspecific interactions in species such as shrimp, salmon, and small flatfish where there is high turnover and high predation coupled with substantial changes in many of their key predators (such as hake, sablefish, marine mammals) over the last forty years. There were, of course, other exceptions to this generalization; in fact one of the strongest interactions appeared to be among several of the slowest growing species; sablefish, shortspine thornyhead, and longspine thornyhead. Essentially, the model suggested that natural mortality rates for longspine thornyheads may have fallen by nearly fourfold over recent decades as a result of substantial declines in sablefish and shortspine thornyheads, their key predators. As a result, the expectation would be that longspine thornyhead abundance would increase over time, a prediction consistent with recent trawl survey results.

However, this work focused on integrating a broad array of species and habitats, and due to their relative rarity and the paucity of food habits data, the piscivorous species of rockfish described in the previous section were not modeled as independent populations. As the fauna and environmental conditions along the continental slope differ tremendously from those on the shelf and near the shelf break, evaluating these interactions more carefully is likely to require development of spatially explicit modeling efforts, coupled with more appropriate consideration of age and/or size based bioenergetic requirements and predation interactions. A comparable, but considerably more complex model, with greater population (demographic) structure, spatial complexity and explicit physical forcing (Fulton, *et al.* 2004), is currently under development by researchers at the NMFS Northwest Fisheries Science Center. As baseline knowledge and modeling abilities increase, such models will hold greater promise for successfully identifying the processes and mechanism of ecosystem change, and guiding decisions that might hasten the recovery of both individual species and sustain the community and ecosystem in which they reside.

Other theoretical considerations point to the potential for an important role for rebuilding species in the California Current over broad spatial and temporal scales, particularly the stocks that were historically more abundant. By virtue of their slow growth and low mortality rate, these stocks may fill a role in stabilizing highly dynamic ecosystems, by dampening what might otherwise be even greater ecological responses by high turnover species to rapid changes or short-term bursts in production (Apollonio 1994). However, the same could be said of any ecosystem for which all stocks were at their “target” levels. The premise of nearly all contemporary fisheries management is that reducing stocks to target levels results is sustainable from a single species perspective, but there is little or no theoretical or empirical basis on which to conclude that this approach is optimal from the perspective of other, codependent elements of the ecosystem (Goodman, *et al.* 2002; Mangel, *et al.* 2000). As Goodman et

al. (2002) discuss, fishing to achieve any MSY-related objectives inevitably shifts the equilibrium biomass, age and size structure of a population from that which occurred in the unfished condition, and any such changes have the potential to propagate through the food web and effect consequent changes on other species.

3.2.2 Genetic and Demographic Effects of Fishing

While contemporary approaches to fisheries science focus on estimating surplus production, stock-recruit relationships and MSYs, it is worth noting that from a purely “holistic” perspective, the fishing down of any species removes or alters energy pathways and ecological structure from either other species (such as seabirds and marine mammals) or other ecosystem processes (Aydin 2004), although this observation does not invalidate the logic of surplus production from a single-species perspective. It has long been assumed that fish stocks and populations, and subsequently the ecosystems in which they exist, are healthy if they are maintained close to the levels that provide MSY. However, there is a growing body of ecological, genetic and theoretical evidence that suggests that this may not necessarily be a fair assumption, neither for the exploited species themselves nor the ecosystems in which they exist. A growing body of literature suggests that fisheries have the potential to effect substantial changes in both genetic and demographic characteristics of fish populations; as Stokes and Law (2000) suggest “to an evolutionary biologist, fishing is a massive uncontrolled experiment in evolutionary selection.” Selection by fisheries has clearly been demonstrated to result in changes in size at age,¹⁷ changes in size and age at maturity, changes in natural mortality and increased total fecundity (Conover and Munch 2002; Mangel, *et al.* 1993; Mangel and Stamps 2001; Stergiou 2002; Stokes and Law 2000); and some examples even suggest changes in body shape, alterations in heritable patterns of distribution and migration, and even changes in avoidance behavior (Heino and Godø 2006; Ricker 1981).

Their results speak not only to the necessity to consider evolutionary consequences, but also to the observation that the consequences could be detrimental to humans as well as fish. Quite simply, these evolutionary consequences can reduce the sustainable yield of a population by decreasing the age at maturity and consequently reducing the relative amount of somatic growth in a population relative to reproductive effort. As Conover (2000) suggests, “Yield... is not a currency that is crucial to fitness. From the fishes’ point of view, the goal is maximizing the relative contribution of genes (not biomass) to succeeding generations.” The current National Standard Guidelines recognize the significance of such factors on both populations and ecosystems, as they state that the benefits of protecting marine ecosystems include “maintaining viable populations (including those of unexploited species), maintaining evolutionary and ecological processes (e.g., disturbance regimes, hydrological processes, nutrient cycles), maintaining the evolutionary potential of species and ecosystems, and accommodating human use” (50 C.F.R. 600.310). Such observations demonstrate that maintaining the role of species in an ecosystem, and minimizing the selective role of fishing on marine fish diversity on multiple levels, are both key challenges and crucial element to any future ecosystem-based approach to the management of marine resources.

¹⁷ As early as 1912 it was noticed that fish caught in the early or developing years of a fishery tended to be larger at age than those caught in more recent years, and it is now known that when mortality increases as a result of size-selected fishing; faster-growing individuals are removed at higher rates than slower-growing individuals. The result is that slower-growing animals make up a greater percentage of their age group; and the population in question is selected to be smaller at a given age over time. The same logic applies to the selection of earlier ages at maturity and to other selective factors.

3.3 Possible Impacts of the Proposed Action

While considerable research has been undertaken to better understand trophic interactions and other ecosystem considerations throughout the U.S. and the world, and to consider the cumulative, large-scale effects of fishing on marine ecosystems from a more holistic perspective, there is no clear consensus on what would actually constitute precautionary harvest policies or rates from a multispecies or ecosystem perspective. As a result, there is no fundamental foundation upon which to consider the consequences of historical overfishing, or alternative strategies in rebuilding depleted species, with respect to the potential impacts or trade-offs to ecological integrity and future sustainability.

From a basic ecological perspective, all species have a role to fill in the system, and the loss or severe reduction of any stock or species could have reverberations throughout the food web. Even the reduction of fished populations to their target levels affects the flow of energy through the marine ecosystem, and has the potential to either modestly or massively alter the structure and integrity of the communities that either prey on, are preyed upon, or otherwise interact with those species. As discussed in Section 3.1.6, some seabirds that depend on juvenile rockfish have undergone declines in breeding success, and declines in the availability of prey have been implicated as potential causes. However, ocean conditions and the effects of fishing are likely to be compounded, and the trends themselves are difficult to discern. Based on the observation that most resident or migratory marine mammal populations in the California Current have been increasing at modest to substantial rate over the past several decades (including California sea lions, harbor seals, elephant seals, gray whales, and humpback whales), it is similarly difficult to expect that the cumulative impacts of fishing have been detrimental for these guilds (independent of the incidental mortality resulting from fishing activity, described in Section 4.3).

Based on what is known or suspected about the large-scale nature of energy flow in upwelling environments, it is reasonable to expect that the cumulative impacts that have resulted from overfishing, and may continue to result from any delay in rebuilding, are modest to negligible when integrated across the entire California Current ecosystem. This is particularly true when considering the potential cumulative impact of depleting these populations below target levels (e.g., 10 percent to 25 percent of historical abundance) relative to depleting such populations to precisely their target levels (e.g., ~40 percent of historical abundance). However, for several rebuilding species, particularly those at higher trophic levels, these impacts may be more significant at smaller spatial scales for some habitat types and regions, since severe depletion may well have resulted in substantial shifts in the community composition of some benthic habitat. Furthermore, clearly identifying and evaluating the potential consequences to the ecosystem of modest changes in population trends and abundance that may result from deviations in rebuilding trajectories, above and beyond those that would have resulted from fishing stocks down precisely to target levels, is an analysis beyond the scope of existing data and capacity. The empirical data, either from visual or trawl surveys, are limited in their resolution, and although theoretical (simulated) studies suggest that thresholds between alternative stable states may exist, identifying such thresholds is beyond the realm of existing capacity.

3.3.1 OY Alternatives

Despite these general observations about the effects of the groundfish management framework on ecosystem processes, the ability to say anything meaningful about the broad-scale ecosystem impacts associated with adopting one of the preferred alternatives above the other is by all measures an intractable question. Clearly, the relationship between OY alternatives for depleted species and targets in related rebuilding plans has the most relevance to ecosystem impacts because of the long-term, cumulative effect. They differ in the trajectories they set for rebuilding populations, and clearly those

alternatives that rebuild stocks the fastest have the greatest potential to minimize the long-term impacts to the ecosystem that may have resulted from their removal. Thus, action alternative 1, which sets depleted species OYs to zero may result in the least ecosystem impacts. And compared to no action, the Council-preferred OY alternative establishes more aggressive rebuilding schedules for depleted species, with the exception of yelloweye rockfish. But these earlier target years are as much a result of stock assessments revealing more favorable conditions in terms of stock productivity as to a reduction in harvest rates. Despite these general observations, there exists no meaningful way of quantitatively assessing the potential difference with respect to the risk of undesirable consequences of choosing one OY alternative over the other. To the extent that the various OY alternatives require corresponding management measures that vary the size of area closures, thus protecting stocks, they may mitigate the potential consequences of fishing to ecological structure and function, although this generalization is unquantifiable.

In general, there is no empirical or theoretical evidence that declines in these stocks of West Coast rockfish have had impacts on predators or higher trophic level species, particularly impacts above and beyond those which might be expected by reduction of biomass to their target levels. However, there is potential evidence, largely theoretical, that among those rebuilding species that are higher trophic level predators there could be cascading ecological consequences to some benthic communities resulting from severe depletion and potential replacement by more opportunistic species. Again, the extent to which such impacts (if real) might be of a greater magnitude than those that would be expected under scenarios in which biomass declined to target levels is impossible to quantify.

3.3.2 *Management Measure Alternatives*

The management measure alternative's principal function is to constrain short-term fishing mortality to levels consistent with the rebuilding targets established in rebuilding plans, or other stock management goals for precautionary zone and healthy stocks. In this respect the management measures that have been implemented by the Council in recent years appear to have contributed to increasing abundance and productivity levels for rebuilding depleted (and other) species, although such improvement may be as much a result of factors outside the control of the management regime, such as changes in climate. Components of the management measure alternatives, and the management framework generally, that employ spatial closures, which effectively eliminate fishing mortality from broad areas of habitat that are optimal for both the rebuilding species and other, healthier groundfish stocks in the California Current, likely have an ancillary mitigating effect with respect to the ecosystem impacts of fishing. The protection of intact functional patches of habitat was identified by Baskett, et al. (2006) as one of the management measures that had the greatest potential to avoid or reverse changes in species composition on small rocky reef habitats. These area closures, intended to reduce bycatch of depleted species, are sited in those depth zones and habitats in which these species are most frequently encountered. As such, they tend to represent the optimal habitat for these species, and are either known or suspected (from catch rate data, trawl surveys, ROV surveys, and other means) to sustain the highest densities of depleted species. Consequently, this approach would be expected to effectively maintain functioning habitat areas and/or metapopulations of rebuilding species with an extremely high degree of protection.

The management measure alternatives are intended to correlate projected total catch to the range of OYs represented by the Council's preliminary low-high range identified at the April meeting for analytical purposes. As suggested above, their effects on the ecosystem operate in two ways: by affecting fish populations directly through measures to reduce fishing mortality and the protection of intact patches of habitat. Thus, management measure alternative 1, intended to constrain total catch to the low end of the range, is likely to have the least adverse impacts with respect to the ecosystem because of the extent of area closures and reductions in fishing mortality for rebuilding species. The Council-preferred

alternative is implements area closures generally similar to those currently in place (no action) except for the reduction in the size of the CCA. Although projected to result in total catch of cowcod exceeding the Council-adopted OY (which is related to rebuilding targets), there is insufficient information to determine whether this will have significant adverse impacts on the marine ecosystem. In particular, the configuration and extent of the area closures within this alternative represents a short-term effect over the next biennium, which may be less relevant, in terms of the ecosystem, than how these types of management measures will be applied over the long term. In summary, it is intuitive that the lower the fishing mortality rate, and the greater the extent of spatial closures over the long term, the greater the potential for rebuilding species to fill their niche or role in the ecosystem relative to the risk of changes or shifts in equilibrium or ecosystem states. But both the precision of multispecies or ecosystem models and their ability to accurately reflect the potential cumulative impacts to the ecosystem that result in slightly differing rebuilding trajectories are extremely low, particularly with respect to any ability to detect thresholds that may exist with respect to alternative stable states within either small or broad-scale habitats and ecosystems.

In comparing the preferred alternative to no action, the cumulative effect of recent action taken to mitigate the adverse effects of fishing to EFH through the implementation of Groundfish FMP Amendment 19 needs to be taken into account. That action not only protects additional habitat areas from trawl fishing impacts into the foreseeable future, but also prohibits the use of large-footrope gear shoreward of the 100 fm depth contour, mitigating impacts to remaining nearshore high-relief reef communities. These measures became effective in June 2006 and will likely further mitigate the effects of fishing in the next biennium.

3.3.3 *Benefits of an Ecosystem Approach to Fishery Management*

Although not a part of the proposed action, an ecosystem-based approach to managing fisheries could more effectively account for and potentially mitigate some of the adverse effects of fishing on the marine ecosystem. A truly integrated ecosystem approach might make management decisions based on accurate indices of ecosystem productivity, the needs of other predators (such as seabirds and marine mammals), and the consequences of fishing on habitat and ecological structure. Unfortunately, the data necessary to develop and adequately parameterize multispecies models are lacking for most ecosystems, including the California Current. Even with adequate data, the ability of multispecies models to make meaningful predictions regarding the consequences of decisions is limited. Although multispecies models are capable of providing insight regarding potential or likely interspecific interactions, and can provide long term (strategic) guidance regarding likely ecosystem impacts of fishing, there are still far too many unanswered basic ecological questions to expect that the ecological consequences of fishing at alternative harvest rates can be described or quantified. For example, May (1999) reminds us that even basic mechanisms responsible for density-dependent or density independent regulatory mechanisms continue to be unresolved for many populations, an issue of particular importance for rockfish, for which stock assessment models estimate a wide spectrum between strong density dependence and strong density independence. It may be that the only certainty that managers can expect is that decisions will have to continue to be made with imperfect information.

