APPENDIX D
DESCRIPTION AND IDENTIFICATION OF ESSENTIAL FISH HABITAT FOR THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

This document contains the identification and description of essential fish habitat (EFH) for the coastal pelagic species (CPS) fishery management plan (FMP) of the Pacific Fishery Management Council (Council). This document also contains fishing and nonfishing threats and potential conservation and enhancement measures to preserve EFH of CPS as specified in the interim final rule to implement the EFH provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), 50 CFR 600 (added by the interim final rule published at 62 Fed. Reg. 66531; December 19, 1997).

1.0 INTRODUCTION

The 1996 amendments to the Magnuson-Stevens Act established new requirements for describing and identifying EFH in federal FMPs. The amendments (16 U. S. C. 1801 *et. seq.*) also require consultation between the National Marine Fisheries Service (NMFS) and federal agencies on activities that may adversely impact EFH for those species managed under FMPs. The amended Magnuson-Stevens Act requires Fishery Management Councils to amend all of their FMPs to describe and identify EFH for the fishery based on guidelines established by NMFS, to minimize to the extent practicable adverse effects on such habitat caused by fishing, and to identify other actions to encourage the conservation and enhancement of EFH. NMFS guidelines on EFH requirements for FMPs were published as an interim final rule in the *Federal Register* on December 19, 1997 (62 FR 66531). These guidelines were used in the description and identification of EFH for the CPS Fishery.

The Magnuson-Stevens Act defines "essential fish habitat" as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." To clarify this definition, the following interpretations are made: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers the full life cycle of a species. The definition of EFH may include habitat for an individual species or an assemblage of species, whichever is appropriate to the FMP.

The CPS fishery includes four finfish (Pacific sardine, Pacific (chub) mackerel, northern anchovy, and jack mackerel) and the invertebrate, market squid. CPS finfish are pelagic (in the water column near the surface and not associated with substrate), because they generally occur above the thermocline in the upper mixed layer. For the purposes of EFH, the four CPS finfish are treated as a single species complex, because of similarities in their life histories and similarities in their habitat requirements. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations.

2.0 DESCRIPTION AND IDENTIFICATION OF ESSENTIAL FISH HABITAT FOR THE COASTAL PELAGIC SPECIES FISHERY

In determining EFH for the CPS, including CPS finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, and jack mackerel) and market squid, the estuarine and marine habitat necessary to provide sufficient CPS production to support a maximum sustained yield (MSY) CPS fishery and a healthy ecosystem was considered. Using Level 1 information, (i.e., presence/absence distribution data) EFH for CPS is based upon a thermal range bordered within the geographic area where a CPS species occurs at any life stage, where the CPS species has occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by the CPS species. EFH for CPS species is derived from distributional (presence/absence) data, oceanographic data (e.g., sea surface temperatures), relationships between oceanographic variables (e.g., temperature), and other published information. Specific EFH boundaries (i.e., the habitat necessary to provide sufficient CPS production) are based on best available scientific information. Sufficient Level 1 information exists to describe and identify EFH in a more precise manner for CPS finfish than for market squid.

The specific description and identification of EFH for CPS finfish accommodates the fact that the geographic range of all CPS finfish varies widely over time in response to the temperature of the upper mixed layer of the ocean, particularly in the area north of Point Arena, California (39° N latitude). This generalization is probably also true for market squid but few data are available. Adult CPS finfish are generally not found at temperatures colder than 10°C or warmer than 26°C and preferred temperatures and minimum spawning temperatures are generally above 13°C (see Figures 2-1 through 2-4). Spawning is most common at 14°C to 16°C.

The east-west geographic boundary of EFH for each individual CPS finfish and market squid 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 exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between 10°C to 26°C. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in sea surface temperatures at below 26°C, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the United States-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the sea surface temperature. The northern EFH boundary is, therefore, the position of the 10°C isotherm which varies both seasonally and annually. EFH for CPS species is summarized in Table 2-1.

Sea surface temperatures and habitat boundaries for CPS finfish vary seasonally and from year to year (Figures 2-1 through 2-4). Year to year variation in temperature and habitat boundaries is most pronounced during the summer. Additionally, variation in the boundaries of preferred habitat are more pronounced than variation in the boundaries of thermal tolerance. These relationships mean that highly mobile mackerels and sardine are seasonally much more abundant in the Oregon to Alaska region during the summer and warm water years (e.g., El Niño) than during the winter and cold water years due to increased habitat availability (Pearcy et al. 1985).

In years with cold winter sea surface temperatures, the position of the 10°C isotherm (a rough estimate of the lower thermal and northern geographic bound for CPS finfish) during February is near Cape Mendocino along the coast (about 40° N latitude) and at about 43° N latitude further offshore (Figures 2-1 through 2-4). In warm years, the 10°C isotherm during February is further north along the coast but still at about 43° N latitude offshore. The 14°C isotherm (a rough measure of the location of preferred temperatures) during February is near the U.S.-Mexico border (about 31° N latitude) in cold years and near Point Arena (about 39° N latitude) in warm years.

Sea surface temperatures and habitat boundaries for CPS finfish extend farther to the north during the summer than during the winter (Figures 2-1 through 2-4). The position of the 10°C isotherm during August is off Canada and Alaska in years with both cold and warm summer sea surface temperatures. The 14°C isotherm during August is off Cape Flattery (about 43° N latitude) in cold years and off Canada above 53° N latitude in warm years. As described above, sea surface temperatures of 14°C to 16°C are generally preferred for spawning. The 16°C isotherm, and preferred spawning habitat for CPS finfish, is south of the 14°C isotherm, but shows the same patterns of variability.

Differences between spawning habitat (14°C to 16°C) and geographic range (>10°C) mean that sardine and Pacific (chub) mackerel tend to move north to feed during summer and south to spawn during winter. Abundance and biomass are probably both related to the geographic extent of spawning. Pacific (chub) mackerel and sardine in particular may have increased reproductive success during warm decades (i.e., the 1930s, 1980s, and 1990s) and it is likely the carrying capacity for CPS is larger during warm water years, because the maximum preferred habitat is larger.

Information regarding the distribution, habitat, life history, abundance, and fishery utilization are available in Section 6.0 of this Appendix. Average February (winter) and August (summer) sea surface temperatures (°C) in the California Current within the EEZ during warm winters, cold winters, warm summers and cold summers from the Comprehensive Ocean Atmosphere Data Set database. Warm winter data are averages for 1958, 1981, and 1983 (years with the warmest temperatures during January through March within a band two degrees Celsius wide along the coast from central Baja California to the Queen Charlotte Islands during 1950 to 1995). Cold winter data are averages for 1950, 1971, and 1972 (years with the coldest January through March sea surface temperatures). Warm summer data are averages for 1983, 1990, and 1992 (years with the warmest July through September sea surface temperatures). Cold summer data are averages for 1952, 1950, and 1955 (years with the coldest July through September sea surface temperatures).

TABLE 2.0. Summary of distribution and essential fish habitat for Pacific CPS including finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, jack mackerel) and market squid. CPS are most common in the upper mixed layer of the ocean (above the thermocline) in a broad band (up to hundreds of miles wide) along the coast. CPS may occur in shallow embayments and brackish water, but do not depend on these habitats to any significant degree. In general, older and larger individuals occur further north and offshore. The northern extent of the distribution and essential fish habitat for CPS depends on temperature and biomass. Northern areas tend to be used most extensively when water temperatures are warm and abundance is high. Adult CPS prefer water temperatures in the range 10°C to 26°C. Spawning and successful reproduction occurs at about 14°C to 16°C. "??" indicates unavailable information.

Common Name (Scientific Name)	Lifestage	Punta Baja - Pt. Conception	Pt. Conception - Cape Blanco	Cape Blanco - Queen Charlotte Islands	Queen Charlotte Is. - Western Aleutian Islands	Benthic Association
Northern anchovy (*Engraulis mordax*)	Eggs/Larvae/ Juveniles	yes	yes	yes	no	no
	Adults	yes	yes	yes	no	no
Pacific sardine (*Sardinops sagax*)	Eggs/Larvae/ Juveniles	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
	Adults	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
Pacific (chub) mackerel (*Scomber japonicus*)	Eggs/Larvae/ Juveniles	yes	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
	Adults	yes	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
Jack mackerel (*Trachurus symmetricus*)	Eggs/Larvae/ Juveniles	yes	yes	no	no	no
	Adults	yes	yes	yes	yes	no
Market squid (*Loligo opalescens*)	Eggs/Larvae/ Juveniles	yes	yes	??	??	yes
	Adults	yes	yes	yes	yes	yes

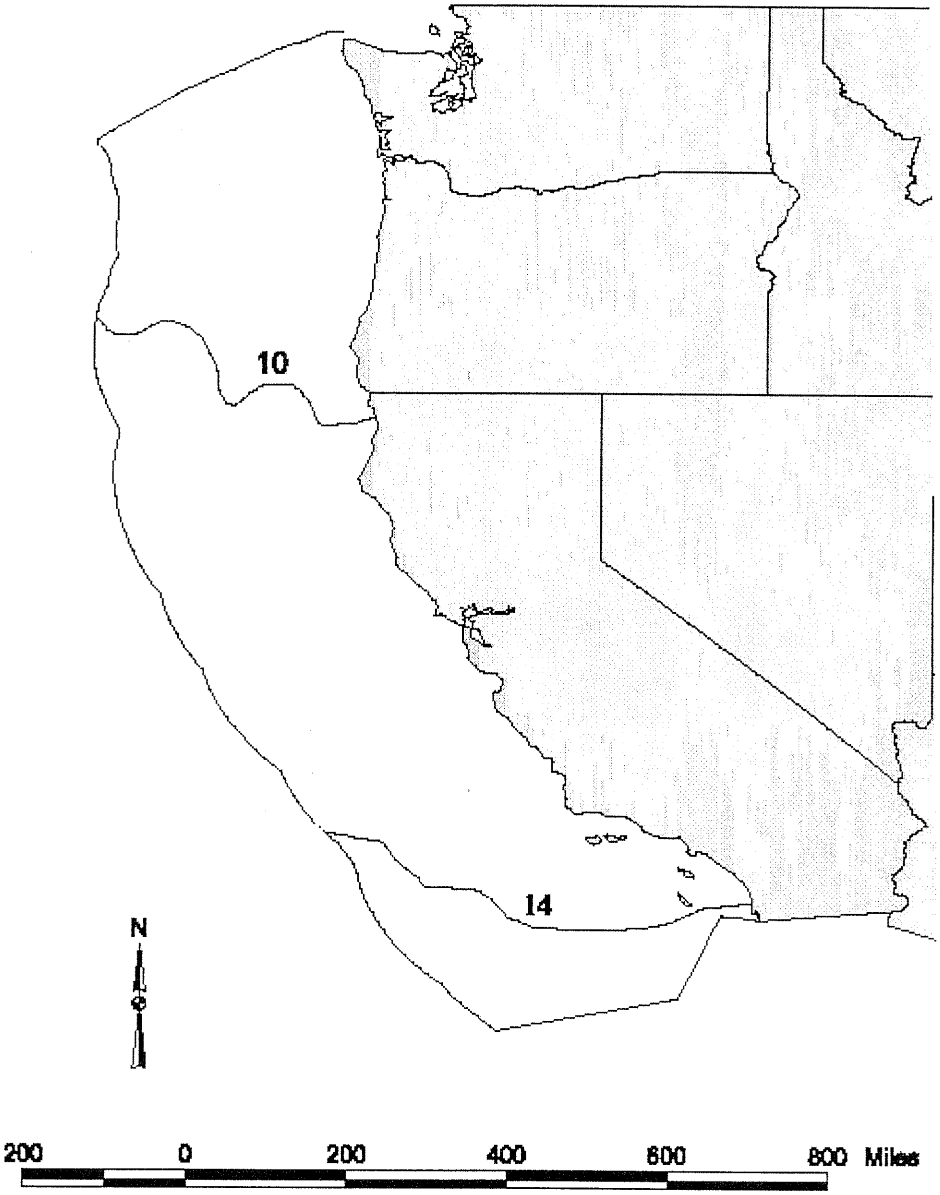

Figure 2-1. February sea surface temperatures (coldest three winters).

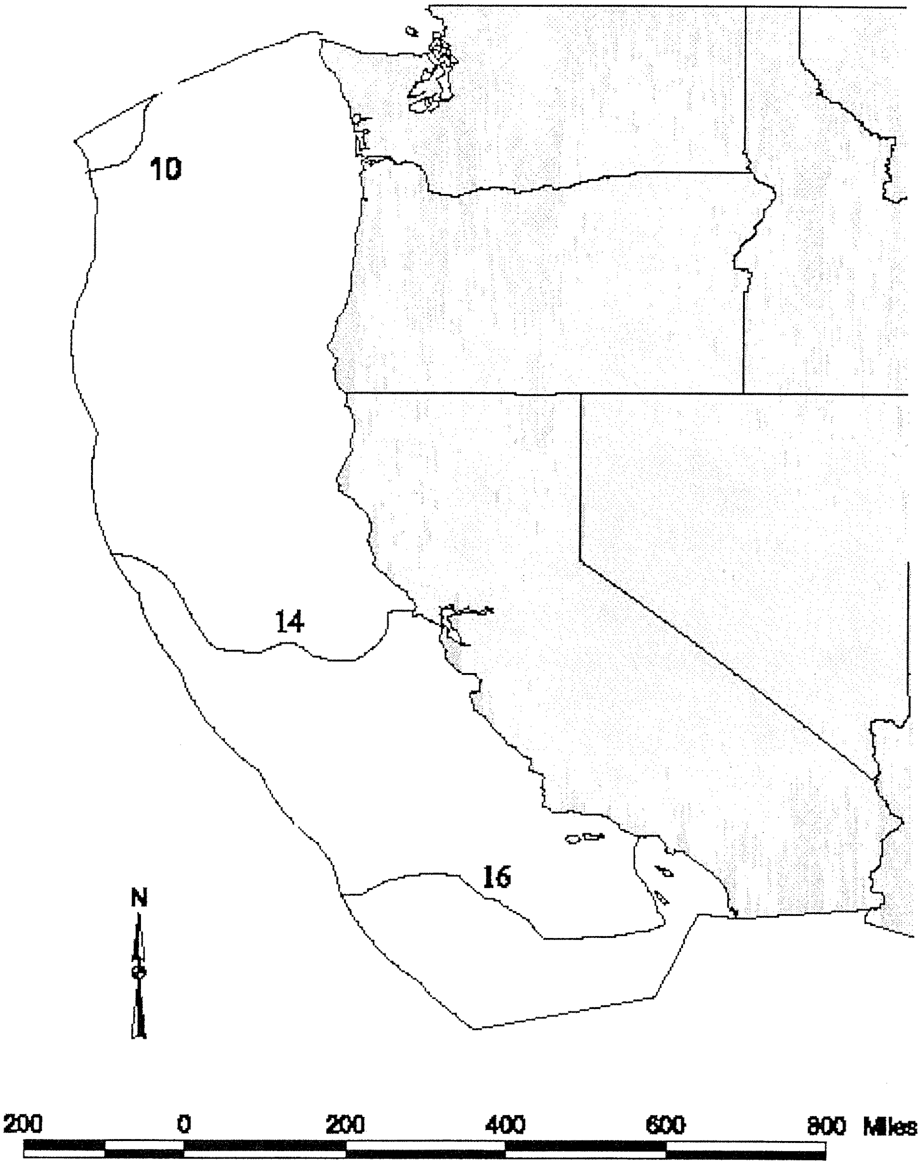

Figure 2-2. February sea surface temperatures (warmest three winters).

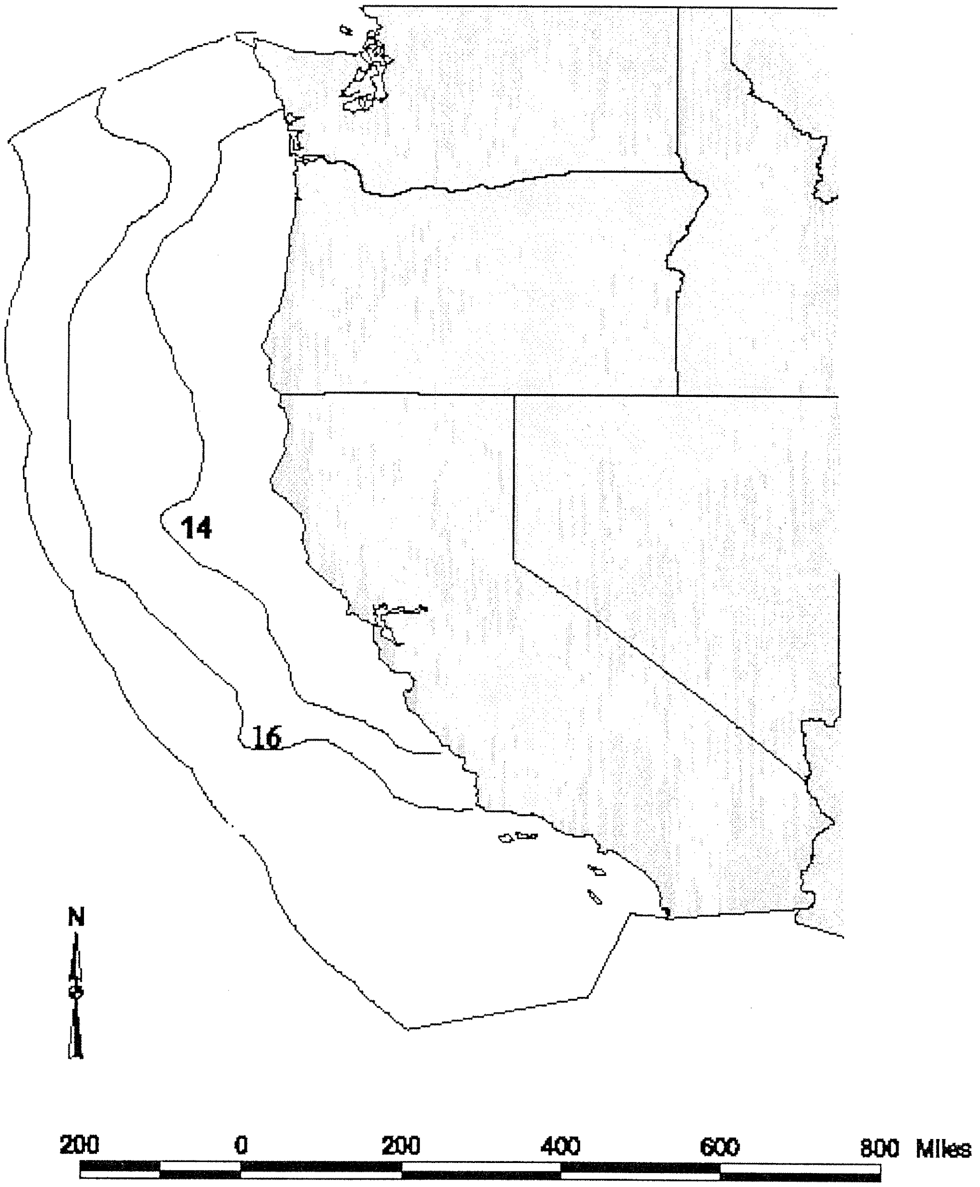

Figure 2-3. August sea surface temperatures (coldest three summers).

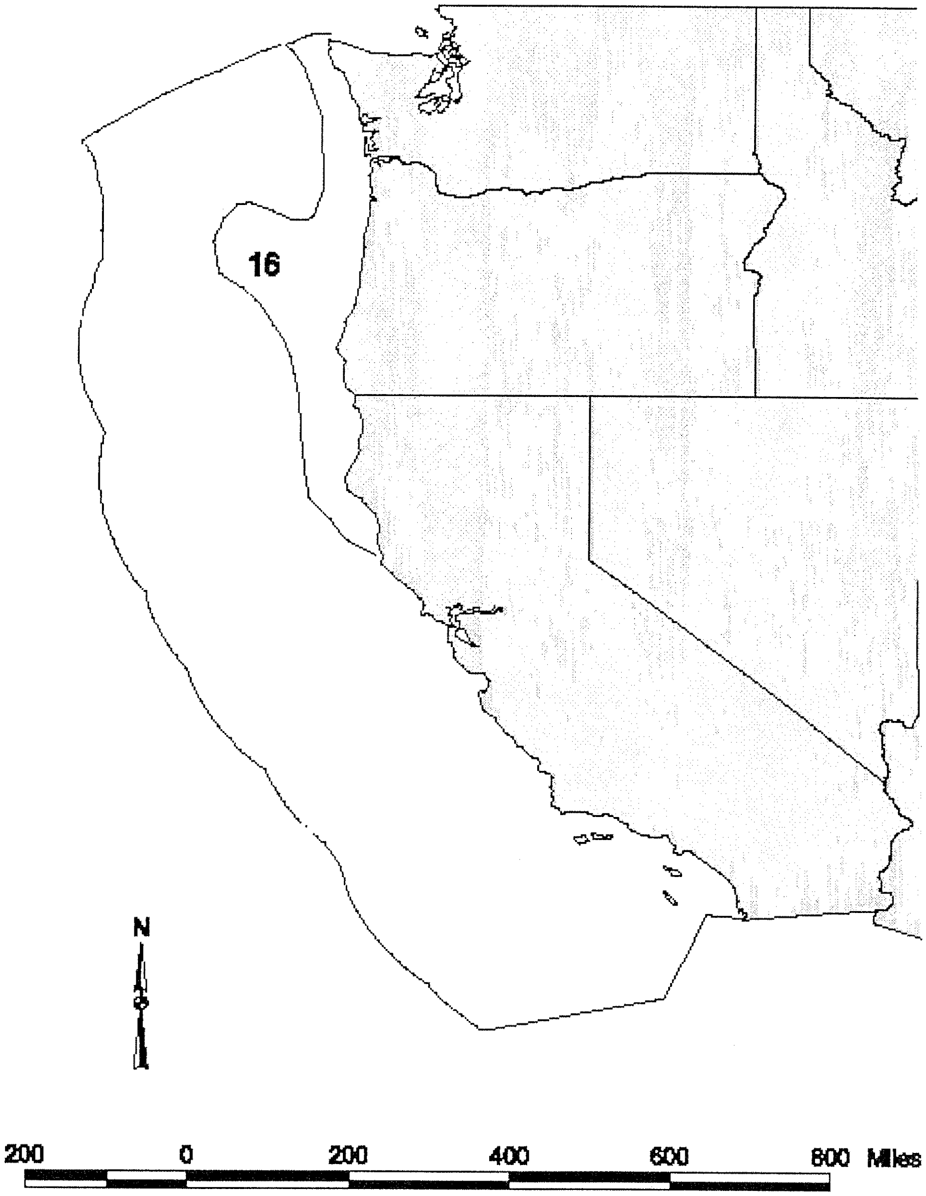

Figure 2-4. August sea surface temperatures (warmest three summers).

3.0 FISHING EFFECTS AND CONSERVATION MEASURES ON COASTAL PELAGIC SPECIES ESSENTIAL FISH HABITAT

3.1 Background

Section 600.815 (a) (3) of the interim final rule lists the mandatory contents of FMPs regarding fishing activities that may adversely affect EFH. The adverse effects from fishing activities may include physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. FMPs must include management measures that minimize adverse effects on EFH from fishing, to the extent practicable, and identify conservation and enhancement measures. They must also contain an assessment of the potential adverse effects of all fishing activities in waters described as EFH. This assessment should consider the relative impacts of all fishing equipment types used in EFH on different types of habitat found within EFH. In completing this assessment, Councils should use the best scientific information available, as well as other appropriate information sources, as available. The assessment should also consider the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that alters EFH.

Councils must act to prevent, mitigate, or minimize any adverse effects from fishing activities, to the extent practicable, if there is evidence that a fishing activity is having an identifiable adverse effect on EFH. In determining whether it is practicable to minimize an adverse effect from fishing, Councils should consider whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; the nature and extent of the adverse effect on EFH; and whether the management measures are practicable, taking into consideration the long and short-term costs and benefits to the fishery and EFH, along with other appropriate factors, consistent with national standard 7 (conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication).

Fishery management options to prevent, mitigate, or minimize adverse effects from fishing activities may include, but are not limited to:

> Fishing gear restrictions: Seasonal and areal restrictions on the use of specified gear; gear modifications to allow escapement of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting gear in sensitive areas; and prohibitions on fishing activities that cause significant physical damage in EFH.
>
> Time/area closures: Closing areas to all fishing or specific gear types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern.
>
> Harvest limits: Limits on the take of species that provide structural habitat for other species assemblages or communities, and limits on the take of prey species.

3.2 Impacts

With the exception of harvesting prey species, fishing for CPS finfish has little effect on CPS EFH because CPS finfish are pelagic at all life stages. Contact between roundhaul gear and substrate is rare in fishing for CPS finfish, because fishing usually occurs in water deeper than the height of the net. Thus, the only opportunity for damage to benthos or EFH for any species in fishing for CPS finfish is from lost gear. There is potential for fishing to impact squid spawning grounds because market squid attach their egg cases to the bottom substrate at spawning sites that include shallow, nearshore areas. Such damage is not believed to be extensive and is transitory with regard to the habitat.

CPS are planktivores at all or most life stages and utilize forage that is not affected by fishing. Pacific (chub) mackerel, jack mackerel, and market squid are piscivorous as adults, however, with diets that include northern anchovy, Pacific (chub) mackerel, young salmon (possibly when water temperatures are warm and pelagic fish are common off the Pacific northwest) and other species of commercial interest. Thus, overfishing of northern anchovy, Pacific sardine, market squid, or other species could adversely affect EFH for Pacific (chub) mackerel, jack mackerel, and market squid. Harvest policies used to manage northern anchovy and Pacific sardine should be taken into consideration while recognizing the importance of these species as forage in the ecosystem as a whole.

Although there are presumably few, if any, direct effects from mid-water trawling on EFH for CPS finfish, other fishery operations may alter species complexity in the water column. Off the Pacific coast, there is a large mid-water trawl fishery for Pacific whiting, primarily occurring north of 39° N latitude. Discharge of offal and processing slurry may affect EFH for CPS. Prolonged offal discards from some large-scale fisheries have redistributed prey food away from mid-water and bottom feeding organisms to surface-feeding organisms like CPS finfish, usually resulting in scavenger and seabird population increases (Hill and Wassenberg 1990, Evans et al. 1994). Offal discards in low-current environments can collect and decompose on the ocean floor, creating anoxic bottom conditions that may affect CPS. Pacific coast marine habitat is generally characterized by strong current and tide conditions, but there may be either undersea canyons affected by at-sea discard, or bays and estuaries affected by discard from shoreside processing plants. As with bottom trawling off the Pacific coast, little is known about the environmental effects of mid-water trawling and processing discards on habitat conditions.

3.3 Conservation Measures to Mitigate Fishing Effects on Coastal Pelagic Species Essential Fish Habitat

There is a growing body of research on the effects of fishing activities on marine habitat and general conclusions about the effects of some gear types on marine habitat may be drawn from this body of research (Auster and Langton, 1998). However, it has been noted above that there has been little research on Pacific coast fisheries EFH and into the fishing effects on such habitat, especially market squid EFH. Implementing measures to mitigate gear impacts on habitat may require research that specifically describes the effects of the fishing gear used in Pacific coast fisheries on marine habitat utilized by market squid. The Council may weigh the magnitude of this potential impact and develop appropriate recommendations for addressing them.

In addition to suggesting measures to restrict fishing gears and methods, NMFS' regulatory guidance on EFH also suggests time/area closures as possible habitat protection measures. These measures might include, but would not be limited to: closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages. Some of these closures may already exist, such as the exclusion of trawling within three miles of the California coastline and areas closed to commercial fishing (e.g., Santa Monica Bay). The Council may examine whether such opportunities exist for CPS and make appropriate recommendations for addressing them.

Beyond protecting natural reserves and areal closures for particular species, the Council may consider creating habitat reserves closed to all fishing. Several no-fishing zones have been created by the North Pacific Fishery Management Council for the waters off Alaska, generally for the purposes of protecting either crabs or marine mammal rookeries.

3.4 References

Auster, P. J. and R. W. Langton. The indirect effects of fishing. Draft document prepared for National Marine Fisheries Service, Office of Habitat Conservation, Silver Spring, MD.

4.0 NONFISHING EFFECTS ON COASTAL PELAGIC SPECIES ESSENTIAL FISH HABITAT

4.1 Background

Section 600.815 (a) (5) of the draft interim EFH regulations pertains to identifying nonfishing related activities that may adversely affect EFH. The section states that FMPs must identify activities that have the potential to adversely affect, directly or cumulatively, EFH quantity or quality, or both. Broad categories of activities which can adversely affect EFH include, but are not limited to: dredging, fill, excavation, mining, impoundment, discharge, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. FMPs should describe the EFH most likely to be adversely affected by these or other activities. For each activity, FMPs should describe known and potential adverse impacts to EFH. The descriptions should explain the mechanisms or processes that may cause adverse effects and how these may affect habitat function. A geographical information system (GIS) or other mapping system should be used to support analyses of data and to present these data in an FMP in order to geographically depict impacts identified in this paragraph.

The Magnuson-Stevens Act requires federal agencies undertaking, permitting or funding activities that may adversely affect EFH to consult with NMFS. Under section 305 (b)(4) of the Magnuson-Stevens Act, NMFS is required to provide EFH conservation and enhancement recommendations to federal and state agencies for actions that adversely affect EFH. However, state agencies and private parties are not required to consult with NMFS. EFH consultations will be combined with existing interagency consultations and environmental review procedures that may be required under other statutes such as the Endangered Species Act, Clean Water Act, the National Environmental Policy Act, the Fish and Wildlife Coordination Act, the Federal Power Act, or the Rivers and Harbors Act.

EFH consultation may be at either a broad programmatic level or project-specific level. Programmatic is defined as "broad" in terms of process, geography, or policy (e.g., "national level" policy, a "batch" of similar activities at a "landscape level", etc.) Where appropriate, NMFS will use a programmatic approach designed to reduce redundant paperwork and to focus on the appropriate level of analysis whenever possible. The approach would permit project activities to proceed at broad levels of resolution so long as they conform to the programmatic consultation. The wide variety of development activities over the extensive range of EFH, and the Magnuson-Stevens Act requirement for a cumulative effects analysis warrants this programmatic approach.

4.2 Nonfishing Effects

The following is a general description of nonfishing related activities that may directly or cumulatively, temporarily or permanently, threaten the physical, chemical and biological properties of the habitat utilized by CPS and/or their prey. The direct result of these threats is that EFH may be eliminated, diminished or disrupted. The list includes common activities with known or potential impacts to EFH. The list is not prioritized nor is it to be considered all-inclusive. The potential adverse effects described below, however, do not necessarily apply to the described activities in all cases, as the specific circumstances of the proposed activity or project must be carefully considered on a case-by-case basis. Furthermore, some of the activities described below may also have beneficial effects on habitat, which need to be considered in any analysis of an action's net effect by agencies conducting adverse effects analysis.

Nonfishing related effects on EFH for CPS finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, or jack mackerel) may not be as adverse relative to other EFH types, because adults and juveniles are mobile, and all life stages are pelagic (in the water column near the surface and not associated with substrate) and dispersed in a wide band along the west coast of north America. However, impacts to CPS finfish prey are conceivable. Nonfishing adverse impacts on EFH may be more important for market squid that attach their egg cases to the substrate at spawning sites that include shallow, near shore areas. Table 4.0-1 summarizes the potential adverse impacts of these nonfishing activities and conservation/enhancement measures to minimize those effects.

4.2.1 Dredging

Dredging navigable waters has a periodic impact on benthic and adjacent habitats during construction and operation of marinas, harbors and ports. Periodic dredging is required to maintain or create ship (e.g., ports) and boat (e.g., marinas) access to docking facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments from rivers or transported by wind, wave, and tidal processes. In the process of dredging, large quantities and qualities of the seafloor are removed, disturbed, and resuspended and the biological characteristics of the seafloor are changed. Turbidity plumes may arise.

4.2.1.1 Adverse Impacts

Dredging events using certain types of dredging equipment can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column habitat utilized by CPS finfish. These turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis (e.g., adjacent eelgrass beds) and the primary productivity of an aquatic area if suspended for variable periods of time. CPS finfish may suffer reduced feeding ability if suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources. Toxic metals and organics, pathogens, and viruses absorbed or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

Dredging as well as the equipment used in the process such as pipelines may damage or destroy spawning, nursery habitat and other sensitive habitats important to market squid. Within bays and harbors, dredging may also modify current patterns and water circulation of the habitat by changing the direction or velocity of water flow, water circulation, or otherwise changing the dimensions of the water body potentially utilized by CPS finfish.

4.2.1.2 References

Collins, M. A. 1995. Dredging-induced near-field resuspended sediment concentration and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A299 151.

Farnworth, E.G., M. C. Nichols, C.N. Vann, L. G. Wolfson, R. W. Bosserman, P. R. Hendrix, F. B. Golley, and J. L. Cooley. 1979. Impacts of sediment and nutrients on biota in surface waters of the United States. EPA; Athens, GA (USA)., Oct 1979., 331 p., Ecol. Res. Series U. S. Environ. Protect. Agency.

LaSalle, M. W., Clarke, D. G., Homziak, J., Lunz, J. D., and Fredette, T. J. (1991). A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A240 567.

Port of Long Beach, California, Port of Los Angeles, California, Department of the Army, Corps of Engineers, Department of the Interior, Fish and Wildlife Service; Department of Commerce, National Oceanic and Atmospheric Administration. 1990. Phase I 2020 Plan and Feasibility Study, Los Angeles and Long Beach Harbors, San Pedro Bay, California. EPA No.: 900342D, 987 pages and maps, September 10, 1990.

4.2.2 Dredge Material Disposal/Fills

The discharge of dredged materials subsequent to dredging operations or the use of fill material in the construction/development of harbors results in sediments (e.g., dirt, sand, mud) covering or smothering existing submerged substrates. Usually these covered sediments are of a soft-bottom nature as opposed to rock or hard-bottom substrates.

4.2.2.1 Adverse Impacts

The disposal of dredged or fill material can result in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. Direct discharges may adversely alter the habitat of benthic organisms such as market squid. Subsequent erosion, slumping, or lateral displacement of surrounding bottom of such deposits can also adversely affect substrate outside the perimeter of the disposal site by changing or destroying benthic habitat. The bulk and composition of the discharged material and the location, method, and timing of discharges may all influence the degree of impact on potential market squid EFH. The discharged material can also change the chemistry of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form.

The discharge of dredged or fill material can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column thereby affecting CPS finfish. These suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area if suspended for lengthy intervals. CPS finfish may suffer reduced feeding ability leading to limited growth and lowered resistance to disease if high levels of suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. Toxic metals and organics, pathogens, and viruses absorbed or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

4.2.2.2 References

Peddicord, R.K. and J. B. Herbich (ed.). 1979. Impacts of open-water dredged material discharge. Proceedings of the eleventh dredging seminar., Publ. by: TAMU; College Station, TX (USA)., Oct 1979., p. 24-40., Rep. Tex. A and M Univ. Sea Grant Program

National Oceanic and Atmospheric Administration. 1991. National Status and Trends Program for marine environmental quality. Progress report on secondary summary of data on chemical contaminants in sediments from the National Status and Trends Program. Tech. Mem. NOS OMA 59. NOAA, NOS, Silver Spring, MD. 29pp.

4.2.3 Oil/Gas Exploration/Production

Oil exploration/production occurs in a wide range of water depths and usually over soft-bottom substrates although hard-bottom habitats may be present in the general vicinity. Oil exploration/production areas are vulnerable to an assortment of physical, chemical, and biological disturbances as oil and gas deposits are located using high energy seismic surveys. EFH may be disrupted by the use and/or installation of anchors, chains, drilling templates, dredging, pipes, and platform legs. During actual operations, chemical contaminants may also be released into the aquatic environment.

4.2.3.1 Adverse Impacts

The impacts of oil exploration-related seismic energy release may interrupt and cause CPS finfish to disperse. Available data indicates that sensitive egg and larval stages within a few meters of the sources of seismic energy releases are not affected, however, disruption to CPS finfish feeding is possible.

Exploratory activities may also result in resuspension of fine-grained mineral particles, usually smaller than silt in the water column. These suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area especially if suspended for lengthy intervals. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion.

The discharge of oil drilling muds can change the chemistry and physical characteristics of the receiving water at the disposal site by introducing toxic chemical constituents thereby potentially impacting market squid EFH. Changes in the clarity and the addition of contaminants can reduce or eliminate the suitability of water bodies for habituation of fish species and their prey.

4.2.3.2 References

Battelle Ocean Sciences. 1988. The Effects of Seismic Energy Releases on the Zoeal Larvae Of the Dungeness Crab *(Cancer magister)*. Submitted by: Battelle Memorial Institute, Marine Research Laboratory, 439 W. Sequim Bay Road, Sequim, Washington to State of California Department of Fish and Game 1416 Ninth Street, Sacramento, California 95814. Contract Number 6c-194398-382

Coats, D. A. 1994. Deposition of drilling particulates off Point Conception, California. Mar. Environ. Res. 37:95-127.

Hyland, J., D. Hardin, M. Steinhauer, D. Coats, R. Green, and J. Neff. 1994. Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. Mar. Environ. Res. 37:195-229.

MEC Analytical Systems. 1995. Disturbance of deep-water reef communities by exploratory oil and gas operations in the Santa Maria Basin and Santa Barbara Channel. U.S. DOI, Minerals Management Service, Camarillo, CA. OCS Study MMS 95-0030

4.2.4 Water Intake Structures

The withdraw of ocean water by offshore water intakes structures is a common coastwide occurrence. Water may be withdrawn for providing sources of cooling water for coastal power generating stations or as a source of potential drinking water as in the case of desalinization plants. If not properly designed, these structures may create unnatural and vulnerable conditions to various fish life stages and their prey.

4.2.4.1 Adverse Impacts

The withdrawal of seawater can create unnatural habitat conditions to the EFH for all life stages of CPS finfish as well as their prey. Various life stages of CPS can be affected by water intake operations such as entrapment through water withdrawal, impingement on intake screens, and entrainment through the heat-exchange systems or discharge plumes of both heated and cooled effluent.

4.2.4.2 References

Helvey, M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47(1) 18-26.

4.2.5 Aquaculture

The culture of estuarine, marine, and freshwater species in coastal areas can reduce or degrade habitats used by native stocks. The location and operation of these facilities will determine the level of impact on the marine environment.

4.2.5.1 Adverse Impacts

A major concern of aquaculture operations is the discharge of organic waste from the farms. Wastes are composed primarily of feces and excess feed and the buildup of waste products into the receiving waters will depend on water depths and circulation patterns. The release of these wastes may introduce nutrients or organic materials into the surrounding water body and lead to a high biochemical oxygen demand (BOD) which may reduce dissolved oxygen, thereby potentially affecting the survival of many aquatic organisms in the area. Net effects to CPS may be either positive or negative.

Aquaculture operations also have the potential to release high levels of antibiotics, disease, as well as allowing cultured organisms to escape into the environment. These events have unknown but potential adverse impacts on fish habitat.

4.2.5.2 References

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4.2.6 Wastewater Discharge

The discharge of point and nonpoint source wastewater from activities including municipal wastewater treatment plants, power generating stations, industrial plants (e.g., pulp mills, desalination plants) and storm drains into open ocean waters, bay or estuarine waters can introduce pollutants detrimental to estuarine and marine habitats. These pollutants include pathogens, nutrients, sediments, heavy metals, oxygen demanding substances, hydrocarbons and other toxics. Historically, wastewater discharges have been one of the largest sources of contaminants into coastal waters. However, whereas wastewater discharges have been regulated under increasingly more stringent requirements over the last 25 years, non-point source/ stormwater runoff has not, and continues to be a significant remaining source of pollution to the coastal areas and ocean. Outfall-related changes in community structure and function, health and abundance may result. Many of these changes can be long-lasting.

4.2.6.1 Adverse Impacts

Wastewater effluent and non-point source/ stormwater discharges may affect the growth and condition of fish associated with wastewater outfalls should high contaminant levels (e.g., chlorinated hydrocarbons; pesticides; herbicides) be discharged. In addition, the high nutrient levels downcurrent of these outfalls may also be a concern. If contaminants are present, they may become bioavailable by absorption across the gills or bioaccumulate as a result of consuming contaminated prey. This is especially true for benthic-feeding fish frequenting wastewater discharge outfalls. Due to bioturbation, diffusion, and other upward transport mechanisms, buried contaminants may migrate to surface layers and become bioavailable.

Prager and MacCall (1993) detected possible effects of contaminant loadings in the ocean off southern California on reproductive success of Pacific sardine but not for northern anchovy or Pacific (chub) mackerel. Contaminant loadings were measured using a synthetic variable that included data from a wide variety of sources along the coast of southern California. The study was meant to generate rather than test hypotheses, however, and results were not definite.

Localized sources of pollution may effect CPS in bays and harbors along the coast but likely may not affect CPS stocks as a whole because CPS are distributed over large areas of the open coast and respond quickly to adverse changes in their environment by moving away. It is known however, that growth and survival of Pacific sardine adults can be affected by low level exposure to paper and cardboard pulp suspended in the water and ingested while feeding. Data are limited for most CPS, but information available for northern anchovy (see below) is probably applicable to other CPS species.

There is relatively little information regarding the water quality requirements and preferences of northern anchovy except for studies in the Los Angeles area concerning environmental problems corrected decades ago. Oxygen depletion due to die-off of massive dinoflagellate blooms caused occasional fish kills in both Santa Cruz Harbor and Fish Harbor (1973 to 1974) at Terminal Island, Los Angeles. Prior to regulatory control, oxygen depletion due to excessive dumping of high oxygen demand wastes into waters with reduced circulation caused episodes of fish kills as well, but such areas provided attractive food supplies preliminary to the oxygen depletion events. Anchovy tended to congregate around areas of sewage outfall, such as White's Point off Palos Verdes Peninsula, and prior to regulatory control, around the outfalls of the Terminal Island fish processors and sewage treatment plant.

Impacts of cannery and sewage waste on anchovy have been studied extensively only in the Los Angeles Harbor area during the 1980s and earlier. At the time of the studies, anchovy reduction processing was only one of the various fishery products that contributed to cannery effluent. Cannery wastes for many years were dumped into Inner Fish Harbor along with pumpings from boat holds and human wastes. The waters were frequently anoxic and the debris laden bottom was devoid of benthic macro organisms. In 1964, two cannery discharges were relocated intertidally outside Fish Harbor in Los Angeles Harbor not far from the sewage treatment outfall (Soule and Oguri, 1973). The Way Street Station outfall received wastes from various canneries and the other discharges effluent from only Starkist canneries. The discharge of cannery wastes was most critical during the fall of the year when seasonal die-off of biota from late summer and early fall plankton blooms and water column turnover placed a heavy natural oxygen demand on the receiving waters (Chamberlain 1975). Soule and Oguri (1976) report that "under (then) present conditions, a small zone within approximately 200 feet of the outfalls exists where numbers of species are low. Adjacent to this zone is a zone of enrichment which extends through most of the outer harbor. Beyond that, conditions return to average coastal populations. The regulations of waste loadings and control of pollutants in the past six-year period has brought the harbor ecosystem from a depauperate biota to a moderately rich one in the immediate outfalls zone, with a very rich biota in the adjacent outer harbor area."

Soule and Oguri (1973) reported that "Nothing is known about the distance traveled by individual anchovies within the harbor, nor about the degree to which they move in and out of the harbor. Catches by the bait boats, presently being surveyed, indicate that there may be an area of inhibition in the immediate vicinity of the cannery outfalls. There are indications that the anchovies move away from the area when the oxygen is low and also when it is excessively high, during plankton blooms. Weather conditions may exert influence as well, for anchovies apparently disappeared from harbor catches prior to heavy winter storms and subsequent rainwater runoff. They also were not caught in the harbor near the end of the season when the Davidson Current brought warmer southerly waters into the area, but reappeared just after water temperatures dropped."

Turbid waters with high densities of edible fine particulate matter apparently made harbor waters an excellent habitat for larval and juvenile fishes. Fish productivity began to decrease when dissolved air flotation treatment (DAF) was installed on the cannery waste streams in 1975, even though esthetically the harbors were improved. The installation of secondary waste treatment at the Terminal Island Treatment Plant and the subsequent connecting of cannery waste streams to the treatment plant in 1977 to 1978 resulted in a dramatic decrease in harbor biota and, in particular, in anchovies (Soule and Oguri 1979; 1980). Benthic populations decreased three-to four-fold in the outer harbor between 1973 and 1978, and the fish populations, sampled by otter trawl, also dropped four-fold. Trawl catches of anchovy in the outer harbor decreased about ten-fold between 1973 and 1974 continued to decrease at a slower rate through 1978 (Soule and Oguri 1980). The offshore anchovy population increased from 1973 to 1974 then decreased about five-fold through 1978 and recovered in 1979. Anchovy and other fish have been attracted to the harbor during episodes when the treatment plant malfunctioned and released high biological oxygen demand floc and wastes, and when dredging created high levels of turbidity and resuspended edible particulates and microbiota. Fish catches by commercial party boats decreased dramatically off the Orange County Sanitation District outfall after conversion to a deep water outlet (Soule and Oguri 1982).

The use of biocides (e.g., chlorine; heat treatments) to prevent biofouling or the discharge of brine as a byproduct of desalinization may reduce the suitability of water bodies for populations of fish species and their prey in the general vicinity of the discharge pipe. The impacts of chlorination and heat treatments, if any, are minimized due to their intermittent use and regulation pursuant to state and/or federal national pollutant discharge elimination system (NPDES) permit requirements. These compounds may change the chemistry and the physical characteristics of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form. In addition to chemical and thermal effects, discharge sites may adversely impact sensitive areas such as emergent marshes, seagrasses, and kelp beds if located improperly.

High discharge velocities may cause scouring at the discharge point as well as entrainment of particulates with resulting turbidity plumes. Turbidity plumes may reduce light penetration and lower the rate of photosynthesis and the primary production in an area if suspension persists. Fish may suffer reduced feeding ability especially if suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion.

A significant portion of impacts to coastal waters may also be caused by nonpoint source pollution. Major sources in coastal waters include agriculture and urban runoff. Other significant sources include faulty septic systems, forestry, marinas and recreational boating, physical changes to stream channels, and habitat degradation, especially the destruction of wetlands and vegetated areas near streams. Runoff can include heavy metals, pesticides, fertilizers, synthetic and petroleum hydrocarbons, and pet droppings. Unless proper management measures are incorporated, these contaminants can find their way into the food web through benthic infaunal communities and subsequently bioaccumulate in numerous fish species.

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4.2.7 Discharge of Oil or Release of Hazardous Substances

The discharge of oil or release of a hazardous substance into estuarine and marine habitats, or exposure to a product of reactions resulting from the discharge of oil or release of a hazardous substance can have both acute and chronic effects on fish resources and their prey.

4.2.7.1 Adverse Impacts

Exposure to petroleum products and hazardous substances from spills or other unauthorized releases can have both acute and chronic effects on fish resources and their prey, and also potentially reduce the marketability of target species. Direct physical contact with discharged oil or released hazardous substances (e.g., toxics; oil dispersants, mercury) or indirect exposure resulting from food chain processes can produce a number of biological responses in fish resources and their prey. These responses can occur in a variety of habitats including the water column, seafloor, bays, and estuaries. Chronic and large oil spills have a significant impact on fishery populations.

Other issues related to the category include efforts to cleanup spills or releases that in themselves can create serious harm to the habitat. For example, the use of potentially toxic dispersants to break up an oil spill may adversely effect the egg, larval, and adult stages of CPS finfish.

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4.2.8 Coastal Development Impacts

Coastal development involves changes in land use by the construction of urban, suburban, commercial, and industrial centers and the corresponding infrastructure. Vegetated and open forested areas are removed by cut-and-fill activities for enhancing the development potential of the land. Portions of the natural landscape are converted to impervious surfaces resulting in increased runoff volumes. Runoff from these developments include heavy metals, sediments, nutrients and organics, including synthetic and petroleum hydrocarbons, yard trimmings, litter, debris, and pet droppings. As residential, commercial, and industrial growth continues, the demand for water escalates. As ground water resources become depleted or contaminated, greater demands are placed on surface water through dam and reservoir construction or other methods of freshwater diversion. The consumptive use of redistribution of significant volumes of surface freshwater causes reduced river flows that can affect salinity regimes as saline waters intrude further upstream.

4.2.8.1 Adverse Impacts

Development activities within watersheds and in coastal marine areas may impact fish habitat on both long-term and short term scales. Runoff of toxics reduces the quality and quantity of water column and benthic EFH for CPS by the introduction of pesticides, fertilizers, petrochemicals, construction chemicals (e.g., concrete byproducts, seals and paints).

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5.0 CONSERVATION AND ENHANCEMENT MEASURES

5.1 Background

Section 600.815 (a) (7) of the EFH regulations states that FMPs must describe options to avoid, minimize, or compensate for the adverse effects and promote the conservation and enhancement of EFH. Generally, nonwater dependent actions should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse affects on EFH, should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions which may adversely affect EFH. Disposal or spillage of any material (dredge material, sludge, industrial waste, or other potentially harmful materials) which would destroy or degrade EFH should be avoided. If avoidance or minimization is not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH should be recommended. FMPs may recommend proactive measures to conserve or enhance EFH. When developing proactive measures, the Council may develop a priority ranking of the recommendations to assist federal and state agencies undertaking such measures.

5.2 Measures

Established policies and procedures of the Council and the NMFS provide the framework for conserving and enhancing essential fish habitat. Components of this framework include adverse impact avoidance and minimization; provision of compensatory mitigation whenever the impact is significant and unavoidable; and incorporation of enhancement. New and expanded responsibilities contained in the Magnuson-Stevens Act will be met through appropriate application of these policies and principles. In assessing the potential impacts of proposed projects, the Council and NMFS are guided by the following general considerations:

- The extent to which the activity would directly and indirectly affect the occurrence, abundance, health, and continued existence of fishery resources.
- The extent to which the potential for cumulative impacts exists.
- The extent to which adverse impacts can be avoided through project modification, alternative site selection or other safeguards.
- The extent to which the activity is water dependent if loss or degradation of EFH is involved.
- The extent to which mitigation may be used to offset unavoidable loss of habitat functions and values.

The following activities have been identified as potentially, directly or indirectly, affecting the habitat utilized by all or some CPS: dredging, fills/dredge material disposal, oil/gas exploration/production, water intake structures, aquaculture, wastewater discharge, discharge of oil or release of hazardous substances, and coastal development. The following measures are suggested in an advisory, not mandatory, capacity as proactive conservation measures that would aid in minimization or avoidance of the adverse effects of these nonfishing activities on essential fish habitat.

5.2.1 Dredging

1. To the maximum extent practicable, new, as opposed to maintenance dredging, should be avoided. Activities that require dredging (such as placement of piers, docks, marinas, etc.) should be sited in deep water areas or designed in such a way as to alleviate the need for maintenance dredging. Projects should be permitted only for water dependent purposes, when no feasible alternatives are available.
2. Where the dredge equipment employed could cause significant long term impacts due to entrainment of prey species, dredging in estuarine waters shallower than 20 feet in depth should be performed during the time frame when prey species are least likely to be entrained.

3. All dredging permits should reference latitude-longitude coordinates of the site so information can be incorporated into GIS for tracking cumulative impacts. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

4. Sediments should be tested for contaminants as per the Environmental Protection Agency and U.S. Army Corps of Engineers requirements to determine proper removal and disposal procedures.

5. The cumulative impacts of past and current dredging operations on EFH should be considered and described by federal, state, and local resource management and permitting agencies and considered in the permitting process.

6. Where a dredging equipment type is used that is expected to create significant turbidity (e.g., clamshell), dredging should be conducted using adequate control measures to minimize turbidity.

5.2.2 Fills/Dredge Material Disposal

1. Upland dredge disposal sites should be considered as an alternative to offshore disposal sites. Fills should not be allowed in areas with subaquatic vegetation or other areas of high productivity. Survey should be undertaken to identify least productive areas prior to disposal. Use of clean dredge material meeting Army Corps of Engineers and state water quality requirements for beach replenishment and other beneficial uses (e.g., creation of eelgrass beds) is encouraged.

2. The cumulative impacts of past and current fill operations on EFH should be addressed by federal, state, and local resource management and permitting agencies and considered in the permitting process.

3. Any disposal of dredge material in EFH should meet applicable state and/or federal quality standards for such disposal.

4. When reviewing open water disposal permits for dredged material, state and federal agencies should identify the direct and indirect impacts such projects may have on EFH. Benthic productivity should be determined by sampling prior to any discharge of fill material. Sampling design should be developed with input from state and federal resource agencies.

5. The areal extent of the disposal site should be minimized. However, in some cases, thin layer disposal may be less deleterious. All non-avoidable, adverse impacts (other than insignificant impacts) should be fully mitigated.

6. All spoil disposal permits should reference latitude-longitude coordinates of the site so information can be incorporated into GIS systems. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

5.2.3 Oil/Gas Exploration/Production

1. Benthic productivity should be determined by sampling prior to any exploratory operations. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.

2. Mitigation should be fully addressed for impacts.

3. Containment equipment and sufficient supplies to combat spills should be on site at all facilities that handle oil or hazardous substances.

4. Each facility should have a "Spill Contingency Plan" and all employees should be trained in how to respond to a spill.

5. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.

5.2.4 Water Intake Structures

1. New facilities that rely on surface waters for cooling should be located in areas of low productivity or areas not prone to congregating CPS and their prey. New discharge points should be located in areas that have low concentrations of living marine resources, or they should incorporate cooling towers that employ sufficient safeguards to ensure against release of blow-down pollutants into the aquatic environment in concentrations that exceed state and/ or federal limits established pursuant to state and/ or federal NPDES regulations.

2. All intake structures should be designed to minimize entrainment or impingement of prey species. Power plant intake structures should be designed to meet the "best technology available" requirements as developed pursuant to Section 316b of the Clean Water Act.

3. Discharge temperatures (both heated and cooled effluent) should comply with applicable temperature limits established pursuant to state and/ or federal NPDES regulations.

5.2.5 Aquaculture Facilities

1. Facilities should be located in upland areas as often as possible. Tidally influenced wetlands should not be enclosed or impounded for mariculture purposes. This includes hatchery and grow-out operations. Siting of facilities should also take into account the size of the facility, the presence or absence of submerged aquatic vegetation, proximity of wild fish stocks, migratory patterns, and competing uses. Areas of high productivity should be avoided to the maximum extent possible.

2. Water intakes should be designed to avoid entrainment and impingement of fish species.

3. Water discharge should be treated to avoid contamination of the receiving water, and should be located only in areas having good mixing characteristics.

4. Where cage mariculture operations are undertaken, water depths and circulation patterns should be investigated and should be adequate to preclude the buildup of waste products, excess feed, and chemical agents.

5. Any net pen structure should have small enough webbing to prevent entanglement by prey species.

6. Measures should be taken to avoid escapement of farmed animals.

7. Mitigation should fully address all impacts.

5.2.6 Wastewater Discharge

1. New outfall structures should be placed offshore sufficiently far enough to prevent discharge water from impacting productive areas. Discharges should be managed to comply with applicable state and/or federal NPDES permit requirements, including compliance with applicable technology-based and water quality-based effluent limits.

2. The establishment of management programs to address non-point source/stormwater pollution water quality issues on a watershed basis is supported and encouraged.

5.2.7 Discharge of Oil or Release of Hazardous Substances

1. Containment equipment and sufficient supplies to combat spills should be on-site at all facilities that handle oil or hazardous substances.

2. Facilities should have a "Spill Contingency Plan", where required by applicable local, state, or federal requirements, and employees identified in the plan as having responsibility for responding to a spill should receive appropriate training.

3. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.

5.2.8 Coastal Development Impacts

1. Prior to installation of any piers or docks benthic productivity should be determined and areas with high productivity avoided. Sampling design should be developed with input from state and federal resource agencies.

2. Fueling facilities should be equipped with all necessary safeguards to prevent spills. A spill response plan should be developed and gear necessary for combating spills should be located on sight.

3. Filling of any aquatic areas should be curtailed as much as reasonably possible.

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TABLE 4.0-1 Adverse nonfishing activities, impacts and conservation/enhancement measures for CPS EFH.

ACTIVITY	**IMPACTS** (Potential)	**CONSERVATION MEASURES** (Advisory)
1. Dredging	• Bottom-dwelling organisms • Turbidity plumes • Bioavailability of toxics • Damage to sensitive habitats	• Curtail/minimize new dredging activities as practicable • Take actions to prevent impacts to flora/fauna • Geo-reference all dredge sites • Contaminant assays • Address cumulative impacts • Minimize turbidity
2. Dredge Material Disposal/fills	• Bottom-dwelling organisms • Turbidity plumes • Toxics becoming biologically available • Damage sensitive habitats • Loss of habitat function	• Place dredge spoils upland if possible;avoid fills in productive areas • Address cumulative impacts • Meet applicable quality requirements for disposal of dredge material in EFH • Identify direct and indirect impacts on EFH • Minimize areal extent of the disposal site • Geo-reference the site
3. Oil/gas Exploration/ production	• Seismic energy release • Discharge of exploratory drill muds and cuttings • Resuspension of fine-grained mineral particles • Composition of the substrate altered	• Avoid areas of high productivity • Provide mitigation • On-site containment equipment • Maintain "spill contingency plan" • Keep oil and hazardous substances from reaching the Aquatic environment
4. Water Intake Structures	• Entrapment, impingement, and entrainment • Loss of prey species	• Locate new facilities away from productive areas • Minimize entrainment or impingement of prey species per CWA 316(b). • Discharge temperatures to meet applicable discharge Limits
5. Aquaculture	• Discharge of pollutants from the facility • Escapement	• Minimize water/habitat quality impacts • Avoid entrainment and impingement losses • Treat and mix water discharges • Preclude waste product buildups • Prevent entanglement of prey species • Prevent escapement • Mitigate impacts
6. Wastewater Discharge	• Wastewater effluent with high contaminant levels • High nutrient levels downcurrent of outfall • Biocides to prevent biofouling • Thermal effects • Turbidity plumes • Stormwater runoff	• Avoid areas of high productivity with new discharge points • Watershed management programs
7. Oil Discharge/ Hazardous Substances Release	• Direct physical contact • Indirect exposure resulting • Cleanup	• Maintain on-site containment equipment and supplies • On-site "Spill Contingency Plan" • Prevent spills from reaching the aquatic environment.
8. Coastal Development Impacts	• Contaminant runoff • Sediment runoff • Filling of aquatic areas	• Shoreline construction should avoid productive areas • Prevent fuel spillage • Curtail fills in estuaries, wetlands, and bay

6.0 COASTAL PELAGIC SPECIES HABITAT/LIFE HISTORY DESCRIPTIONS

6.1 Northern Anchovy

6.1.1 Distribution and Habitat

Northern anchovy are distributed from the Queen Charlotte Islands, British Columbia, to Magdalena Bay, Baja California and anchovy have recently colonized the Gulf of California. The population is divided into northern, central and southern subpopulations, or stocks. The southern subpopulation is entirely within Mexican waters. The central subpopulation, which supports significant commercial fisheries in the U.S. and Mexico, ranges from approximately San Francisco, California, to Punta Baja, Baja California. The bulk of the central subpopulation is located in the Southern California Bight, a 20,000-square-nautical-mile area bounded by Point Conception, California, in the north and Point Descanso, Mexico, (about 40 miles south of the U.S.-Mexico boarder) in the south.

Northern anchovy in the central subpopulation are typically found in waters that range from 12°C to 21.5°C; however, laboratory defined lethal temperatures occur at seven degrees Celsius and 29°C (Brewer 1976). There is a great deal of regional variation in age composition and size, with older and larger anchovy found farther offshore and to the north (Parrish et al. 1985). The pattern is accentuated in warm years and during the summer (Methot 1989).

There is a great deal of regional variation in age composition and size with older and larger individuals further offshore and to the north (Parrish et al. 1985). These patterns are accentuated during warm years such as El Niño and when abundance is high (Methot 1989). The geographic distribution of northern anchovy has been more consistent over time and is more nearshore than the geographic distribution of Pacific sardine. In the Oregon to Vancouver Island region northern anchovy must overwinter in upper mixed layer temperatures as low as eight degrees Celsius to nine degrees Celsius; short term laboratory lethal temperatures for northern anchovy are seven degrees Celsius (Brewer 1976).

Eggs and larvae are found near the surface, generally at depths of less than 50 meters and in the same areas as spawning adults. Anchovy eggs are most abundant at about 14°C. All life stages are found in the surface waters of the EEZ.

Methot found that near shore habitat areas (<90 meters) between Pt. Conception, California and Pt. Banda, Baja California represented 23% of the available habitat for central stock juvenile northern anchovy . Densities of juvenile anchovy in near shore areas were about ten times higher than in other habitat areas. He concluded that near shore habitats supported at least 70% of the juvenile anchovy population (Methot 1981, Smith 1985).

6.1.2 Life History

Northern anchovy are small, short-lived fish typically found in schools near the surface. Northern anchovy rarely exceed four years of age and 18 cm total length, although individuals as old as seven years and 23 cm have been recorded. Natural mortality is thought to be $M = 0.6$ to 0.8 year^{-1}, which means that 45% to 55% of the total stock would die each year of natural causes if no fishing occurred. Northern anchovy eat phytoplankton and zooplankton by either filter feeding or biting, depending on the size of the food.

Anchovy spawn during every month of the year, but spawning increases in late winter and early spring and peaks from February to April. Preferred spawning temperature is 14°C and eggs are most abundant at temperatures of 12°C to 16°C. Females spawn batches of eggs throughout the spawning season at intervals as short as seven to ten days. The eggs, found near the surface, are typically ovoid and translucent and require two to four days to hatch, depending on water temperatures. Both the eggs and larvae are found near the surface. Anchovy in the central subpopulation are all sexually mature at age two. The fraction of one-year-olds that is sexually mature in a given year depends on water temperature and has been observed to range from 47% to 100% (Methot 1989). This phenomenon affects estimates of spawning population.

6.1.3 Fisheries

Northern anchovy in the central subpopulation are harvested by commercial fisheries in California and Mexico for reduction, human consumption, live bait, dead bait, and other nonreduction commercial uses. Anchovy landed in Mexico are used primarily for reduction, although small amounts are probably used as bait.

The northern subpopulation supports a small bait fishery (one to four boats) off Oregon and Washington. The small quantities of the northern subpopulation are taken for use as bait.

Anchovy landed by the reduction fisheries are converted to meal, oil, and soluble protein products sold mainly as protein supplements for poultry food and also as feed for pigs, farmed fish, fur-producing animals, laboratory animals, and household pets. Meal obtained from anchovy is about 65% protein (meal from other fishes is 50% to 55% protein).

Anchovy harvested by the live bait fishery in California are not landed but are kept alive for sale to anglers as bait and chum (in contrast anchovy sold as "live" bait off Oregon and Washington may be killed at time of sale). Transactions between buyers and sellers of live bait take place either at sea or at bait wells tied up at docks. Bait dealers generally supply party boats on a contract basis and receive a percentage of the fees paid by passengers. Bait is also sold by the scoop to anglers in private vessels.

Anchovy landed by the nonreduction (other than live bait) fishery are used as dead frozen bait, fresh fish for human consumption, canned fish for human consumption, animal food, and anchovy paste.

6.1.4 Relevant Trophic Information

Northern anchovy are subject to natural predation throughout all life stages. Eggs and larvae fall prey to an assortment of invertebrate and vertebrate planktivores. As juveniles, anchovy are vulnerable to a wide variety of predators, including many recreationally and commercially important species of fish. As adults, anchovy are fed upon by endangered salmon stocks, endangered birds (California brown pelican *Pelecanus occidentalis californicus* and least tern *Sterna albifrons browni)* numerous fishes (some of which have recreational and commercial value) mammals, and birds. Links between brown pelican breeding success and anchovy abundance have been documented (Anderson et al. 1980, 1982; Jacobson and Thomson 1989).

6.2 Jack Mackerel

Biological information about jack mackerel is available in MacCall et al. (1980), MacCall and Stauffer (1983), and in references cited below.

6.2.1 Distribution and Habitat

Jack mackerel are a pelagic schooling fish that ranges widely throughout the northeastern Pacific, from the Pacific coast to an offshore limit approximated by a line running from Cabo San Lucas, Baja California, to the eastern Aleutian Islands, Alaska. Much of the range lies outside the 200-mile U.S. EEZ (MacCall and Stauffer 1983).

Small jack mackerel (10 cm to 30 cm FL and up to six years of age) are most abundant in the Southern California Bight, where they are often found near the mainland coast and islands and over shallow rocky banks. Older, larger fish (50 cm to 60 cm FL and 16 years to 30 years) range from Cabo San Lucas, Baja California, to the Gulf of Alaska, where they are generally found offshore in deep water and along the coastline to the north of Point Conception. Large fish rarely appear in southern inshore waters. Fish of intermediate lengths (30 cm to 50 cm TL; nine years to 20 years of age) were found in considerable numbers during the spring of 1991 around the 200-mile limit of the U.S. EEZ off southern California; fish off five years to nine years of age were the most numerous and fish ten years to 20 years old were common (Nebenzahl 1997).

Jack mackerel sampled over several years by trawl surveys off Oregon and Washington ranged from 30 cm to 62 cm and four years to 36 years old. More than half of the fish sampled were greater than 20 years old and fish greater than 30 years old were common (Nebenzahl 1997). As with other CPS finfish, older and larger fish are most common further north and offshore. Jack mackerel differ from the other CPS species in that they are quite long lived and more commonly found offshore. Jack mackerel older than 30 years are common in the northern portion of their range (Nebenzahl 1997). Spawning occurs farther offshore than for other CPS (Jacobson et al. 1997).

Jack mackerel off southern California move inshore and offshore as well as north and south. They are more available on offshore banks in late spring, summer and early fall than during the remainder of the year. In southern California waters, jack mackerel schools are often found over rocky banks, artificial reefs, and shallow rocky coastal areas. They remain near the bottom or under kelp canopies during daylight and venture into deeper surrounding areas at night. Young juvenile fish sometimes form small schools beneath floating kelp and debris in the open sea.

6.2.2 Life History

Jack mackerel grow to about 60 cm and live 35 years or longer. Estimates of natural mortality are uncertain, but the natural mortality rate (M) averaged over the life span of a typical fish is probably less than 0.20 year to 0.25 year^{-1}. This means that about 18% to 22% of the total stock would die each year of natural causes if no fishing occurred.

Small jack mackerel taken off southern California and northern Baja California eat large zooplankton (copepods, pteropods, and euphausiids), juvenile squid, and anchovy. Larvae feed almost entirely on copepods.

Although immature jack mackerel can be found off southern California at all times of the year, 50% or more of all females reach sexual maturity during their first year of life. Older jack mackerel, in samples taken about 200 miles offshore from Southern California, spawned about every five days and the average female may spawn as many as 36 times per year Macewicz and Hunter (1993).

The spawning season for jack mackerel off California extends from February to October, with peak activity from March to July (MacCall and Prager 1988). Young spawners off southern California begin spawning later in the year than older spawners. Little is known of the maturity cycle of large fish offshore, but peak spawning appears to occur later in more northerly waters.

Large predators like tunas and billfish eat jack mackerel, but except as young-of-the-year and yearlings, jack mackerel are probably a minor forage source for smaller predators. Older jack mackerel probably do not contribute significantly to food supplies of marine birds, because they are too large to be eaten by most bird species and school inaccessibly deep. Little information is available on predation of jack mackerel by marine mammals. Jack mackerel are not often eaten by California sea lions, *Zalophus californianus*, or northern fur seals, *Callorhinus ursinus*.

6.2.3 Fishery Utilization

The southern California segment of the stock has been fished since the late 1940s, when jack mackerel served as a substitute for the failing sardine fishery. Purse seiners prefer Pacific (chub) mackerel, because jack mackerel tend to occur further from port and over rocky bottoms where there is increased risk of damage to nets. Mason (1991) describes the history of management for the jack mackerel fishery off southern California.

Offshore, large adult jack mackerel are sometimes taken incidentally in trawls for Pacific whiting. During the 1970s, foreign trawl fisheries may have caught 1,000 mt to 2,000 mt annually, but catches by foreign and joint-venture fishers in the 1980s ranged from nil to about 100 mt.

6.3 Pacific Sardine

Biological information about Pacific sardine *Sardinops sagax caerulea* is available in Frey (1971), Clark and Marr (1955), Ahlstrom (1960), Murphy (1966), MacCall (1979), and in the references cited below. Other common names for Pacific sardine include California pilchard, pilchard (in the northern part of its range), and sardina monterey (in the southern part of its range).

6.3.1 Distribution and Habitat

Sardines as a group of species are small pelagic schooling fish that inhabit coastal subtropical and temperate waters. The genus *Sardinops* is found in eastern boundary currents of the Atlantic and Pacific, and in western boundary currents of the Indo-Pacific oceans. Recent studies indicate that sardines in the Alguhas, Benguela, California, Kuroshio, and Peru currents, and off New Zealand and Australia are a single species (*Sardinops sagax*, Parrish et al. 1989) but stocks in different areas of the globe may be different at the subspecies level (Bowen and Grant 1997).

Pacific sardines are pelagic at all life history stages. They occur in estuaries, but are most common in the near shore and offshore domains along the coast. Pacific sardine are highly mobile and move seasonally along the coast (Radovich 1983). Older adults may move from spawning grounds in southern California and northern Baja California to feeding grounds off the Pacific northwest and Canada. Younger adults (ages two to four) appear to migrate to feeding grounds primarily in central and northern California. Juveniles occur in near shore waters off of northern Baja California and southern California (Clark 1940). Eggs and larvae occur nearly everywhere adults are found and eggs are most abundant between 14°C and 15°C (Lluch-Belda et al. 1991; Lo et al. 1994). When abundance is high, eggs and larvae may be concentrated 50 km to 150 km offshore of the area north of Point Conception with lesser quantities found in the region offshore of the Channel Islands. When abundance is low, eggs and larvae may be concentrated nearer shore and further south. These patterns probably depend on both sea surface temperatures and sardine abundance because they are accentuated during warm years and when abundance is high.

Sardine have at times been the most abundant fish species in the California Current (Barnes et al. 1992). When abundance is high and environmental conditions are favorable, Pacific sardine are distributed from the tip of Baja California (23° N latitude) to southeastern Alaska, and throughout the Gulf of Mexico. When abundance is low, as during the late 1960s and 1970s, sardine are not found in commercial quantities north of Point Conception and may be restricted to waters off southern and central Baja California. Dramatic changes in distribution, depending on environmental conditions and abundance (which are tightly linked) occur in sardine populations around the world (Lluch-Belda et al. 1989).

It is generally accepted that sardine off the West Coast of North America form three subpopulations or stocks. A northern subpopulation (northern Baja California to Alaska), a southern subpopulation (off Baja California), and a Gulf of California subpopulation were distinguished on the basis of serological techniques (Vrooman 1964). A recent electrophoretic study (Hedgecock et al. 1989) showed, however, no genetic variation among sardines from central and southern California, the Pacific coast of Baja California or the Gulf of California. A fourth, far northern, subpopulation has also been postulated (Radovich 1982). Although the ranges of the northern and southern subpopulations overlap, the stocks may move north and south at similar times and not overlap significantly. The northern stock is exploited by U.S. fisheries and is included in this FMP.

Pacific sardine probably migrated extensively during historical periods when abundance was high, moving north as far as British Columbia in the summer and returning to southern California and northern Baja California in the fall. Tagging studies (Clark and Janssen 1945) indicate that the older and larger fish moved farther north. Migratory patterns were probably complex and the timing and extent of movement were affected by oceanographic conditions (Hart 1973) and stock biomass. During the 1950s to 1970s, a period of reduced stock size and unfavorably cold sea surface temperatures, the stock apparently abandoned the northern portion of its range. At present, the combination of increased stock size and warmer sea surface temperatures are causing the stock to reoccupy grounds off northern California, Oregon, Washington, and British Columbia. Abandonment and recolonization of the higher latitude portion of their range has been associated with changes in abundance of sardine populations around the world (Parrish et al. 1989).

6.3.2 Life History

Pacific sardines may reach 41 cm, but are seldom longer than 30 cm. They may live as long as 13 years, but individuals in historical and current California commercial catches are usually younger than five years. In contrast, the most common ages in the historical Canadian sardine fishery were six years to eight years. There is a good deal of regional variation in size at age and size at age increases from south to north (Phillips 1948). Size and age at maturity may decline with a decrease in biomass, but latitude and temperature also are important (Butler 1987). At low biomass levels, sardines appear to be fully mature at age one, whereas at high biomass levels only some of the two-year-olds are mature (MacCall 1979).

Age-specific mortality estimates are available for the entire suite of life history stages (Butler et al. 1993). Mortality is high at the egg and yolk sac larvae stages (instantaneous rates in excess of 0.66 d^{-1}). Adult natural mortality rates has been estimated to be M=0.4.$year^{-1}$ (Murphy 1966; MacCall 1979) and 0.51 $year^{-1}$ (Clark and Marr 1955). A natural mortality rate of M = 0.4 $year^{-1}$ means that 33% of the sardine stock would die each year of natural causes if there were no fishery.

Pacific sardines spawn in loosely aggregated schools in the upper 50 meters of the water column. Spawning occurs year-round in the southern stock and peaks April through August between Point Conception and Magdalena Bay, and January through April in the Gulf of California (Allen et al. 1990). Off California, sardine eggs are most abundant at sea surface temperatures of 14°C to 16°C and larvae are most abundant at 13°C to 16° C. Temperature requirements are apparently flexible, however, because eggs are most common at 17°C to 21°C and in the Gulf of California and at 22°C to 25°C off Southern Baja (Lluch-Belda et al. 1991).

The spatial and seasonal distribution of spawning is influenced by temperature. During periods of warm water, the center of sardine spawning shifts northward and spawning extends over a longer period of time (Butler 1987; Ahlstrom 1960). Recent spawning has been concentrated in the region offshore and north of Point Conception (Lo et al. 1996). Historically, spawning may also have been fairly regular off central California. Spawning was observed off Oregon, and young fish were seen in waters off British Columbia in the early fishery (Ahlstrom 1960) and during recent years (Hargreaves et al. 1994). The main spawning area for the historical population off the U.S. was between Point Conception and San Diego, California, out to about 100 miles offshore, with evidence of spawning as far as 250 miles offshore (Hart 1973)

Sardines are oviparous multiple-batch spawners with annual fecundity that is indeterminate and highly age or size dependent. Butler et al. (1993) estimate that two year old sardines spawn on average six times per year whereas the oldest sardines spawn 40 times per year. Both eggs and larvae are found near the surface. Sardine eggs are spheroid, have a large perivitelline space, and require about three days to hatch at 15°C.

Sardine are planktivores that consume both phytoplankton and zooplankton. When biomass is high, Pacific sardine may consume a significant proportion of total organic production in the California Current system. Based on an energy budget for sardine developed from laboratory experiments and estimates of primary and secondary production in the California Current, Lasker (1970) estimated that annual energy requirements of the sardine population would have been about 22% of the annual primary production and 220% of the secondary production during the 1932 to 1934, a period of high sardine abundance.

6.3.3 Fishery Utilization

The sardine fishery first developed in response to demand for food during World War I. Landings increased from 1916 to 1936, and peaked at over 700,000 mt. The Pacific sardine supported the largest fishery in the western hemisphere during the 1930s and 1940s, with landings along the coast in British Columbia, Washington, Oregon, California, and Mexico. The fishery declined, beginning in the late 1940s and with some short-term reversals, to extremely low levels in the 1970s. There was a southward shift in the catch as the fishery decreased, with landings ceasing in the northwest in 1947 to 1948, and in San Francisco in 1951 to 1952. Sardines were primarily used for reduction to fish meal and oil and as canned food, with small quantities taken for live bait. An extremely lucrative dead bait market developed in central California in the 1960s.

In the early 1980s, sardine began to be taken incidentally with Pacific (chub) mackerel and jack mackerel in the southern California mackerel fishery and primarily canned for pet food, although some were canned for human consumption. As sardine continued to increase in abundance, a directed fishery was reestablished. Sardine landed in the directed sardine fisheries off southern and central California are mostly canned for human consumption and sold overseas, with minor amounts sold fresh for human consumption and animal food. Small quantities are harvested for dead bait and live bait. Sardines landed in Mexico are used primarily for reduction.

6.3.4 Relevant Trophic Information

Pacific sardines are taken by a variety of predators throughout all life stages. Sardine eggs and larvae are consumed by an assortment of invertebrate and vertebrate planktivores. Although it has not been demonstrated in the field, anchovy predation on sardine eggs and larvae was postulated as a possible mechanism for increased larval sardine mortality from 1951 to 1967 (Butler 1987). There have been few studies about sardine as forage, but juvenile and adult sardines are consumed by a variety of predators, including commercially important fish (e.g., yellowtail, barracuda, bonito, tuna, marlin, mackerel, hake, salmon, and sharks), seabirds (pelicans, gulls, and cormorants) and marine mammals (sea lions, seals, porpoises, and whales). In all probability, sardine are fed on by the same predators (including endangered species) that utilize anchovy (Table 1.1.2-1). It is also likely that sardines will become more important as prey as their numbers increase. For example, while sardine were abundant during the 1930s, they were a major forage species for both coho and chinook salmon off Washington (Chapman 1936).

6.4 Pacific (Chub) Mackerel

Pacific (chub) mackerel (*Scomber japonicus*) found off the Pacific coast of the U.S. are often called “blue” or “chub” mackerel and are the same species as mackerel of various names found elsewhere in the Pacific, Atlantic and Indian oceans (Collett and Nauen 1983). A synopsis of the biology of Pacific (chub) mackerel is available in Schaefer (1980) and references cited below. The northeastern Pacific stock (see below) is included in this fishery management plan.

6.4.1 Distribution and Habitat

Pacific (chub) mackerel in the northeastern Pacific range from Banderas Bay, Mexico, to southeastern Alaska, including the Gulf of California (Hart 1973). They are common from Monterey Bay, California, to Cabo San Lucas, Baja California, but are most abundant south of Point Conception. Pacific (chub) mackerel usually occur within 20 miles of shore but have been taken as far offshore as 250 miles (Fitch 1969; Frey 1971; Allen et al. 1990; MBC 1987).

There are three spawning stocks along the Pacific coasts of the U.S. and Mexico: one in the Gulf of California, one in the vicinity of Cabo San Lucas, and one extending along the Pacific coast north of Punta Abreojos, Baja California (Collette and Navem 1983; Allen et al. 1990; MBC 1987). The latter “northeastern Pacific” stock is harvested by fishers in the U.S. and Mexico and included in this FMP.

Pacific (chub) mackerel adults are found in water ranging from 10°C to 22.2°C (MBC 1987), and larvae may be found in water around 14°C (Allen et al. 1990). As adults, Pacific (chub) mackerel may move north in summer and south in winter between Tillamook, Oregon, and Magdalena Bay, Baja California. Northerly movement in the summer peaks during El Niño events (MBC 1987). There is an inshore-offshore migration off California, with increased inshore abundance from July to November and increased offshore abundance from March to May (Cannon 1967; MBC 1987). Adult Pacific (chub) mackerel are commonly found near shallow banks. Juveniles are found off sandy beaches, around kelp beds, and in open bays. Adults are found from the surface to depths of 300 meters (Allen et al. 1990). Pacific (chub) mackerel often school with other pelagic species, particularly jack mackerel and Pacific sardine.

6.4.2 Life History

The largest recorded Pacific (chub) mackerel was 63 cm long and weighed 2.8 kg, but Pacific (chub) mackerel taken by commercial fishing seldom exceed 40 cm or one kg (Hart 1973; Roedel 1938). The oldest recorded age for a Pacific (chub) mackerel was 11 years, but most caught commercially are less than four years old (Fitch 1951). Some Pacific (chub) mackerel mature as one-year-olds, and all are sexually mature by age four (Prager and MacCall 1988). The annual rate of natural mortality (M) is thought to be about 0.5 $year^{-1}$, which means that 39% of the stock would die each year of natural causes in the absence of fishing (Parrish and MacCall 1978).

Pacific (chub) mackerel larvae eat copepods and other zooplankton including fish larvae (Collette and Nauen 1983; MBC 1987). Juveniles and adults feed on small fishes, fish larvae, squid and pelagic crustaceans such as euphausids (Clemens and Wilby 1961; Turner and Sexsmith 1967; Fitch 1969; Fitch and Lavenberg 1971; Frey 1971; Hart 1973; Collette and Nauen 1983).

Pacific (chub) mackerel in the northeastern Pacific stock spawn from Eureka, California, south to Cabo San Lucas in Baja California (Frey 1971; MBC 1987) between three and 320 km from shore. They seldom spawn north of Point Conception (Fritzsche 1978; MBC 1987) although young of year mackerel have been recently reported as far north as Oregon and Washington due, perhaps, to current warm sea surface temperatures. Spawning peaks from late April to July (MacCall and Prager 1988). Like most CPS, Pacific (chub) mackerel have indeterminate fecundity and seem to spawn whenever sufficient food is available and appropriate environmental conditions prevail. Actively spawning fish appear capable of spawning every day or every other day (Dickerson et al. 1992).

Pacific (chub) mackerel larvae are subject to predation from a number of invertebrate and vertebrate planktivores. Juveniles and adults are eaten by larger fishes, marine mammals, and seabirds. Predators include porpoises, California sea lions (*Zalophus californianus*), brown pelican (*Pelecanus occidentalis*), striped marlin (*Terapturus audax*), black marlin (*Makaira indca*), sailfish (*Istiophorus platypterus*), bluefin tuna (*Thunnus thynnus*), white sea bass *(Atractoscion nobilis)*, yellowtail (*Seriola dorsalis*), giant sea bass (*Stereolepis gigas*), and various sharks (MBC 1987). Although consumed in significant numbers by a wide variety of predators, Pacific (chub) mackerel are likely not as important as forage than Pacific sardine or northern anchovy which are smaller in size (i.e., available to a wider variety of predators) and often more abundant.

6.4.3 Fishery Utilization

Pacific (chub) mackerel in the northeastern Pacific are harvested by commercial fisheries in California and Mexico; some recreational harvest also occurs. Pacific (chub) mackerel are sold as fresh fish, canned for human consumption and pet food, and reduced to fish meal and oil.

Pacific (chub) mackerel are often taken by anglers and in considerable numbers, though seldom as a target species (Allen et al. 1990). During 1980 to 1989, the recreational catch averaged 1,330 mt per year (Wolf 1989) and Pacific (chub) mackerel was numerically the most important species taken in the California commercial passenger fishing boat fleet during the period of 1978 to 1989.

6.5 Market Squid

Market squid (*Loligo opalescens)* along the west coast of North America were studied extensively during 1960 through 1980 (Recksiek and Frey 1978; Symposium of the 1978 CalCOFI Conference[1]), but little research applicable to fisheries management has been carried out since then. Recent increases in squid landings (see below) have stimulated a variety of new research projects but results have not yet been published.

6.5.1 Distribution and Habitat

Adult and juvenile market squid (Dickerson and Leos 1992) are distributed throughout the California and Alaska current systems from the southern tip of Baja California, Mexico (23° N latitude) to southeastern Alaska (55° N latitude). They are most abundant between Punta Eugenio, Baja California and Monterey Bay, central California. Market squid are harvested near the surface and generally considered pelagic, but are actually found over the continental shelf from the surface to depths of at least 800 meters. They prefer

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1/ See papers by various authors published during 1979 *in*: Calif. Coop. Oceanic Fish. Invest. Rep. 20: 21-71.

oceanic salinities and are rarely found in bays, estuaries, or near river mouths (Jefferts 1983). Adults and juveniles are most abundant between temperatures of ten degrees Celsius and 16°C (Roper et al. 1984).

Spawning squid concentrate in dense schools near spawning grounds, but habitat requirements for spawning are not well understood. Spawning occurs over a wide depth range, but the extent and significance of spawning in deep water is unknown. Known major spawning areas are shallow semi-protected near shore areas with sandy or mud bottoms adjacent to submarine canyons where fishing occurs. In these locations, egg deposition is between five meters (Jefferts 1983) and 55 meters (Roper and Sweeney 1984), and most common between 20 meters and 35 meters. Off California, squid and squid eggs have been taken in bottom trawls at depths of about 800 meters near Monterey (Bob Leos, California Department of Fish and Game, pers. comm.) and have been observed at 180 meters near the Channel Islands (Roper and Sweeney 1984). Factors that determine spawning grounds have not been precisely identified. Hatchlings (called "paralarvae") are presumably dispersed by currents. Their distribution after leaving the spawning areas is largely unknown.

Attempts to differentiate squid stocks using anatomical and genetic characters have been inconclusive. Thus, the number of market squid stocks or subpopulations along the Pacific coast is unknown.

6.5.2 Life History

Market squid are small short-lived molluscs reaching a maximum size of 30 cm total length, including arms (Roper and Sweeney 1984). Age and growth studies suggest than some individuals may live up to two years, but most mature and spawn when about one year old (Spratt 1979). In the laboratory squid have been reared to maturity and spawned at six months of age. Histological examination of squid testes and ovaries using electron microscopy suggests that squid spawn once over a short time period before dying (Greib 1978; Knipe 1978), although this is a topic of current research and some debate.

Spawning occurs year-round (Jefferts 1983). Peak spawning usually begins in southern California during the fall-spring season. Off central California, spawning normally begins in the spring-fall season. Squid spawning has been observed off Oregon during May through July. Off Washington and Canada, spawning normally begins in late summer. Year-round spawning likely reduces effects of poor temporary local conditions for survival of eggs or hatchlings. Year-round spawning suggests that stock abundance is not dependent on spawning success during a single short season or a single spawning area.

Males on spawning grounds are larger than females. Males reach 19 cm dorsal mantle length, a maximum weight of 130 grams and have larger heads and thicker arms than females. Females reach 17 cm dorsal mantle length and a maximum weight of 90 grams. Mating has been observed on spawning grounds just prior to spawning, but may also occur before squid move to the spawning grounds. Males deposit spermatophores into the mantle cavity of females and eggs are fertilized as they are extruded (Hurley 1977). Females produce 20 egg to 30 egg capsules and each capsule contains 200 eggs to 300 eggs that are suspended in a gelatinous matrix within the capsule. Females attach each egg capsule individually to the substrate. As spawning continues, mounds of egg capsules covering more than 100 m^2 may be formed.

Spawning is continuous and eggs of varying developmental stages may be present at one site. Eggs take three months to hatch at seven degrees Celsius to eight degrees Celsius, one month at 13°C and 12 days to 23 days at ten degrees Celsius (Jefferts 1983). Newly hatched squid (called "para larvae") are about 2.5 mm to three mm in length and resemble miniature adults. Hatchlings are dispersed by currents and their distribution after leaving the spawning areas is largely unknown.

Few organisms eat squid eggs although bat stars and sea urchins have been observed doing so (Jefferts 1983). Like northern anchovy and Pacific sardine (Table 1.1.2-1), market squid are probably important as forage to a long list of fish, birds, and mammals including threatened, endangered, and depleted species (Morejohn et al. 1978). Some of the more important squid predators are king salmon, coho salmon, lingcod, rockfish, harbor seals, California sea lions, sea otters, elephant seals, Dall's porpoise, sooty shearwater, Brandt's cormorant, rhinoceros auklet, and common murre.

Squid feed on copepods as juveniles gradually changing to euphausiids, other small crustaceans, small fish, and other squid as they grow (Karpov and Cailliet 1978).

6.5.3 Fishery Utilization

Market squid are harvested commercially primarily off southern and central California although some catch occurs throughout their range. Fishing occurs on spawning grounds and occurs during the spawning season. Peak catches occur off southern California during the winter, off Central California during the late spring and summer, and later in the summer off Oregon to Alaska.

Commercial squid fishing vessels use purse seines primarily, although scoop nets are also used in the southern California fishery. Lights are usually used to bring the squid schools up near the surface where they are more easily captured by seine or scoop net. Purse seines used for squid typically do not hang as deep as purse seines used for other species so contact with the bottom is reduced. However, squid eggs are occasionally observed in purse seines when the seines contact the bottom. Egg mortality associated with purse seining for squid has not been quantified.

The California squid fishery accounts for most of the coast wide landings. Minor amounts of market squid are landed in Canada, Washington, and Oregon . The size of the Mexican fishery is unknown but is thought to be minor. The California annual squid catch set records of 56, 70, and 80 thousand mt during 1994 to 1996.

In California, most squid marketed for human consumption is frozen, but minor amounts are canned or sold fresh. Historically, the domestic demand for frozen squid has been relatively small, and most of the increased production from California during 1994 to 1996 was frozen and exported to Europe, Spain, and China. Squid is also frozen for bait and supplied to domestic commercial and sport fishers and is an important source of live bait for the California sport fishing industry.

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TABLE 6.1 Summary of habitat information for northern anchovy.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac and planktivorous	Year-round, peaks from Feb. to April	Surface waters of the EEZ	Near surface, < 50m	12°C to 21.5°C
Adults	Phytoplankton, zooplankton	Year-round	Surface waters of the EEZ	Near surface, < 50m	12° C to 21.5°C

TABLE 6.2 Summary of habitat information for jack mackerel.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac; larvae consume copepods	Feb. to Oct.with peak from March to July	Pelagic, schooling	Pelagic	10°C to 26°C
Juveniles	N/A	Year-round	Sometimes in small schools under floating kelp and debirs	Pelagic	10° C to 26°C
Adults	Zooplankton (copepods, pteropods and euphausids, juvenile squid, and northern anchovy	Year-round	Inshore and offshore; sometimes over rocky bottoms	Pelagic	10°C to 26°C

TABLE 6.3 Summary of habitat information for Pacific sardine.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac and planktivorous	Year-round, with peak in April-August	Pelagic, 50-150 km offshore	Upper 50 m	Eggs: 14°C to 16°C Larvae: 14°C to 16°C
Juveniles	Planktivorous	Year-round	Pelagic	Above thermocline	10° to 26°C
Adults	Phytoplankton and zooplankton	Year-round	Pelagic, sometimes in estuaries	Above theromcline	10° C to 26°C

TABLE 6.4 Summary of habitat information for Pacific (chub) mackerel.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac; copepods and fish larvae	Peaks from late April to July	N/A	Surface	14°C
Juveniles	Small fishes, fish larvae, squid, and pelagic crustaceans such as euphausids	Inshore-offshore migration off CA July to Nov.; increased offshore abundance March to May	Off sandy beaches, around kelp beds, and in open bays	N/A	10°C to 26°C
Adults	Small fishes, fish larvae, squid, and pelagic crustaceans such as euphausids	Inshore-offshore migration off CA July to Nov.; increased offshore abundance March to May	Usually within 20 miles of shore, but as far as 250 miles offshore; near shallow banks	Surface to 300 m	10°C to 22.2°C

TABLE 6.5 Summary of habitat information for market squid, continued.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and para larvae (newly hatched squid)	N/A	Year-round	Shallow semi-protected nearshore areas with sandy or mud bottoms adjacent to submarine canyons; distribution of paralarvae is largely unknown		10°C to 26°C
Juvenile	Copepods	N/A	N/A	N/A	10°C to 26°C
Adult	Euphausiids and other small crustaceans, small fish and other squid	Spawn year	Rarely found in bays, estuaries or near river mouths	Surface to 800 m	10°C to 26°C

7.0 RESEARCH NEEDS

Research in general needs to address additional life history information, nonfishing impacts and the potential for conservation and enhancement measures. In addition, because potential overfishing of northern anchovy, Pacific sardine, market squid, or other species could adversely affect the EFH for other species such as Pacific (chub) mackerel, jack mackerel, and market squid; the dynamics of predator-prey relationships within the context of an ecosystem perspective should be investigated.

Studies on effects of fishing activities (e.g., mid-water trawling, processing discards) on the EFH of CPS should be considered.

Consideration should be given to research necessary to describe, identify, and map EFH based on at least level 2 and level 3 information, and ideally, level 4 information. More specific information on the preferred habitats of CPS is needed for more narrowly identifying areas of EFH (not the whole EEZ).

Review and revision of the EFH components of this FMP should be undertaken as necessary. Part of this review should address the specific research needs identified below for each species:

7.1 Northern Anchovy

Northern anchovy is a well studied species and no areas of concern or important research gaps related to EFH have been identified.

7.2 Jack Mackerel

Migrations for feeding and spawning are not well known. Adult jack mackerel may migrate southwards into California during the winter to spawn, however it is also possible that many older jack mackerel overwinter in the region north of 39° N latitude, particularly in offshore regions. Better information on the seasonal distribution and migratory behavior of jack mackerel would be useful. There is no evidence of stock structure in jack mackerel along the West Coast.

7.3 Pacific Sardine

No areas of concern or important research gaps related to EFH have been identified for Pacific sardine with the exception of the debate over how many sardine stocks exist along the West Coast during periods of high and low abundance.

7.4 Pacific (Chub) Mackerel

No areas of concern or important research gaps related to EFH have been identified for Pacific (chub) mackerel.

7.5 Market Squid

Market squid are poorly understood, relative to CPS finfish. As described above, impacts on EFH are most likely during fishing which occurs almost entirely on spawning aggregations in shallow water. There are two areas of potential concern that have not been quantified: damage to substrate used to attach eggs, and damage to egg masses.

Information about how squid spawning grounds are distributed with depth and their locations along the coast is required; information on spawning grounds in deep water and to the north of central California is particularly meager. In addition, information about egg survival and paralarvae production per unit area in different types of spawning habitats is needed for understanding potential impacts of fishing in shallow water.

Dispersal of adults and paralarvae along the West Coast (i.e., stock structure) is required for determining how local impacts might be mitigated by recruitment from other areas in this short lived species.

Egg mortality associated with purse seining for squid has not been quantified.

Factors that determine spawning grounds have not been precisely identified.