APPENDIX E
SUMMARY INFORMATION FOR PLANKTON AND ICHTHYOPLANKTON

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The primary source of data for plankton present off the California coast is the long-term sampling and analysis program conducted under the California Cooperative Fisheries Investigations (CalCOFI). CalCOFI represents a partnership between the California Department of Fish & Wildlife (CDFW), the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS), and the University of California, Integrative Oceanography Division.

With survey efforts initiated in 1949, the original efforts were designed to study the ecological aspects of the sardine population collapse off California. At present, CalCOFI focuses on the study of the marine environment off the coast of California, the management of its living resources, and the monitoring of indicators of El Niño and climate change. CalCOFI conducts quarterly cruises off Southern and Central California, collecting a suite of hydrographic and biological data on station and underway. Data collected at depths down to 500 meters (m) include: temperature, salinity, oxygen, phosphate, silicate, nitrate (NO_3^-) and nitrite (NO_2^-), chlorophyll, transmissometer, photosynthetically active radiation (PAR), carbon-14 (C14) primary productivity, phytoplankton biodiversity, zooplankton biomass, and zooplankton biodiversity. Ancillary data collected include continuous underway sea surface and meteorological measurements (SCIMS); Acoustic Doppler Current Profiler (ADCP) data; the Continuous Underway Fish Egg Sampler (CUFES [winter and spring]); trace metals; sediments; Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) net sampling; bio-optics; carbon dioxide partial pressure (PCO_2) air-sea interface, and atmospheric measurements. Marine mammal and seabird visual surveys are conducted during transits between stations, as well as recording marine mammal acoustics.

CalCOFI hosts an annual conference, and publishes a scientific journal as well as quarterly hydrographic data reports for each cruise while maintaining a publicly accessible data server. CalCOFI hydrographic and plankton data are distributed to the community for use without restriction. Methods for data collection and processing are summarized in the introductions of cruise data reports. Annual CalCOFI reports and bi-annual data reports are available either online or via the University of California, San Diego (UCSD)/Scripps Institution of Oceanography (SIO) libraries.

In 2004, the CalCOFI surveys became part of the Long Term Ecological Research (LTER) network as a site to understand the pelagic ecosystem of the California Current (CCE). The CCE-LTER project has expanded CalCOFI goals and, with additional seawater sample analyses and vertical net tows, has broadened the scope of its 62 year times-series. LTER also conducts seasonal process cruises in the CalCOFI grid and operates autonomous gliders along several CalCOFI survey lines. While the vast majority of the CalCOFI sampling sites are in Federal waters, there are several nearshore sites with applicability to State waters.

Since the pioneering research of Sverdrup and Allen (1939), physical and biochemical variables have been measured to better understand the link between physical processes and biological responses in the Southern California Bight (SCB). For instance, the CalCOFI program has conducted routine measurements of chlorophyll and major nutrients, in addition to hydrographic surveys, since 1984 (Hayward and Venrick 1998). However, very nearshore waters adjacent to the coastline were not regularly observed until Southern California Coastal Ocean Observing System (SCCOOS) stations were added to the current CalCOFI grid in 2004. Thus, while the vast majority of the CalCOFI survey efforts are in deep-water and beyond 3 nautical miles (nm), there are several nearshore shallow stations that are applicable to the Low Energy Offshore Geophysical Permit Program (OGPP) Update Mitigated Negative Declaration (MND). Given the recent acquisition of these data, the magnitude and variability of primary productivity in nearshore waters of the SCB is not yet well known (Kim et al. 2009).

In spite of the absence of a long-term historical database on phytoplankton, recent research findings are available. Omand et al. (2012) and Kim et al. (2009) characterized the seasonal phytoplankton cycle in the SCB, noting that it generally begins with a large spring bloom, followed by a series of episodic blooms during the rest of the year. Dense blooms observed nearshore, in water depths less than 20 m, may last only a few days. Harmful algal blooms (HABs) may also occur, producing adverse effects such as toxins, fish gill damage, or anoxia (Smayda 1997; Anderson et al. 2008). HABs that occur in the nearshore are particularly damaging because of the high exposure to coastal and benthic habitats (Ormand et al. 2012).

One of the prominent ecosystem features of the California Current System is the spring phytoplankton bloom along a narrow coastal band, within 20 to 50 kilometers (km) of the shore. This phenomenon results in strong seasonality and an inshore-offshore gradient of primary production (e.g., see Strub et al. 1990; Thomas et al. 1994; Leggard and Thomas 2006; Kim 2008).

Picophytoplankton is composed of three groups and includes the cyanobacteria *Prochlorococcus* spp., *Synechococcus* spp., and small eukaryotic algae. Picophytoplankton contribute greater than 50 percent of the biomass and production in warm oligotrophic tropical and subtropical open oceans (Agawin et al. 2000). *Prochlorococcus* spp. has been found to be more abundant in oligotrophic water than in eutrophic water, and *Synechococcus* spp. is ubiquitous in the upper layers of temperate and warm oceans (Zhao et al. 2010).

In Southern California, Tai and Palenik (2009) determined that *Synechococcus*, with unique ecological niches, are distributed along a coastal to offshore transect within the SCB. The composition of the *Synechococcus* communities generally changed with the nitricline, thermocline, and chlorophyll maximum depths, each of which deepened as sampling moved offshore.

Off the Central California coast (Central Coast region), site-specific studies by Pennington and Chavez (2000) have characterized the seasonal fluctuations in physical oceanographic parameters and nutrient characteristics over an eight-year time period

(1989–1996), and their subsequent influences on chlorophyll concentrations and primary production in Monterey Bay. During spring and summer, upwelling brings high-nutrient water to the surface of Monterey Bay. Nutrients, sunlight, and some degree of water column stratification lead to high primary production and elevated chlorophyll values during the upwelling period. During the upwelling period, flora within the Bay are dominated by diatoms, especially *Chaetoceros* spp.

In the North Central Coast region, Pennington and Chavez (2000) analyzed a three-year data set (2000–2003) of nearshore upwelling events off Bodega Bay. As part of the Coastal Ocean Processes: Wind Events and Shelf Transport (CoOP WEST) study, nutrients, carbon dioxide (CO_2), size-fractionated chlorophyll, and phytoplankton community structure were measured. The ability of the ecosystem to assimilate nitrate and silicic acid/silicate ($Si(OH)_4$) and accumulate particulate material (i.e., phytoplankton) was realized in all three years, following short events of upwelling-favorable winds with subsequent periods of relaxed winds. This was observed as phytoplankton blooms, dominated by chlorophyll in cells greater than 5 micrometers (µm) in diameter that reduced ambient nutrient levels to below detection limits (i.e., reported as zero by Wilkerson et al. 2006). Seasonal wind-driven upwelling supplies abundant nutrients to support increased phytoplankton productivity.

Studies of nearshore zooplankton tend to be site-specific. Barnett and Jahn (1987) characterized nearshore zooplankton off San Onofre (Southern California), identifying distinguishable nearshore and offshore assemblages. Nearshore, in water depths less than 30 m, the copepods *Acartia clausi* and *Oithona oculata*, and barnacle larvae were present. Offshore assemblages included the copepods *Calanus pacificus*, *Eucalanus californicus*, and *Rhincalanus nasutus*, occupying water having less chlorophyll and less near-surface nutrients (i.e., of more oceanic character). Throughout the year, nearshore and offshore assemblages were distinguishable, with the change occurring around the 30-m contour. In spring and summer, most nearshore taxa shifted slightly seaward, leaving a third assemblage, characterized by a very high abundance of *Acartia* spp. copepodids and maximum abundances of *A. clausi* and *O. oculata* near the beach.

CalCOFI ichthyoplankton abundance data are also published at approximately yearly intervals as NMFS Technical Memos, and the data have provided the basis for numerous papers published in a variety of scientific journals. The many advances in fish egg and larval identification made as a result of the CalCOFI surveys have been documented in a descriptive atlas (Moser 1996).

In addition to the CalCOFI surveys and Fisheries Resources Division (FRD) resource surveys (e.g., annual Pacific Sardine biomass cruise), there are several data available from a variety of other research programs, including the Southern California Nearshore Ichthyoplankton survey (2004–2005; Lavenberg et al. 1986), the Cowcod Conservation Area high resolution ichthyoplankton and oceanographic surveys (2002–2005), and the Marine Ecological Reserves survey (1998–1999; Watson et al. 1999, 2002a,b). These surveys provide monitoring abundance trends of cowcod, bocaccio, and other fishes in non-routinely trawled or untrawlable areas. Of particular note, the nearshore ichthyoplankton survey effort was conducted in shallow coastal waters (8 to 75 m depth) at four Southern California sites, reoccupying sampling stations last surveyed during the 1980s. Results were compiled to estimate the degree of change in the fish fauna near shore during the approximately 20 years between surveys, and to provide more information on eggs and larvae of nearshore fishes than is available from the standard CalCOFI sampling grid.

Ichthyoplankton data for California are also available through NOAA's Northeast Pacific Ichthyoplankton Information System (IIS), accessible at NOAA's website (http://access.afsc.noaa.gov/ichthyo/index.cfm). This site allows the user to access data on the early life history of fishes collected by the Alaska Fisheries Science Center (AFSC) Recruitment Processes Program, which includes Fisheries-Oceanography Coordinated Investigations (FOCI). AFSC scientists have conducted ichthyoplankton cruises in 1972 and yearly from 1977 until the present. The resulting database includes over 230 cruises which have sampled in four different geographic areas: The Gulf of Alaska between the Aleutian Islands and Southeast Alaska; the Eastern Bering Sea including the area surrounding the Pribilof Islands; north of Bering Sea, above 66°N; and the Washington/Oregon/California coastal area. This latter area would include survey results applicable to this MND, complementing the efforts of the CalCOFI.

The NOAA IIS data website can be used to identify unknown fish eggs and larvae by using known data such as meristics, distribution, and illustrations of developmental stages, or as a source of original data on the early life history stages of fishes of the Bering Sea and Northeast Pacific Ocean, including Northern California. A taxonomic guide to the early life history stages of the more than 200 fishes that spawn in these areas was published by Matarese et al. (1989). More recently, a synoptic atlas presenting data on spatial and temporal trends in the dominant fish eggs and larvae from these regions has been completed (Matarese et al. 2003). These publications complement earlier advances in regional ichthyoplankton taxonomy (e.g., Moser 1996; Busby 1998) and a meta-database of ichthyoplankton cruise data.

In addition to plankton surveys, there are several sources for plankton and fish biomass estimates. For example, since 2000, the Southwest Fisheries Science Center (SWFSC) has augmented CalCOFI surveys with multi-frequency-acoustic sampling to estimate the abundance of mid-trophic level species (e.g., myctophids, euphausiids, small pelagics). Research vessels are typically equipped with four echosounders that operate at 38, 70, 120, and 200 kilohertz (kHz) to locate, identify, and estimate school or patch size. Data are converted to biomass densities using accepted combined target strength-to-length and length-to-biomass conversions. Length samples were collected via surface trawls.

Within the context of monitoring climate change, NOAA Fisheries convened a workshop in 2006 to summarize research to date and to propose sentinel plankton species in the

California Current Large Marine Ecosystem (LME) that can indicate climatic regime changes (NOAA Fisheries 2006). Sentinel plankton species are identified in **Table E-1**.

Table E-1. Proposed Sentinel Plankton Species in the California Current Large Marine Ecosystem (LME) that can Indicate Climatic Regime Changes (From: NOAA Fisheries 2006)

Characteristics	Species
Cosmopolitan (Throughout the California Current System)	
Copepods	*Calanus pacificus, Metridia* cf. *pacifica, Paracalanus parvus*
Euphausiids	*Thysanoessa spinifera, Euphausia pacifica*
Pteropods	*Limacina helicina*
Salps	*Salpa fusiformis*
Doliolids	*Dolioletta gegenbauri*
Medusae	*Chrysaora fuscescens*
Ichthyoplankton	Pacific Sardine, *Sardinops sagax;* Northern Anchovy, *Engraulis mordax;* Market Squid, *Loligo opalescens;* Pacific Hake (Pacific Whiting), *Merluccius productus*
CalCOFI Region (Central California to Baja Mexico)	
Copepods	*Pareucalanus attenuatus, Euchaeta media, Neocalanus robustior, Pleuromamma gracilis*
Euphausiids	*Euphausia eximia, Euphausia gibboides, Euphausia pacifica, Euphausia recurva, Nyctiphanes simplex, Thysanoessa spinifera*
Doliolids	*Doliolum denticulatum*
Salps	*Cyclosalpa affinis, Cyclosalpa bakeri, Pegea social, Salpa maxima*
Decapods	*Pleuroncodes planipes*
Ichthyoplankton	Mexican lampfish, *Triphoturus mexicanus*

Acronyms: CalCOFI = California Cooperative Oceanic Fisheries Investigations.

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