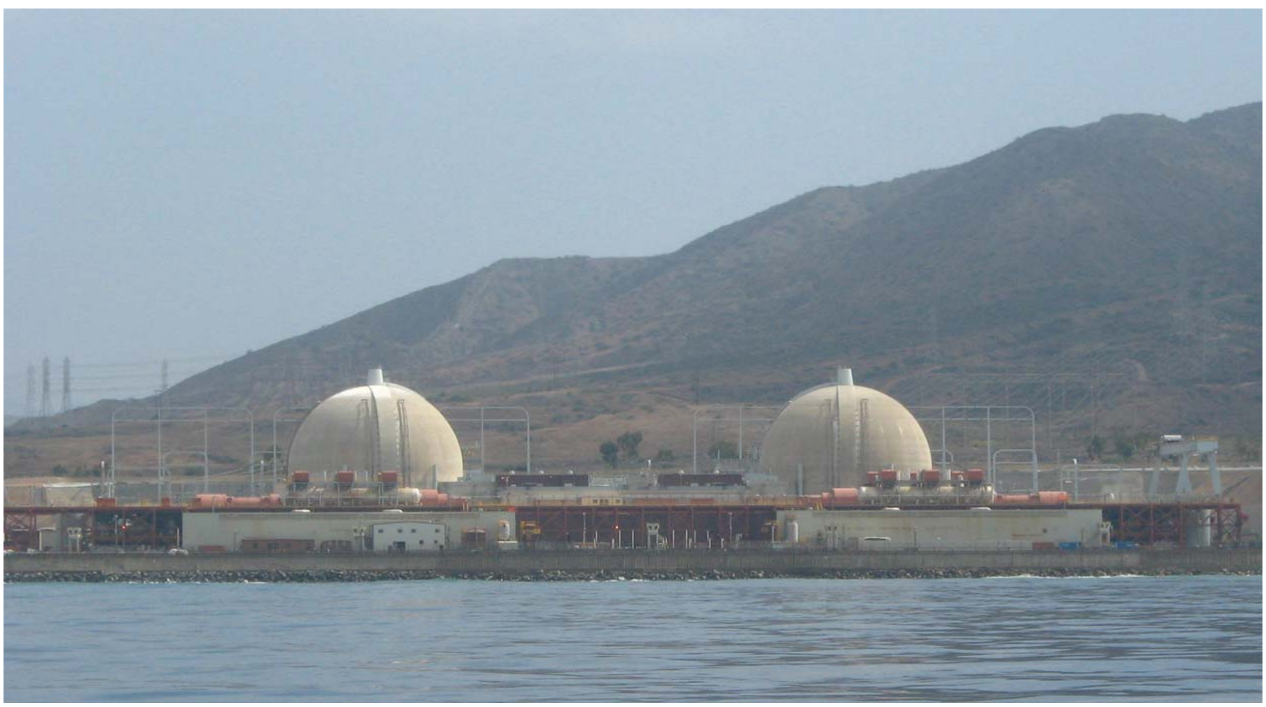
2021
ANNUAL MARINE ENVIRONMENTAL ANALYSIS AND INTERPRETATION



San Onofre Nuclear Generating Station

SOUTHERN CALIFORNIA EDISON

An EDISON INTERNATIONAL™ Company

ANNUAL MARINE

ENVIRONMENTAL ANALYSIS

AND

INTERPRETATION

San Onofre Nuclear Generating Station

July 2022

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Report Preparation/Data Collection – Oceanography and Marine Biology

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EXECUTIVE SUMMARY

This report presents analysis and discussions of the oceanographic and marine biological studies conducted in 2021 near the San Onofre Nuclear Generating Station (SONGS), located on the Southern California coastline between the cities of San Clemente and Oceanside. Physical and biological data were analyzed to 1) fulfill National Pollutant Discharge Elimination System (NPDES) regulatory requirements, and 2) assess the operational effects of SONGS on the marine environment. These studies meet receiving water monitoring requirements of the San Diego Regional Water Quality Control Board (SDRWQCB), as specified in the NPDES permit for SONGS Unit 2 and Unit 3 (NPDES No. CA0109282, California Regional Water Quality Control Board, San Diego Region, Order No. R9-2015-0073).

GENERATING STATION OPERATION – 2021

The following is a brief description of the plant operating characteristics during 2021.

Unit 1. The unit was permanently shut down in 1992 and plant systems have been decommissioned. Flows from the sewage treatment plant discharge through the Unit 2 outfall.

Unit 2. The unit was permanently shut down in 2013 and is in the process of decommissioning. The daily maximum discharge flow from January to December was <25.0 million gallons per day (MGD), with an annual daily average of 20.8 MGD. The flow was largely the result of the operation of saltwater dilution pumps from both Units 2 and 3 intake structures, with some flow coming from several in-plant wastes and the former Unit 1 area sources. The discharge from the saltwater dilution pumps was in service for 358 days.

Unit 3. The unit was also permanently shut down in 2013 and is in the decommissioning process. There was no discharge flow during the year; all dilution water flow was returned to the ocean via the Unit 2 outfall.

OCEANOGRAPHIC PROCESSES AND WATER QUALITY

Oceanographic conditions during 2021 near SONGS, including temperature, dissolved oxygen (DO), and hydrogen ion concentration (pH), along with aerial photography of turbidity conditions, were documented. An overall evaluation of water quality parameters has been summarized below. Both Units 2 and 3 are in the decommissioning process.

The continuous water temperature data from Stations C22S, C2S, and F2S indicated that mean seasonal surface water temperatures at all stations and depths in 2021 were generally cooler than in 2020 in winter, summer, and fall and warmer in spring. In 2021, there were nine periods with conspicuous, short-term surface water temperature decreases. Wind vectors during these periods indicated offshore coastal winds that resulted in strong upwelling of cool bottom water at all three locations. Temperature decreases ranged from 1.5°C to 7.0°C and occurred in January, March through June, and August through October with the largest decrease occurring in August.

Average seasonal temperatures in 2021 were compared with the 32-year seasonal means measured at the SONGS thermistor stations. Water temperatures were lower than the long-term means at all stations and depths in winter, summer, and fall and warmer in spring (= quarters, e.g. January-March is winter, April-June is spring, etc.). Average seasonal temperatures in 2021, for all stations and depths each season, ranged from 1.5°C cooler in summer to 0.8°C warmer in spring than the long-term seasonal means.

Daily surface temperature measurements from Stations C22S, C2S, and F2S recorded during 2021 were compared with daily measurements taken at Dana Point or the San Clemente Pier over a 66-year period between 1955 and 2020. Overall, average surface water temperatures for all stations in 2021 were about 0.2°C warmer than the long-term mean values. Surface water temperatures in 2021 fluctuated from –5.9° to +3.5°C around the long-term mean values.

Vertical temperature gradients were computed as the difference between the surface and bottom temperatures divided by the water depth at the station. The temperature gradients in 2021 were weakest, generally less than 0.1°C/m, from January through March and in December. Strongest gradients were recorded from May through August, although gradients decreased to near zero during upwelling events at Stations C2S and C22S. Station F2S gradients were much less variable then at the other two stations and remained greater than 0.2°C/m from May through August. The maximum gradient was slightly more than 0.7°C/m at both Stations C2S and C22S in August, and slightly lower than 0.6°C/m at Station F2S in both July and August

Spatial surface and bottom water temperature comparisons were made between the reference (Station C22S) and impact (Stations C2S and F2S) sites using mean daily temperatures. Throughout the year, surface water temperature differences between Stations C2S and C22S averaged about 0.1°C, with Station C2S slightly cooler most of the year. Differences between Stations F2S and C22S, although variable, were the same on average; temperatures at Station F2S were slightly cooler than at Station C22S for just over five months of the year. Seasonally, the Station C22S surface mean value was warmer than Station C2S during all seasons, and warmer than Station F2S in winter. Bottom water temperature comparisons indicated greater differences at depth than those in surface waters. Throughout the year, bottom water temperatures at Station C2S were an average of almost 0.3°C warmer than those recorded at Station C22S, with a maximum daily difference of 2.4°C in July. At Station F2S, which is deeper than the other two stations, bottom water temperatures were an average of 0.8°C cooler than at Station C22S. The maximum daily bottom water temperature difference of 3.8°C cooler between Stations F2S and C22S occurred in July. Seasonally, the Station C2S bottom mean value was warmer than Stations C22S and F2S during all seasons.

Water column temperature profiles were recorded at 29 receiving water stations quarterly to document the extent of any thermal plume. In general, surface-to-bottom temperature differences were related to station depth, with greater differences found at deeper, offshore stations and smaller differences at the shallower, inshore stations. There was no apparent pattern to surface temperatures in the vicinity of SONGS, which did not create a thermal discharge during the year.

Surface water quality measurements were recorded quarterly at 10 receiving water stations to determine compliance with NPDES permit standards for DO concentrations and pH. The concentrations of DO at all SONGS impact stations complied with requirements in the NPDES permit (the mean surface DO values at the impact stations were not depressed more than 10% with respect to the mean found at the surface at the reference stations). The mean annual DO value of 8.36 mg/L found near the discharges was typical of the marine environment, and was nearly identical to the mean value of 8.57 mg/L found at the reference stations. The pH at the SONGS impact stations complied with NPDES permit requirements in that the pH values did not exceed the maximum 0.2-unit deviation with respect to the reference stations during all four quarterly cruises.

KELP DENSITY STUDY

The 2021 surveys for the Giant Kelp Density Study continued to evaluate the giant kelp community near SONGS using fixed and random quadrat surveys. The species monitored were selected because of their ecological interactions with giant kelp and include other algae species that compete for substrate or block settlement of giant kelp spores, herbivores that consume giant kelp, and invertebrate predators on those herbivores. A fixed quadrat sampling program was conducted in June, September, and November 2021 in the San Onofre Kelp Forest (SOK) and San Mateo Kelp Forest (SMK), with a random quadrat sampling program conducted concurrently at both areas during the June and November 2021 surveys. This study was derived using methods developed during historic monitoring surveys.

The seafloor beneath the SOK is composed primarily of cobble (small moveable rocks) and sand. The main substrate available for giant kelp attachment in SOK is cobble, which becomes unstable as attached giant kelp grows (and increases buoyancy) to a point that it can float the cobble from the bottom and out of the forest. Although this type of substrate supports other giant kelp forests in the region, giant kelp in southern California is typically found growing on exposed bedrock reefs. The proportions of cobble and sand differed considerably among areas within SOK in 2021. The relatively high proportion of sand, which can abrade kelp blades (stipes) and even shear kelp from attachments, results in a seafloor with changing substrate constituents and variable attachment opportunities. Boulders, which are a more stable substrate for giant kelp attachment than cobble, occurred in relatively low proportions at most SOK stations.

Analysis of giant kelp densities since 1978 throughout SOK indicated that the giant kelp forest is spatially and temporally variable. In 2021 no giant kelp was observed at any of the survey sites during either survey method, a decrease from 2020 when giant kelp was recorded in the November random survey. Giant kelp has recorded an annual decline in mean density since 2014, possibly a result of the unusually warm water temperatures observed in the northeast Pacific ocean during that time period which reduces the availability of nutrients needed to sustain growth. Three local kelp beds, SOK, SMK, and Barn Kelp have recorded variable surface canopies in the past six years, but all three have different maximum bottom depths and substrate compositions which may explain the variation in surface canopy.

San Mateo Kelp is characterized by a more stable bottom composition than typical of SOK, with higher proportions of boulder and cobble, and lower proportions of sand. San Mateo Kelp is nearby and served as a reference site for SOK surveys from 1978 through 1989, and again since 1995.

Giant kelp densities at SOK have been variable and much reduced compared to densities recorded when monitoring began in 1978, although peaks in density have occurred about every seven years. High sea urchin densities have periodically removed all giant kelp at SMK stations. In 2021, no giant kelp was observed during any fixed or random quadrat survey, similar to the 2019 and 2020 surveys.

Densities of understory kelps have typically been low and have shown less interannual variability over most of the monitoring period than giant kelp with extended periods with densities near zero; in 2021 mean annual density in SOK for both stalked kelp (*Pterygophora californica*) and bladder chain kelp (*Cystoseira osmundacea*) increased while oarweed (*Laminaria farlowii*) decreased from 2020. Densities of both stalked kelp and oarweed are within the range of values recorded over the past 15 years, while bladder chain kelp density has shown a marked increase in the past five years. All three understory kelps have recorded an increase in density in SOK since 2014 when giant kelp began declining. In SMK, mean density of stalked kelp increased and oarweed and bladder chain kelp decreased from 2020.

Macroinvertebrate densities have varied considerably for several species of sea urchins (*Strongylocentrotus* spp and *Lytechinus pictus*) and Pacific sea stars (*Pisaster* spp). Bat star (*Patiria miniata*) nearly disappeared from SOK in 1983 and densities have remained low since, with slight increases since 2002. In 2021, bat stars were observed at Station 14-15 during one survey and Stations 10 and 18-19 during all three surveys. Mean *Strongylocentrotus* spp densities increased from those in 2020 but were lower than the high density recorded in 2011. White sea urchin (*Lytechinus pictus*) was only observed at two stations in 2021 (at similar densities as in 2020); it was first observed in 2017 after an absence of four years. Mean abundances of Pacific sea stars have fluctuated in the area after the decline observed in 1997. Some of these patterns appear to coincide with changes in environmental conditions, in particular, the extended El Niño in 1982-1984 when densities of common macroinvertebrates and kelps decreased dramatically. Pacific sea star were not observed at any station in 2021; they were last observed in 2014.

IN-PLANT FISH MONITORING

In-plant fish monitoring requires two circulating water intake pumps to be operational to provide flushing water for the operation of the traveling screens and to provide discharge flow for the fish return system. Circulating water pumps were not operational during 2021 so fish impingement monitoring was conducted by visual observation of the forebays. Only one saltwater dilution pump was operated per unit. As a result, circulated water use at each intake was reduced by approximately 99% compared to operational conditions. The lower circulating volumes from the saltwater dilution pumps have significantly reduced intake flow velocities, which likely allow fishes to avoid entrainment into the onshore circulating water system. Monthly visual inspections confirmed no impingement was observed on screens since the plant shut down.

FISH POPULATION STUDY

Semiannual otter trawl fish surveys in 2021 caught a total of 2,233 fish representing 27 species offshore of the coast between San Mateo Point and Don Light, including directly offshore of SONGS. Overall, a higher abundance of fish was caught during the fall sampling when 1,202 fish representing 22 species were caught. In spring, 1,031 fish representing 19 species were caught.

Diversity was variable among stations in the respective seasons; San Mateo showed the highest diversity of 1.39 in Spring while San Onofre showed the highest diversity of 1.58 in Fall and overall. The most abundant species overall in 2021 were Northern Anchovy, Speckled Sanddab, and Queenfish.

Trawl sampling in 2021 documented seasonal variations in the fish communities near San Mateo, San Onofre, and Don Light. Overall, in 2021 and throughout the historical period of record, since 1995, the mean abundances have fluctuated within the range of observations made in prior years, particularly for the most commonly encountered fish along each isobath. Currently, there is no apparent trend to suggest a community response to decreased flow.

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CHAPTER 1 STUDY INTRODUCTION AND GENERATING STATION DESCRIPTION

INTRODUCTION

This report presents analyses and interpretations of the oceanographic and marine biological data collected during 2021 for Southern California Edison Company (SCE) in the vicinity of the San Onofre Nuclear Generating Station (SONGS).

PURPOSE OF SAMPLING

The purpose of this report is to fulfill the NPDES 2021 oceanographic and marine biological monitoring requirements for SONGS Units 2 and 3, established by the San Diego Regional Water Quality Control Board (SDRWQCB) (NPDES No. CA0109282, Order No. R9-2015-0073). These sampling results are also submitted to the United States Nuclear Regulatory Commission (NRC) and the United States Environmental Protection Agency (EPA).

REPORT APPROACH AND ORGANIZATION

This report presents and interprets data collected in 2021. The Annual Marine Environmental Analysis and Interpretation is organized by study element and all pertinent findings associated with a particular study are addressed in the appropriate chapter. This report, as with previous annual reports, concentrates on documenting results of the marine monitoring performed in response to regulatory requirements. The chapters within this volume address the physical oceanographic and biological conditions in the area, and include temperature, turbidity, water quality, fish, subtidal hard benthos, and kelp studies conducted in 2021 for the NPDES Operational Program for SONGS Units 2 and 3.

DESCRIPTION OF THE STUDY AREA

SONGS is located along the California coastline at 33° 22.0'N and 117° 33.5'W between the cities of San Clemente and Oceanside. The immediate study area is located along the nearshore zone as shown in Figure 1-1.

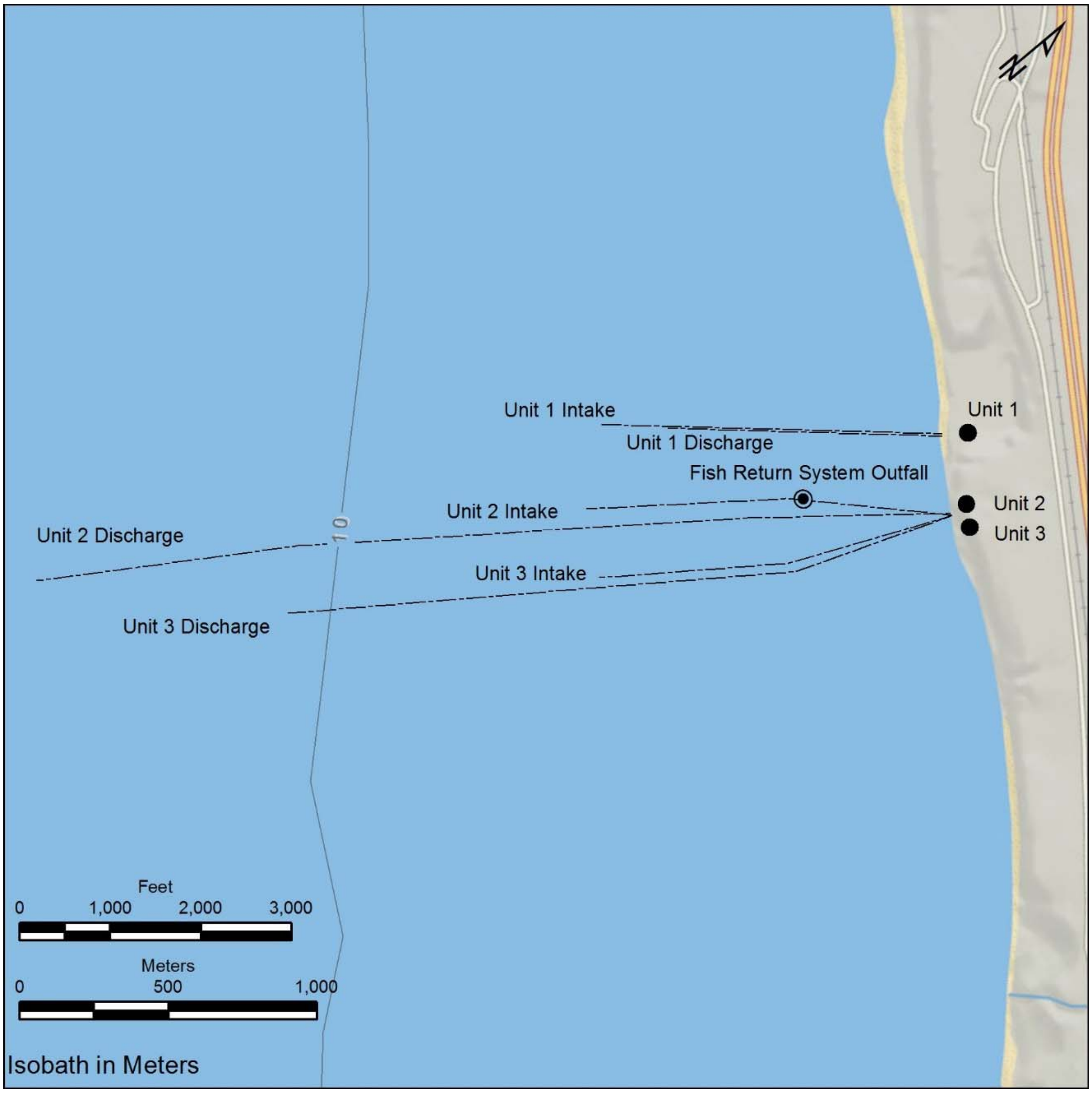


Figure 1-1. Location of Study Area. Isobaths in meters.

HISTORICAL BACKGROUND

A description of the generating station operational history and historical summaries of studies performed in past annual reports, including a chronological summary of major SCE marine ecological programs at San Onofre, are detailed in Appendices 1-1 through 1-3.

GENERATING STATION OPERATION - 2021

The following is a brief description of the plant operating characteristics during 2021. Intake and discharge design characteristics are presented in Table 1-1.

Unit 1

The unit was permanently shut down on November 30, 1992. Plant systems have been decommissioned. Flows from the sewage treatment plant are discharged through the Unit 2 outfall and are accounted for in the combined discharge.

Unit 2

The unit was permanently shut down on June 7, 2013 and is in the decommissioning process. The combined average discharge flow from January to December was <25.0 million gallons per day (MGD), with an annual daily average of 20.8 MGD. The flow was largely the result of the operation of saltwater dilution pumps from both Units 2 and 3 intake structures, with some flow coming from several in-plant wastes and Unit 1 sources. The discharge from the saltwater dilution pumps was in service for 358 days in 2021.

Unit 3

The unit was permanently shut down on June 7, 2013 and is in the decommissioning process. There was no discharge flow during the year; all dilution water flow was returned to the ocean via the Unit 2 discharge.

2021 RECEIVING WATER MONITORING PROGRAM

The 2021 Receiving Water Monitoring Program for Units 2 and 3 presented in this report contains the following sections and information:

- Oceanographic Conditions
- Kelp Density Study
- In-Plant Fish Assessment
- Fish Population Monitoring

Oceanographic conditions in the vicinity of SONGS, including temperature, dissolved oxygen (DO), and hydrogen ion concentration (pH), along with aerial photography of turbidity conditions, are documented and discussed in Chapter 2.

Table 1-1. Summary of circulating water system (CWS) design characteristics at San Onofre. Note: current flow rates and volumes at each unit are less than one percent of design values.

Units 2 and 3	
INTAKE	
Distance from shoreline*	970 m (3,183 feet [ft])
Flow rate	3,142.9 cubic meters/minute (m^3/min) (830,000 gallons/min [gpm])
Entrance velocity	0.5 meters/second (mps) (1.7 ft/second [fps])
Bottom material	Sand
Bottom profile	Mild slope
Cap dimensions	14.0 m (49 ft) diameter
Cap depth below MLLW	3.7 m (12.3 ft)
Cap height above bottom	5.4 m (17.8 ft)
Cap overhang from riser	2.2 m (7.3 ft)
Opening height	2.1 m (7 ft)
Rip-rap profile	Mounded, low relief
PIPES	
Offshore diameter	5.5 m (18 ft)
Velocity	2.2 mps (7.3 fps)
Length	
Intake	Unit 2 - 970 m (3,183 ft) Unit 3 - 970 m (3,183 ft)
Discharge	Unit 2 - 2,450 m (8,350 ft) Unit 3 - 1,835 m (6,020 ft)
Pump to condenser velocity	2.1 mps (6.9 fps)
Condenser to screenwell	2.1 mps (6.9 fps)
TRANSIT TIME	
Intake to screenwell	7.9 min
Screenwell to pump	1.5 min
Pump to condenser	0.6 min
Condenser to outfall	U2 - 18.5 min / U3 - 13.3 min
SCREENWELL	
Quiet areas	Yes
Flow pattern	Angled and uniform
Screen approach velocity	0.6 mps (2.0 fps)
Velocity through screen	1.0 mps (3.0 fps)
Screen number / type	7 - travelling (each)
Screen mesh opening	0.95 centimeter (cm) (3/8 inch [in.])
Trash bar opening	2.54 cm (1 in)

* Assuming a 45.7 m (150 ft) beach in front of the Units 2 and 3 seawall (the distance from the seawall to Mean Higher High Water (MHHW) = 15.2 m ± 15.2 m [50 ft ± 50 ft]; distance from seawall to Mean Lower Low Water (MLLW) = 61 m ± 30.5 m [200 ft ± 100 ft].

The Kelp Density Study consisted of fixed and random location samples, was performed between June and November and, with comparison and discussion of historical data, is presented in Chapter 3.

In-Plant Fish Assessment was not possible without circulating water pumps operating due to screen wash water-pressure requirements. No normal operation fish impingement surveys, nor heat treatments or “fish chase” fish returns prior to heat treatments, occurred during 2021. The fish return system was not operational at either unit as it requires operation of two circulating water pumps. A summary statement is presented in Chapter 4.

The Fish Population Monitoring section assesses the annual and long-term effects of the operation of SONGS in the marine environment around the plant; it is comprised of fish trawls over soft bottom habitat and is presented in Chapter 5.

The 2021 monitoring requirements and sampling dates for all offshore monitoring conducted for San Onofre are presented in Table 1-2.

Table 1-2. Data collection record indicating the months and days of sampling for studies conducted off San Onofre in 2021.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oceanographic Surveys												
Continuous Temperature Monitoring	← ------------Datalogger recorded on a quarter-hourly basis ------------ →											
Aerial Photographs of Turbidity	-	-	28	-	-	-	16-17	-	29	-	-	1/2/2022
Water Quality & Temperature Profiling	-	11	-	-	27	-	-	-	9	-	-	1
Biological Surveys												
Fish Otter Trawls	-	-	-	29	-	-	-		-	-	-	17
Kelp Density Study Fixed Areas Random Areas	-	-	-	-	-	18 18	-	-	8 -	-	19 19	-

LITERATURE CITED

SCE 1981. Physical and hydraulic description of Southern California Edison Company’s San Onofre Nuclear Generating Station cooling water system. Prepared by Lawler, Matusky, Skelly Engineers, Los Angeles, CA 76-RD-51.

Appendix 1-1. History of operations of the generating station.

SONGS Unit 1 began commercial operation in 1968 and stopped generation of electricity November 30, 1992. It was a baseload plant and was normally operated at full capacity. The operating capacity of Unit 1 was 436 megawatts (MW). As illustrated in Figure 1-1 and described in Table 1-1, seawater was drawn from a point 907.4 meters (m) (2,977 feet [ft]) offshore at a water depth of approximately 8.2 m (27 ft). This cooling water was discharged 750.4 m (2,462 ft) offshore in approximately 7.6 m (25 ft) of water. The seawater circulating system was removed from service in late 2006 when the conduits were sealed. The NPDES permit was subsequently terminated by the SDRWQCB on April 11, 2007.

SONGS Unit 2 began low-power testing in 1982, became commercially operational in August 1983, and stopped generation of electricity in January 2012. SONGS Unit 3 began start-up testing in 1982, became commercially operational in April 1984, and stopped generation of electricity in January 2012. Each of the units had an operating capacity of 1,100 MW. The once-through cooling water system for each unit had a flow rate of 3,142.9 cubic meters/minute (m^3/min) (830,000 gallons per minute [gpm]) and a normal operational temperature increase across the condensers of about 10.6ºC (19ºF). As seen in Figure 1-1 and described in Table 1-1, the intakes are located 970.2 m (3,183 ft) offshore in 9.8 m (32 ft) of water. Both units have diffuser type discharges consisting of 63 ports each spread over a distance of 750 m (2,462 ft). The Unit 2 diffuser begins 1,795 m (5,888 ft) offshore and ends 2,545 m (8,350 ft) offshore (measured from the screen well) and ranges in depth from 11.9 m (39 ft) to 14.9 m (49 ft) (SCE 1981). The Unit 3 diffuser begins 1,084 m (3,558 ft) offshore and extends to 1,835 m (6,020 ft) at its terminus, and ranges in depth from 9.8 m (32 ft) to 11.6 m (38 ft).

Appendix 1-2. Specific topics and years of San Onofre Annual Reports with a comprehensive review of those topics reported.

Topics	SCE Annual Report
<u>Oceanography</u>	
Currents	1981, 1973, 1969
Satellite Remote Sensing	1991, 1982, 1981
Sedimentology	1989, 1981, 1969
Temperature	1985, 1981, 1973, 1969
Turbidity	1993, 1991, 1990, 1986, 1981, 1973, 1969
Water Quality	1980, 1969
<u>Biology</u>	
Fish in the Receiving Waters	1992, 1981, 1973
Fish In-Plant	1982, 1973
Fisheries	1982, 1973
316(b) Demonstration	1988
Intertidal-Sand	1981, 1973, 1969
Intertidal-Cobble	1982, 1973, 1969
Kelp Canopy	1983, 1981, 1973, 1969
Kelp and Subtidal Cobble	1992, 1990, 1987, 1986, 1983, 1981, 1973, 1969
Plankton	1982, 1973, 1969
Subtidal Soft-Bottom	1981, 1973, 1969

Appendix 1-3. Major Southern California Edison Marine Ecological Programs conducted from 1964 to present.

Program and Study Elements	Dates Program and Study Elements were in Effect
Marine Environmental Monitoring (MEM) Oceanography - bimonthly temperature, turbidity, currents, and water quality Biological - plankton, benthos, and intertidal	1964 - June 1977
Environmental Technical Specifications (ETS) - National Pollutant Discharge Elimination System (NPDES) Oceanography - bimonthly temperature, turbidity, water quality, and continuous temperature Biological - plankton, hard benthos, kelp, gill netting, and impingement	December 1975 - March 1982[1]
Sand Disposal Study (SDS) Kelp, Intertidal and subtidal infauna, and hard benthos	June 1975 - June 1976
Construction Monitoring Program (CMP) Sedimentology, kelp, infauna (intertidal and subtidal), and intertidal special study	Dec 1976 - Dec 1979 Dec 1984 - 1987[2]
Preoperational Monitoring Program (PMP) Oceanography - bimonthly temperature, turbidity, water quality and continuous temperature Biological - plankton, hard benthos, gill netting, trawling, kelp, and special ichthyoplankton study (78-mid 79)	June 1978 – June 1981
316(b) Program[3] Biological - monthly larval entrainment and transit loss determination (1979, 1980); evaluation of fish return system	March 1978 - 1986; 2006-2007
Interim Studies – NPDES Oceanography - continuous temperature and aerial turbidity photographs Biological - trawling, fish impingement and kelp studies	September 1979 - March 1983
Operational Program – NPDES Oceanography - continuous temperature and aerial turbidity photographs Biological – trawling, fish impingement*, and kelp studies (impingement became visual observation only when circulator pumps were turned off due to flow requirements for screenwash operations)	June 1983 - Present

1 Although the ETS was terminated at the end of 1980, NPDES requirements continued through 1981, then were suspended after January 1982, as Unit 1 was offline. The program was replaced in June 1982 by the Interim Program.

2 Some observational aspects of the earlier CMP were continued in the Interim and Operational Programs to provide a useful time series of information on the continued health of the kelp bed and intertidal areas. Additional CMP studies began in December 1984 with removal of the retaining wall for the construction lay-down pad.

3 The report for the 316(b) study for Unit 1 was submitted to the San Diego Regional Water Quality Control Board (SDRWQCB) on April 30, 1982. The 316(b) study for Units 2 and 3 was submitted to the SDRWQCB as part of the 1988 Annual Report (SCE 1988, Chapter 10). An updated 316(b) study for Units 2 and 3 was completed and submitted to the SDRWQCB in 2008.

CHAPTER 2 OCEANOGRAPHIC PROCESSES AND WATER QUALITY

INTRODUCTION

The purpose of the offshore monitoring program is to assess the effect of operations by SONGS on the marine environment. This monitoring is part of an ongoing program that has been underway for more than forty years. A historical overview of the temperature, water quality, and turbidity programs is shown in Appendices 2-1 through 2-3. The oceanographic and water quality monitoring programs have provided data for analysis of the potential impact on the marine environment in the vicinity of SONGS. These oceanographic and water quality studies meet the objectives and requirements of the NPDES permit. In 2021, both Units 2 and 3 were in the decommissioning process.

This chapter summarizes the 2021 oceanographic data and the water quality studies in order to demonstrate compliance with the NPDES permit. This summary includes:

1. Continuous measurements of water temperature with *in-situ* instruments at three stations.
2. Quarterly cruises to obtain water temperature profiles at 29 receiving water stations near SONGS.
3. Quarterly surface measurements of DO concentrations and pH at 10 stations.

METHODS

DATA COLLECTION PROGRAM

Continuous temperature monitoring

Water temperature measurements were recorded at 15-minute intervals at three stations as required in the SONGS Units 2 and 3 NPDES permit. Figure 2-1 illustrates the locations of SONGS and the sampling stations. Station C2S, located 610 m downcoast from the former Unit 1 discharge conduit (the designated "zero line" reference point for all offshore monitoring), is in water that is 9 m deep relative to mean lower low water (MLLW); Station F2S, located within the San Onofre Kelp Forest (SOK), 760 m downcoast of the zero line (and 600 m downcoast of the Unit 2 discharge), is at a depth of 14 m; and the reference location, Station C22S, is 6,710 m downcoast from the Unit 1 discharge in water that is 9 m deep. Temperature was recorded at three depths at Stations C2S and C22S by sensors located near surface, at mid-depth (4 m below the sea surface), and near bottom. Temperatures at Station F2S were recorded at four depths: near surface, two at mid-depths (4 m and 10 m below the sea surface), and near bottom. Stations C2S and F2S were positioned to determine if the plant discharge had an impact on ambient ocean temperatures. Station C22S, located outside of the area of potential influence of the discharges, was designated as a reference station.

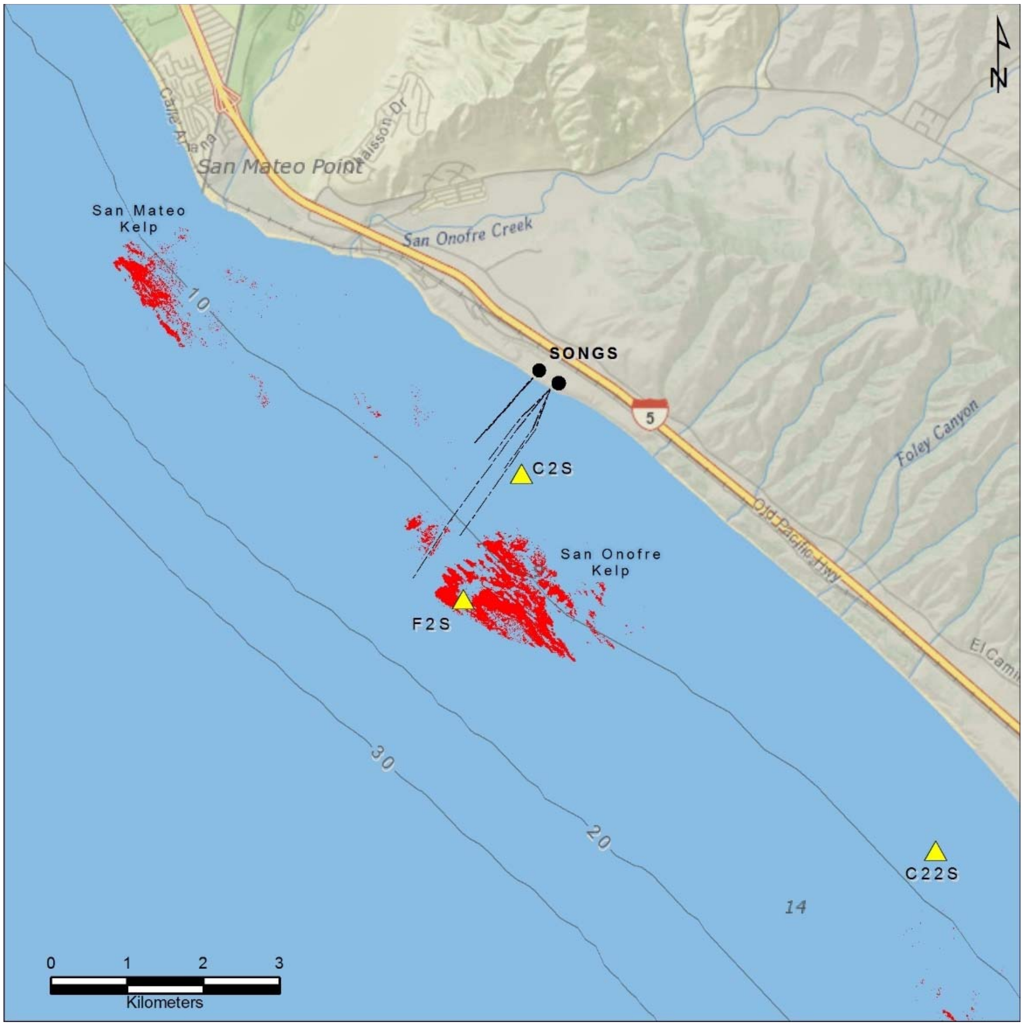


Figure 2-1. Locations of continuous temperature monitoring Stations C2S, F2S, and C22S offshore San Onofre.

The *in-situ* monitoring of water temperature was attained using "HOBO Water Temp Pro®" underwater data loggers manufactured by Onset Computer Corporation with water temperature measurements programmed to record every 15 minutes. Two data loggers were placed at each depth at each station, with overlapping retrieval schedules to assure a high level of data return. Monitoring arrays were serviced monthly and individual data logger units rotated approximately every eight weeks. On retrieval, data recorded by each logger were uploaded to a computer and saved to a Microsoft Office Excel spreadsheet that ordinated all temperature data by date and sampling times for each station and depth.

Monthly data files were subjected to detailed inspection before proceeding with the database update. The inspection procedure included graphing the quarter-hourly temperatures to enable detection of inconsistent or outlier data. If such data were found, the data point(s) were evaluated for inclusion in temperature analysis. If the data were determined to be anomalous by this process, they were removed from the data series prior to analysis. If data from both side-by-side deployed thermistors were accepted, the values utilized for further processing were an average of both results. Final processing included averaging of daily data, and these average values were included in this report. All data, including anomalous data (marked), were included in the raw data files.

In 2021, the F2S spar sank on March 21 and was replaced on April 28. Both surface thermistors were lost, and F2S-4 and F2S-10 were found on the bottom; data was lost at all three depths during this time. Daily temperature averages are provided in the electronic data appendix.

Temperature profiles and water quality monitoring

A total of 29 stations near SONGS were surveyed each quarter to obtain water column temperature profiles (Figure 2-2). The station coordinates are presented in Appendix 2-4. Ten of these stations are designated as water quality monitoring stations where surface measurements of DO and pH were additionally taken. Quarterly cruises were conducted on February 11, May 27, September 9, and December 1, 2021. Temperature profiles and water quality measurements corresponding to the four quarterly cruises conducted in 2021 are documented in this report.

Locations for the stations are based on the zero-line reference, with stations arranged in a grid pattern upcoast (N) and downcoast (S) of the zero line (Figure 2-2). Numerical designations are related to historic onshore-offshore monitoring transect locations upcoast (1, 2, 4 and 8) and downcoast (1, 2, 4, 8 and 22). Stations of approximately similar depth are designated by the same initial letter: C = 10 m, F = 12 m, H = 15 m, J = 20 m, and M = 25 m. Using this system, Station F2N represents the second transect line upcoast of the zero line at 12-m depth. The line of stations farthest downcoast—Stations C22S, F22S, H22S, J22S, and M22S—are the designated reference stations. These stations are 6,706 m downcoast of the zero line to provide a reference station for each depth.

During each quarterly cruise, depth, temperature, DO, pH, and light transmittance were recorded continuously by a Sea-Bird Scientific® Water Quality Monitoring Profiler (SBE 19*plus* V2 or 25) as it was lowered through the water column. The profiler stores water quality data in internal memory for later download and analysis. Data were downloaded from the instrument to a laptop computer in the field and checked for anomalous readings using proprietary software (Seasave-v7.26). If necessary, based on field review, stations were re-sampled. After data collection, vertical water quality profiles were created in Microsoft Office Excel. The profiles provided information about the distribution of temperature, DO, and pH through the water column, and allowed comparisons among stations throughout the sampling array. To assist with seasonal comparisons, false-color contour images depicting surface water temperatures during each quarterly cruise were created using ArcGIS Pro 2.8. Quarterly data tables and water column profiles for each station are presented in the electronic data appendix; the parameters reported include temperature, DO, and pH. Additional parameters recorded and reported in the data appendices are light transmission, salinity, and chlorophyll-a.

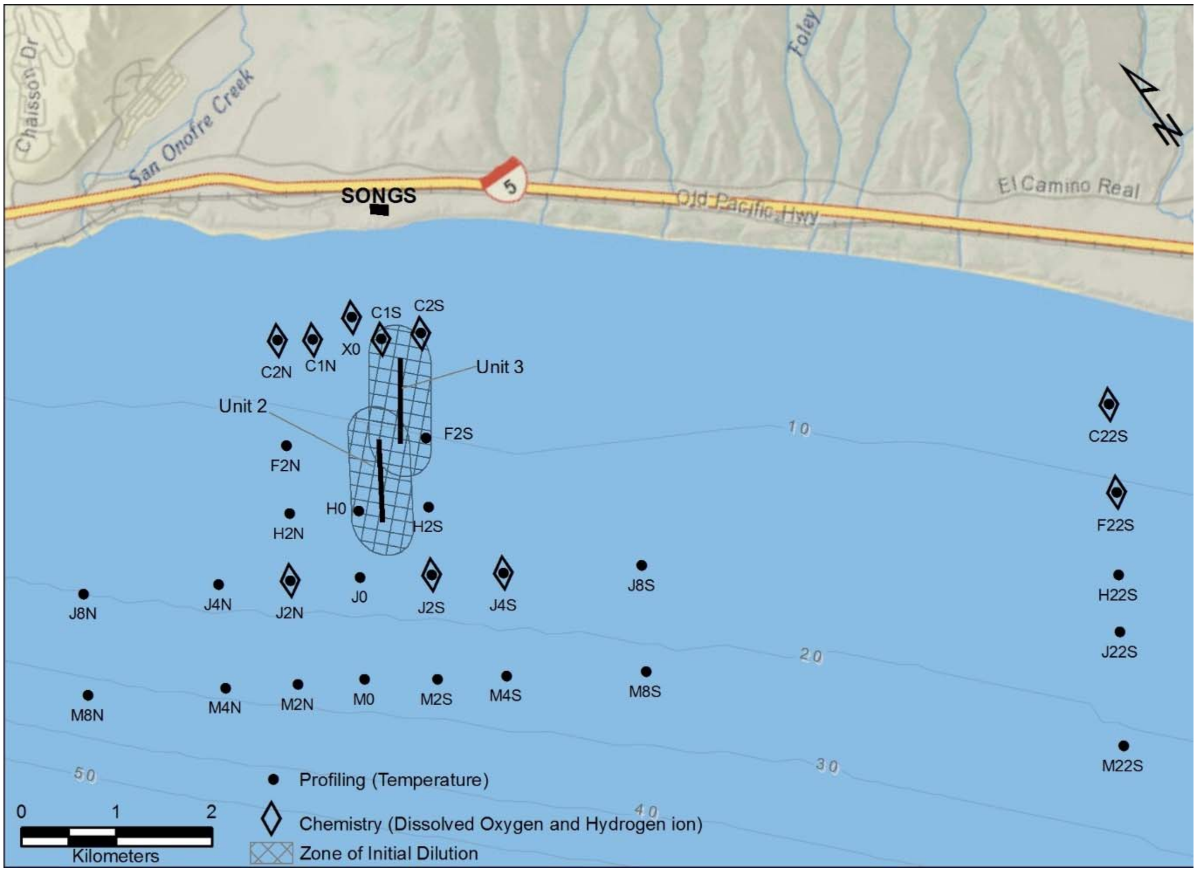


Figure 2-2. Locations of temperature and water quality profiles offshore San Onofre.

RESULTS AND DISCUSSION

OCEAN TEMPERATURE

Ocean temperature near SONGS has been monitored to evaluate the potential impact of waste heat introduced into the ocean by the operation of the power plant; since SONGS was shut down in 2013 no waste heat has been generated, but monitoring has continued per the NPDES permit. To accomplish this local ocean temperatures are measured and regional temperature databases provide background for analysis and interpretation and to relate the 2021 measurements to long-term monitoring data and regional historical data.

To understand water temperature variability at San Onofre, information about processes that take place over large spatial and temporal scales is needed. The main physical oceanographic factors that control temperature structure in the Southern California Bight are seasonal water density stratification, seasonal wind regimes, and major oceanic anomalies such as El Niño and La Niña events, broadly discussed as El Niño Southern Oscillation (ENSO).

In the nearshore environment, regional winds may produce upwelling or downwelling events that fill the coastal shelf region with relatively cold or warm water, respectively (Sverdrup et al. 2003). These events have time scales of a few days. Upwelling occurs most frequently during spring and summer when northerly winds are common, and is a principle means by which nutrients are brought into shallow nearshore waters. When southerly winds blow, water tends to accumulate near the shore, forcing the warmer surface water down and depriving the nearshore water of nutrients. This type of water movement is known as downwelling.

2021 West Coast and Southern California Bight Surface Temperature

Figures 2-3 (January to June) and 2-4 (July to December) show large-scale spatial and temporal distribution of surface water temperature anomalies in the northeastern Pacific Ocean, including the coast of California, during 2021. Images were created from data abstracted from the National Oceanic and Atmospheric Administration (NOAA) CoastWatch ERDDAP Browser using the Multi-scale Ultra-high Resolution (MUR) sea surface temperature (SST) Analysis Anomaly fv04.1, Global, 0.01°, 2002-present, monthly dataset (NOAA 2022).

Sea surface temperature conditions in the San Diego region were 0.5 – 1.0°C above the 19-year monthly average temperature in December 2020 (not shown) and remained at about 0.5°C warmer than average through mid-January. From mid-January through June nearshore water temperatures returned to near-average conditions (Figure 2-3). In July, a period of nearshore warming occurred along the coastline, about +0.5 – 1.0°C, with oceanic offshore waters greater than 2.0°C warmer than the long-term average. In September, temperatures were still slightly above average, and returned to near-average conditions through the end of the year. Slightly cooler-than-average temperatures persisted in the north Pacific at the end of 2021.

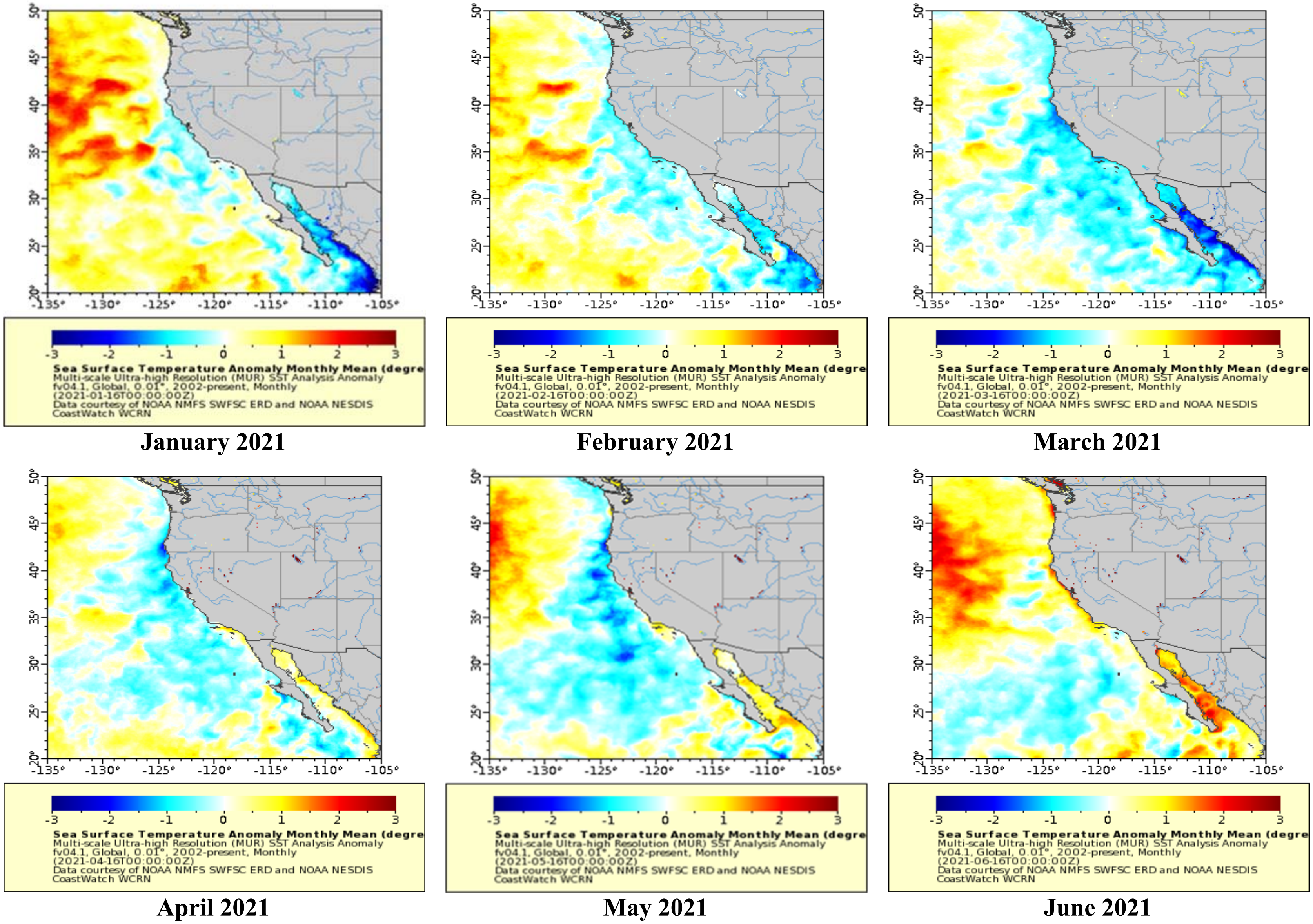


Figure 2-3. Coastal ocean mean sea surface temperature (SST °C) deviations from normal, January through June 2021. NOAA Coast Watch, MUR Analysis SST Anomalies.

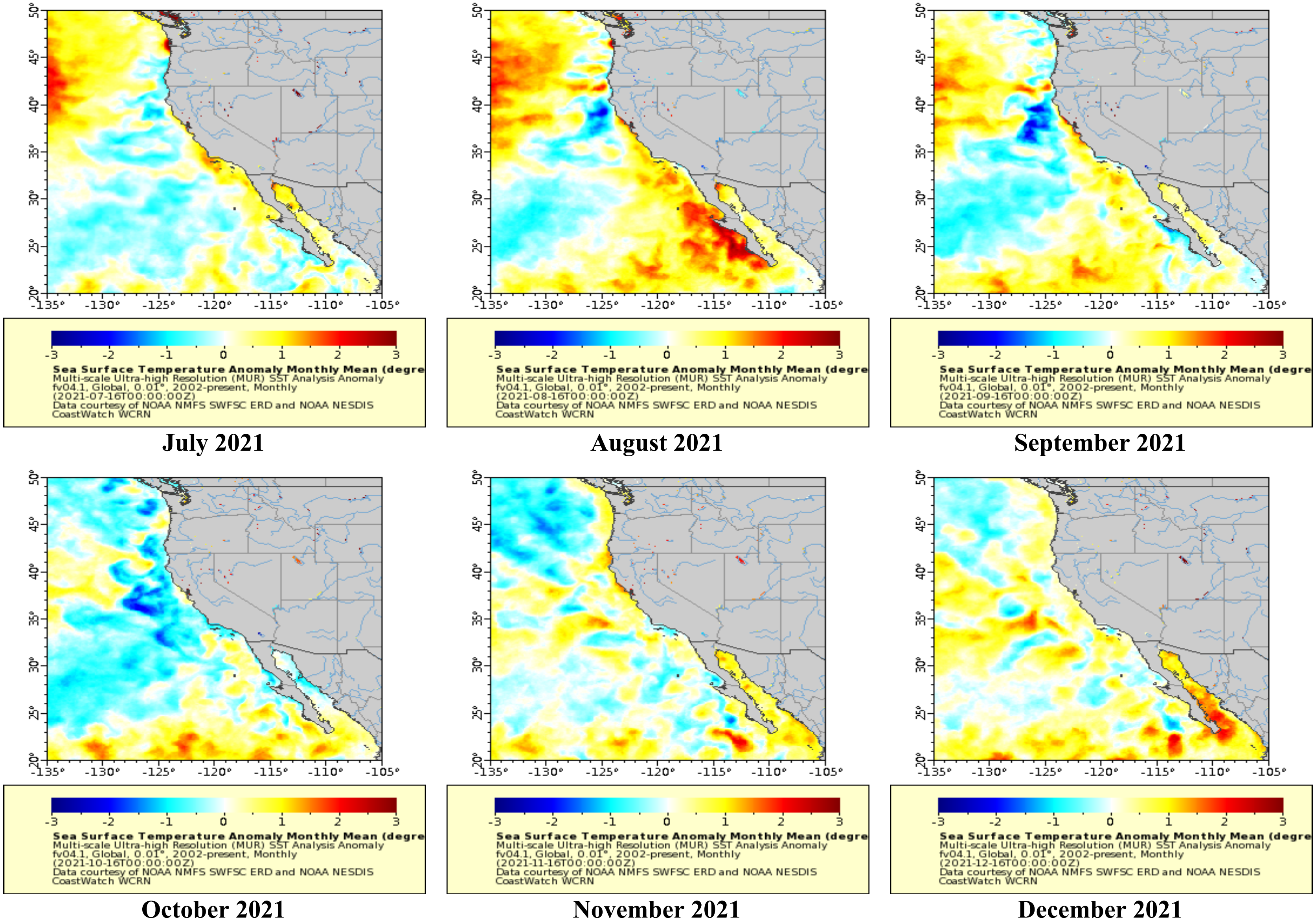


Figure 2-4. Coastal mean sea surface temperature (SST °C) deviations from normal, July through December 2021. NOAA Coast Watch, MUR Analysis SST Anomalies.

Figure 2-5 shows the Pacific SST conditions during October 2021 illustrating below-average SST anomalies along the equatorial Pacific that were present through most of 2021 (NOAA 2022). At the beginning of the year, weak La Niña conditions were present at the equator; conditions changed in May with colder temperature anomalies from 0.5°C below average developing along the equator and increasing in area and intensity to 2.0°C below average by November. Figure 2-5 shows equatorial conditions in October 2021, as well as the SST anomalies that were warmer than normal in the North Pacific. The mild La Niña conditions forecast in early 2021 developed fully by year's end. An ENSO-neutral condition is forecast for spring 2022.

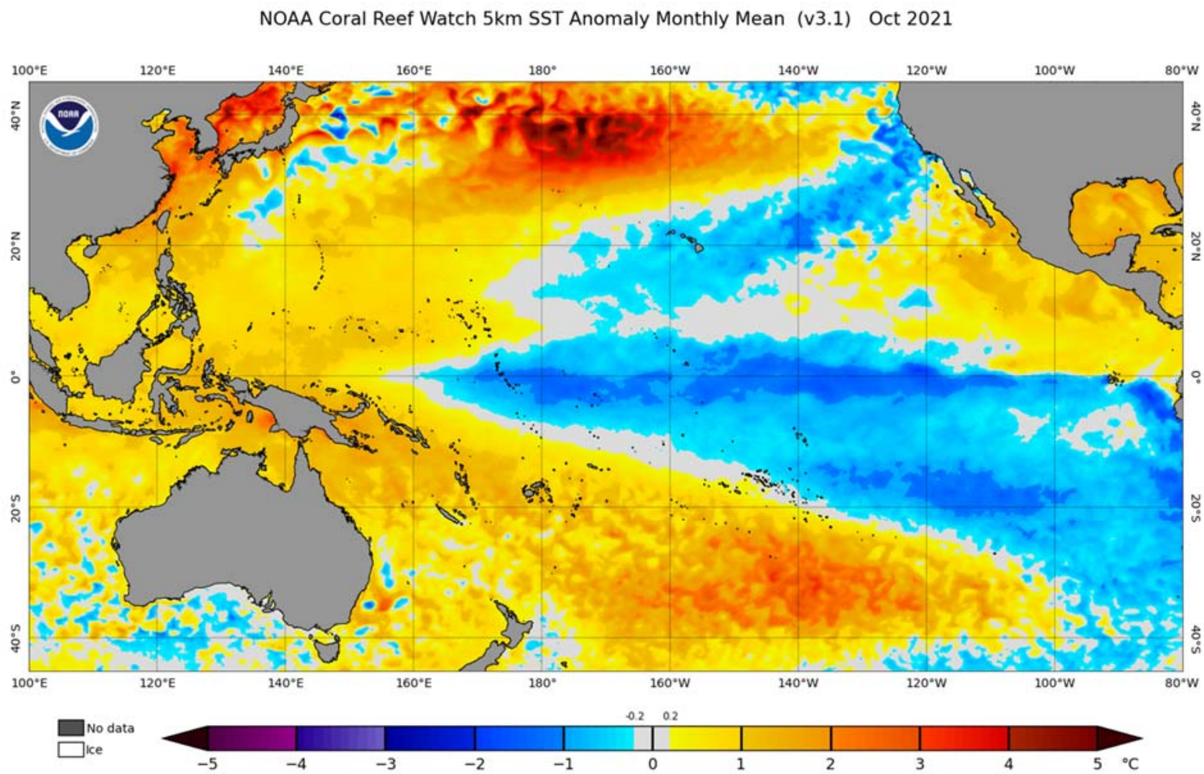


Figure 2-5. Pacific Sea Surface Temperature Anomalies for October 2021 showing below average temperature conditions along the central-Pacific Equatorial Region and the nearshore temperatures along the southern California coast of the United States.

2021 San Onofre Temperature

Daily mean surface and bottom water temperatures at continuous temperature monitoring Stations C22S, C2S, and F2S are provided in Figures 2-6 through 2-8. In 2021, there were 9 periods (depicted in Figure 2-6) with conspicuous, short-term surface water temperature decreases of 1.5°C to 7.0°C. These decreases occurred in January, March through June, and August through October (Figure 2-6). The greatest temperature decreases occurred in August and were associated with offshore coastal winds that resulted in unusually strong upwelling indices (NOAA-PFEG 2022). Warmest bottom water temperatures were generally recorded at Station C2S while coolest bottom water temperatures were recorded at Station F2S, the deepest station, located offshore of Station C2S. Seasonal means of daily water temperatures at Stations C22S, C2S, and F2S for the differing depths are provided in Table 2-1. Average daily surface temperatures were highest in spring and summer at Station C22S and Station F2S. The bottom temperatures were cooler during all four seasons at Station C22S compared to those at C2S (at the same depth), while coolest bottom temperatures overall were recorded at Station F2S due to the deeper depth. Analysis of the 2021 SONGS water temperatures indicates the mean seasonal surface temperatures at the three continuous monitoring stations were similar, differing by 0.1°C during the winter, 0.4°C in spring, 0.3°C in summer, and by about 0.2°C in fall. Comparing mean surface temperatures in 2021 to those from 2020, 2021 was cooler at all stations in winter and spring by about 1.3°C and 0.1°C on average, respectively, and cooler in summer and fall both by 0.7°C on average (SCE 2021). The highest and lowest average daily surface water temperatures were recorded at Station C22S, 23.42°C in summer (July) and 13.08°C in Winter (March) (Figure 2-6).

Table 2-1 also shows the long-term, 33-year seasonal mean of daily water temperatures recorded during the ongoing monitoring program. Temperatures were lower than the long-term means at all stations and depths in winter, summer, and fall, and warmer in spring. Average seasonal temperatures in 2021, for all stations and depths each season, ranged from 1.5°C cooler in summer to 0.8°C warmer in spring than the long-term seasonal means. Overall, average water temperatures for all stations and depths in 2021 were about 0.5°C cooler than the 33-year mean value. Values recorded at all depths at the three continuous monitoring stations were within the range of water temperatures previously reported in the study area (SCE 1990-2021).

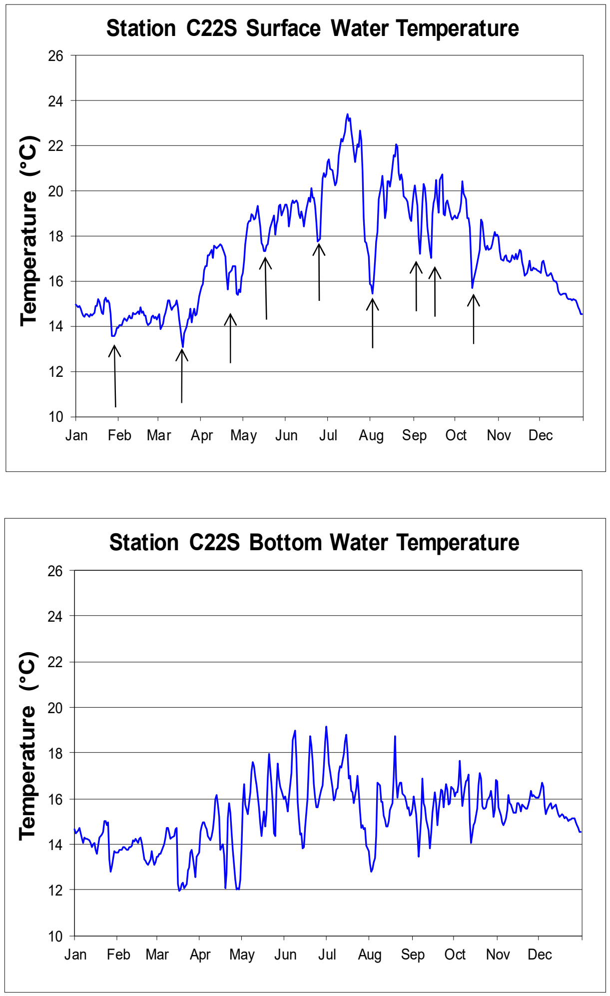


Figure 2-6. Daily mean surface and bottom water temperatures at Station C22S for 2021. Short-term temperature decreases are marked with arrows.

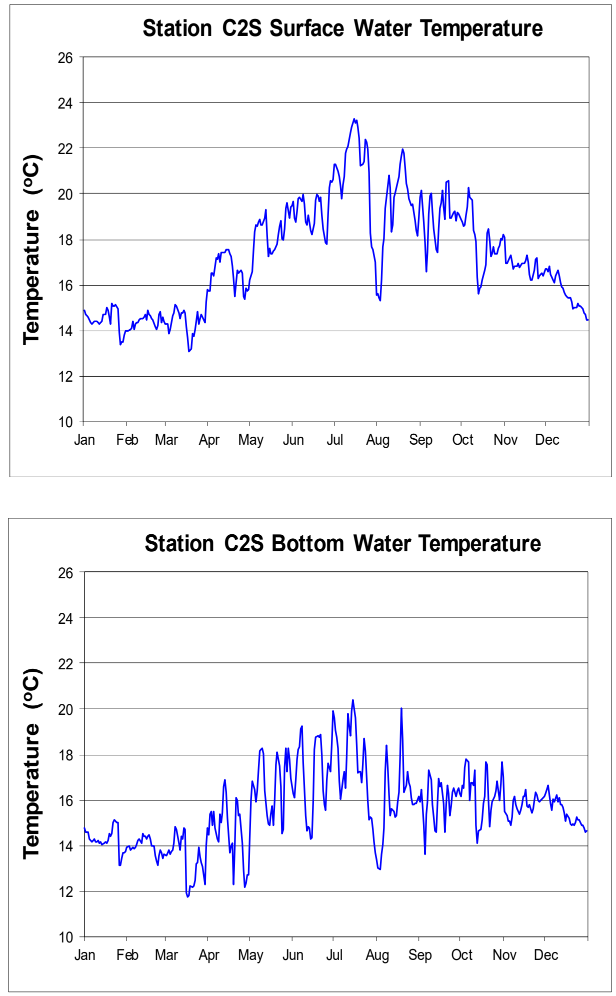


Figure 2-7. Daily mean surface and bottom water temperatures at Station C2S for 2021.

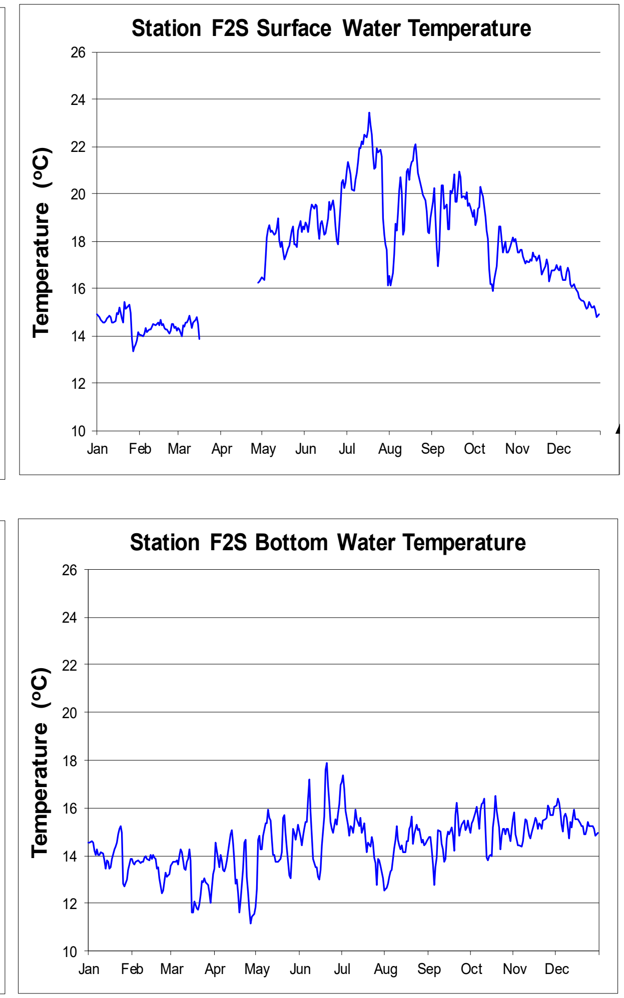


Figure 2-8. Daily mean surface and bottom water temperatures at Station F2S for 2021. (Surface data gap see text in continuous temperature monitoring section above).

Table 2-1. Summary of seasonal (= quarters) means of daily temperatures (°C) for 2021.

Station	Depth (m)	Year(s)	Winter	Spring	Summer	Fall
C22S	0	2021	14.50	18.13	19.95	16.86
		1989-2021	15.15	17.87	20.59	17.41
	4	2021	14.29	17.45	18.57	16.59
		1989-2021	14.94	17.21	19.46	17.17
	10	2021	13.79	15.55	15.87	15.70
		1989-2021	14.42	15.19	16.74	16.36
C2S	0	2021	14.43	18.06	19.79	16.77
		1989-2021	15.19	17.94	20.54	17.42
	4	2021	14.23	17.45	18.58	16.49
		1989-2021	14.97	17.28	19.59	17.15
	10	2021	13.88	16.09	16.45	15.85
		1989-2021	14.59	15.82	17.37	16.57
F2S	0	2021	14.47	18.46	20.07	16.99
		1989-2021	15.50	17.71	20.52	17.62
	4	2021	14.30	17.96	18.94	16.77
		1989-2021	15.18	17.27	19.69	17.44
	10	2021	13.83	15.92	15.72	15.78
		1989-2021	14.68	15.57	17.18	16.66
	14	2021	13.56	14.36	14.65	15.28
		1989-2021	14.29	14.08	15.57	16.03

Red values are the higher of the 2021 or the 1989-2021 long-term value for each depth/season.

To examine similarities between the reference and impact stations, computed correlation coefficients of the daily mean surface and bottom temperatures between the three stations are provided in Table 2-2. The correlation coefficient is a measure of the strength of the straight-line or linear relationship between two variables; it takes on values ranging between +1 and -1, with values between 0.8 and 1.0 indicate a strong positive linear relationship via a firm linear rule. Comparisons of the surface temperatures between stations indicate the highest level of correlation (1.0). Comparisons of bottom temperatures between stations show that the best correlation (0.96) was between the reference (Station C22S) and the SONGS station at similar depth (Station C2S), with the lowest correlation of 0.81 between the shallow and deep SONGS stations (Stations C2S and F2S, respectively).

Table 2-2. Correlation coefficients for daily mean temperatures for 2021.

Depth	C22S and C2S	C22S and F2S	C2S and F2S
Surface	1.00	0.88	0.88
Bottom	0.96	0.88	0.81

Comparison of 2021 Temperature with Regional Historical Data

Daily morning surface water temperature measurements from Stations C22S, C2S, and F2S recorded during 2021 were compared with regional daily temperature measurements averaged over a 66-year period between 1955 and 2020 (Dana Point from 1955 to 1965 and then from the San Clemente Pier 1965 to 2020; SIO 2021) (Figure 2-9). This data set provides a long-term regional mean to compare to daily temperatures recorded during the monitoring year. At all three stations, surface water temperatures were cooler than the regional mean for about seven months of the year and warmer than the regional mean for about five months.

In 2021, the surface temperature patterns at all three stations were very similar. For the first four weeks of the year temperatures were comparable to the regional mean at all three stations (Figure 2-9). In February 2021 surface temperatures at all stations fell below the regional mean during an upwelling event until late-April when surface temperatures oscillated above and below the mean through mid-July when another upwelling event resulted in temperatures dropping 6°C during a one-week span. All station temperatures rose above the regional mean in the beginning of August before dropping below the regional mean and generally remained below the regional mean through mid-November. Starting in mid-November, temperatures for all three stations oscillated around the regional mean for two weeks and then generally remained within 1.0°C of the regional mean, with slight variations among the three stations.

Overall, average surface water temperatures for all stations in 2021 were 0.2°C warmer than the long-term mean values. Surface water temperatures in 2021 fluctuated from –5.9° to +3.5°C around the long-term mean values. In 2021 maximum SSTs were recorded in July, the same month the regional mean peaked.

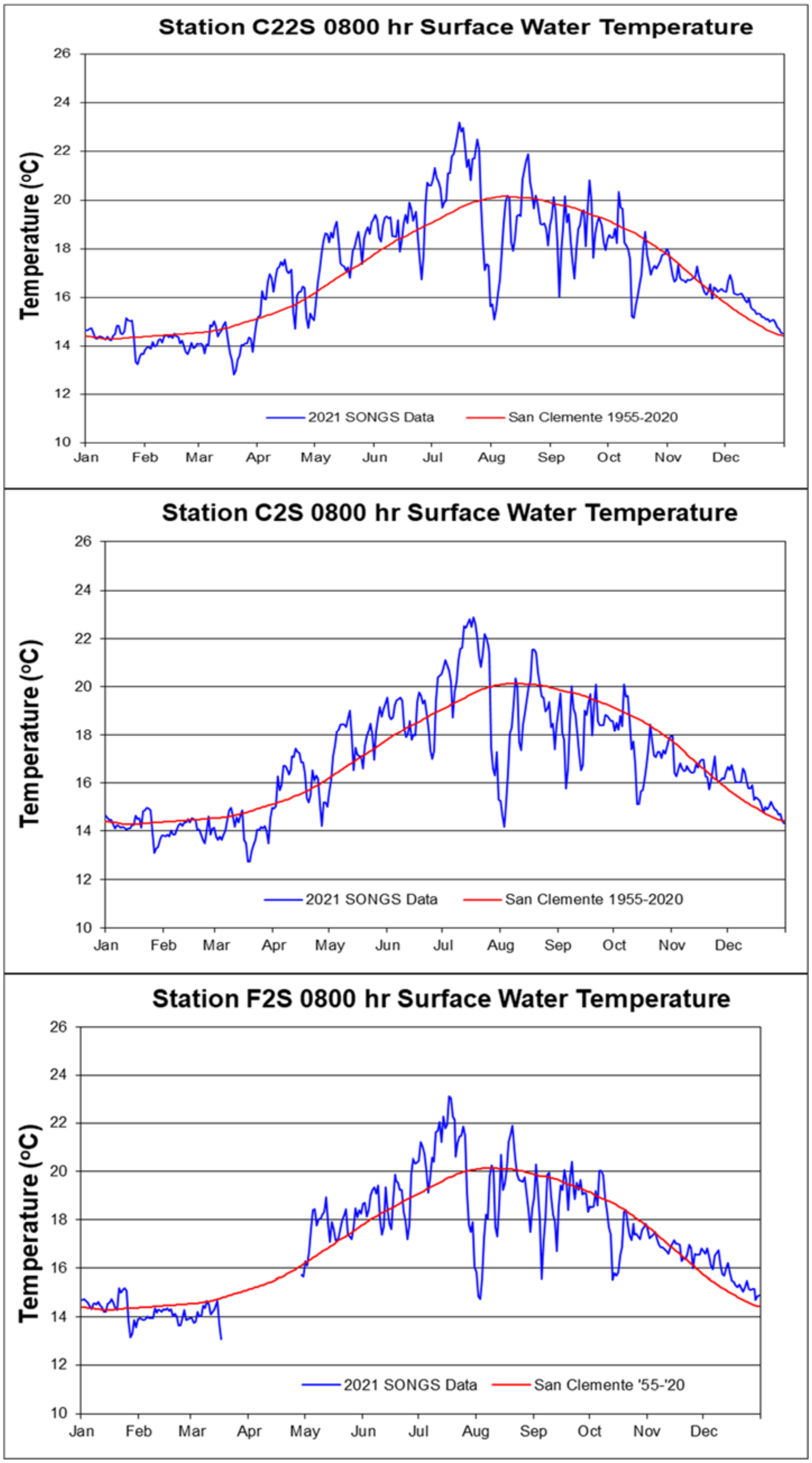


Figure 2-9. **Comparison of daily surface temperatures during 2021 at San Onofre with daily regional surface temperatures from the San Clemente area from 1955-2020 (SIO 2021).**

Vertical Temperature Distribution

Density stratification and turbulence are the main factors that determine vertical mixing rates in the nearshore waters. Density stratification due to solar heating of the water column, influxes of warm water from downwelling periods, and cool water from upwelling events inhibit vertical turbulence. Turbulence is generated by wind stress on the sea surface and by bottom stress due to currents. At Stations C22S and C2S, storm-related wave turbulence in winter results in a nearshore water column that is usually well mixed, with minor differences between surface and bottom temperatures (Table 2-3). With increased depth, however, the impact of such vertical mixing decreases, resulting in greater surface-to-bottom differences in water temperatures at Station F2S in winter and spring than found closer to shore. In 2021, temperature differences from surface to bottom at Station F2S were greater during all four seasons than those at Stations C22S and C2S, which is expected because of the greater depth at Station F2S. Stations C22S and C2S are at the same depths, and compared to Station F2S, surface-to-bottom temperature differences were more similar at Station C2S and Station C22S during all seasons, although Station C22S had a larger gradient during all four seasons.

Table 2-3. Seasonal surface-to-bottom temperature differences (°C) in 2021.

Station	Year(s)	Winter	Spring	Summer	Fall
C22S	2021	0.71	2.58	4.08	1.16
	1989-2021	0.73	2.68	3.85	1.05
C2S	2021	0.55	1.97	3.34	0.92
	1989-2021	0.59	2.13	3.18	0.85
F2S	2021	0.91	4.10	5.42	1.71
	1989-2021	1.21	3.63	4.95	1.60

Red values are the highest difference for each season.

In the past, overall similarities in surface and bottom temperatures at Station C2S were attributed to the proximity of the Unit 3 diffuser line, which, when operating, promoted mixing through the water column throughout the year resulting in reduced surface-to-bottom thermal differences compared to the other stations. In 2021, Station C2S surface-to-bottom differences were again lower during all seasons than those of Station C22S, although flow at the Unit 3 diffusers has been terminated. The surface-to-bottom temperature differences were lower than the long-term mean values at all three stations during winter and differences were greater than the means at all three stations during summer and fall at Station C2S and reference site, C22S.

The vertical temperature gradients for Stations C22S, C2S, and F2S are shown in Figure 2-10. Each temperature gradient was computed as the difference between the surface and bottom temperatures, divided by the water depth of the station in meters (Δ °C/m). These figures show the seasonal pattern of thermal stratification typical of the coast of California. With lower solar radiation and more surface mixing in the winter and fall, the thermal gradient diminishes. As solar radiation increases and the winter storms subside, the thermal gradient intensifies in summer. In 2021, temperature gradients were weakest, generally less than 0.1°C/m, from January through March and in December. Strongest gradients were recorded from May through August, although gradients decreased to near zero during upwelling events at Stations C2S and C22S. Station F2S gradients were much less variable then at the other two stations and remained greater than 0.2°C/m from May through August. The maximum gradient was slightly more than 0.7°C/m at both Stations C2S and C22S in August, and slightly lower than 0.6°C/m at Station F2S in both July and August.

Spatial Temperature Trends

To determine spatial temperature trends near SONGS, mean daily surface temperatures for the year were compared between the reference (Station C22S) and the two stations offshore of SONGS (Stations C2S and F2S) (Figure 2-11). Throughout the year, daily mean surface water temperature averaged about 0.1°C cooler at Station C2S than at the reference station. Station C2S was cooler than Station C22S for slightly more than eight months. Temperatures generally varied by less than ±0.2°C throughout the year; the greatest difference between the stations, +0.7°C, occurred in November. Similarly, the seasonal means were 0.1°C cooler at Station C2S than Station C22S during each season (Table 2-1). Daily mean surface water temperature differences between Station F2S and Station C22S, although variable, were the same on average over the one-year period. Temperatures at Station F2S were slightly cooler than those at Station C22S for just over five months of the year. Temperatures generally varied by less than ±0.3°C throughout the year. The largest difference in surface temperature between the stations (1.5°C) occurred in September (Figure 2-11). Seasonal means varied about -0.2°C to +0.3°C between Station F2S and Station C22S, with Station F2S cooler during winter and spring and warmer during summer and fall (Table 2-1).

The relationship between bottom temperatures at the SONGS impact stations and reference station was quite different from that at the surface, with Station C2S warmer, and Station F2S cooler, than Station C22S for most of the year (Figure 2-12). At Station C2S, bottom water temperatures averaged about 0.3°C warmer than at Station C22S, with the largest difference of 2.4°C occurring in July. The seasonal mean bottom temperatures were warmer at Station C2S than Station C22S by less than 0.1°C in winter, 0.5°C in spring, 0.6°C in summer, and 0.2°C in fall (Table 2-1). At Station F2S, which is deeper than the other two stations, bottom water temperatures averaged 0.8°C cooler than at Station C22S for the year with the greatest difference of 3.8°C cooler in July. The seasonal mean bottom temperatures indicate that Station F2S was cooler than Station C22S in all seasons, with differentials varying about 0.2°C in winter to 1.2°C in summer (Table 2-1). Bottom temperature differences were highly variable among the stations throughout the year, with temperature oscillations ranging less than 1.0°C (January to March and December) to 0.6°C to 1.2°C between April and November.

Temperature Profiles at Fixed Monitoring Stations

Temperature near SONGS could be affected by the operation of the facility; although without steam generation, once through water flow is only for dilution purposes with no temperature increase. The fixed-station monitoring program was designed to sample a total of 29 receiving water stations near SONGS (Figure 2-2) to determine the extent of any thermal plume. False-color contour images depicting SSTs recorded during the four quarterly cruises are shown in Figure 2-13. As expected, no thermal plumes near the discharges were apparent during any of the four quarters. Water column profiles for each station are shown in the electronic data appendices for each survey (Data Appendices WQ-1 to WQ-4).

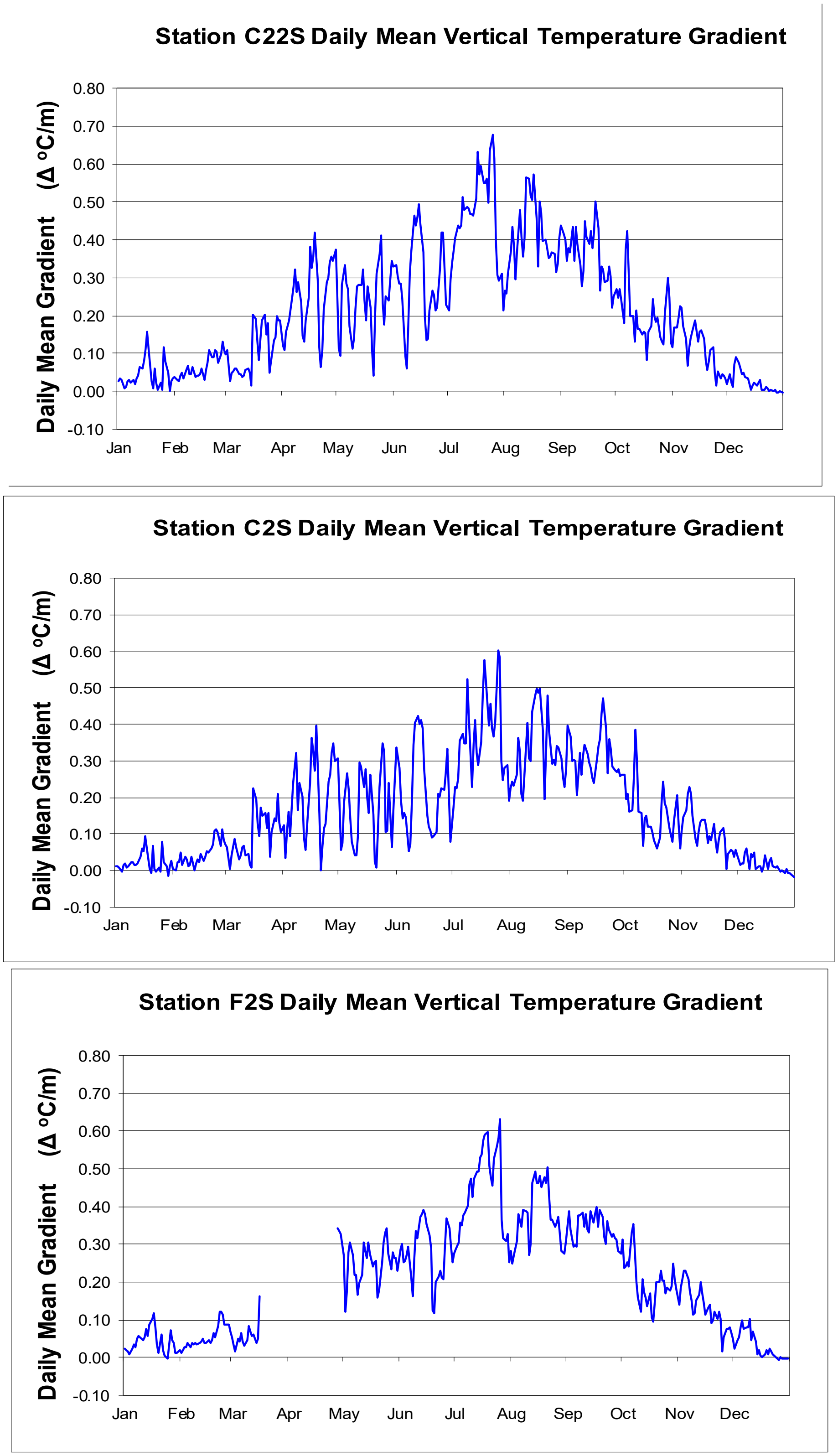


Figure 2-10. Daily mean vertical temperature gradients at Stations C22S, C2S, and F2S for 2021.

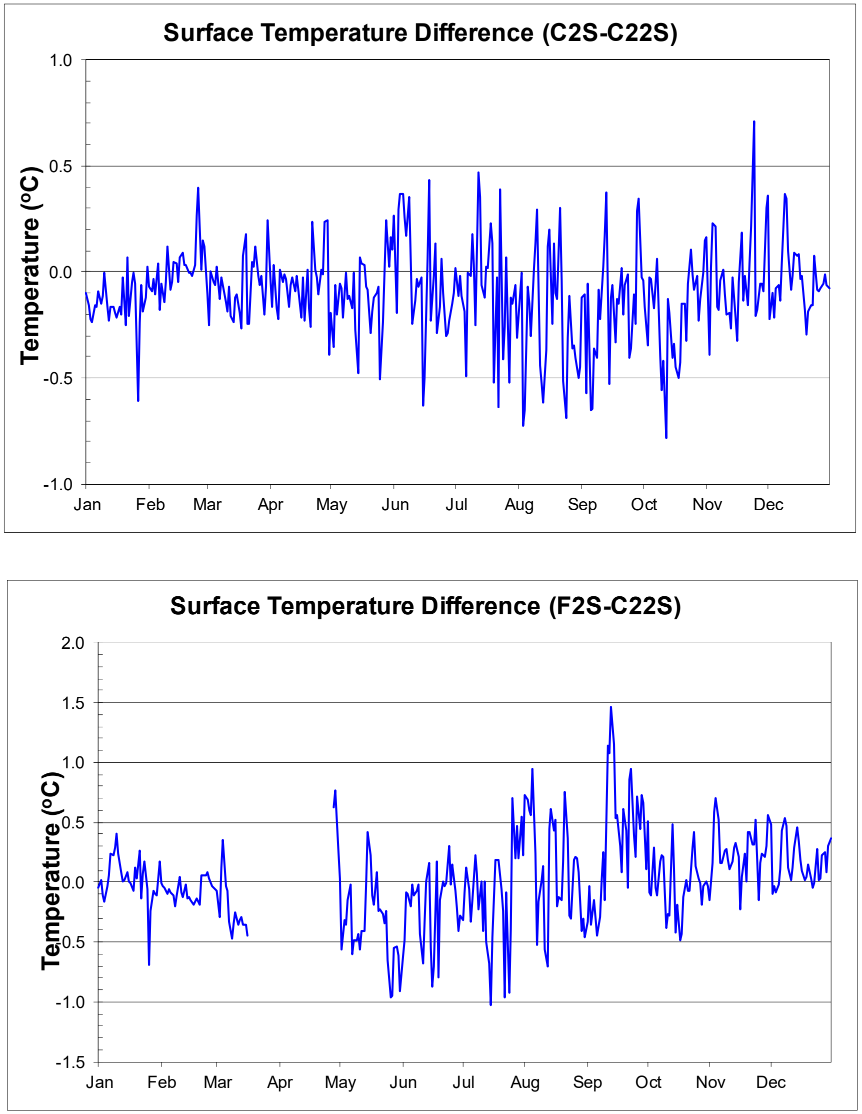


Figure 2-11. Daily mean surface temperature differences between the reference Station (C22S) and the impact Stations (C2S and F2S) for 2021. (Note: vertical scale varies).

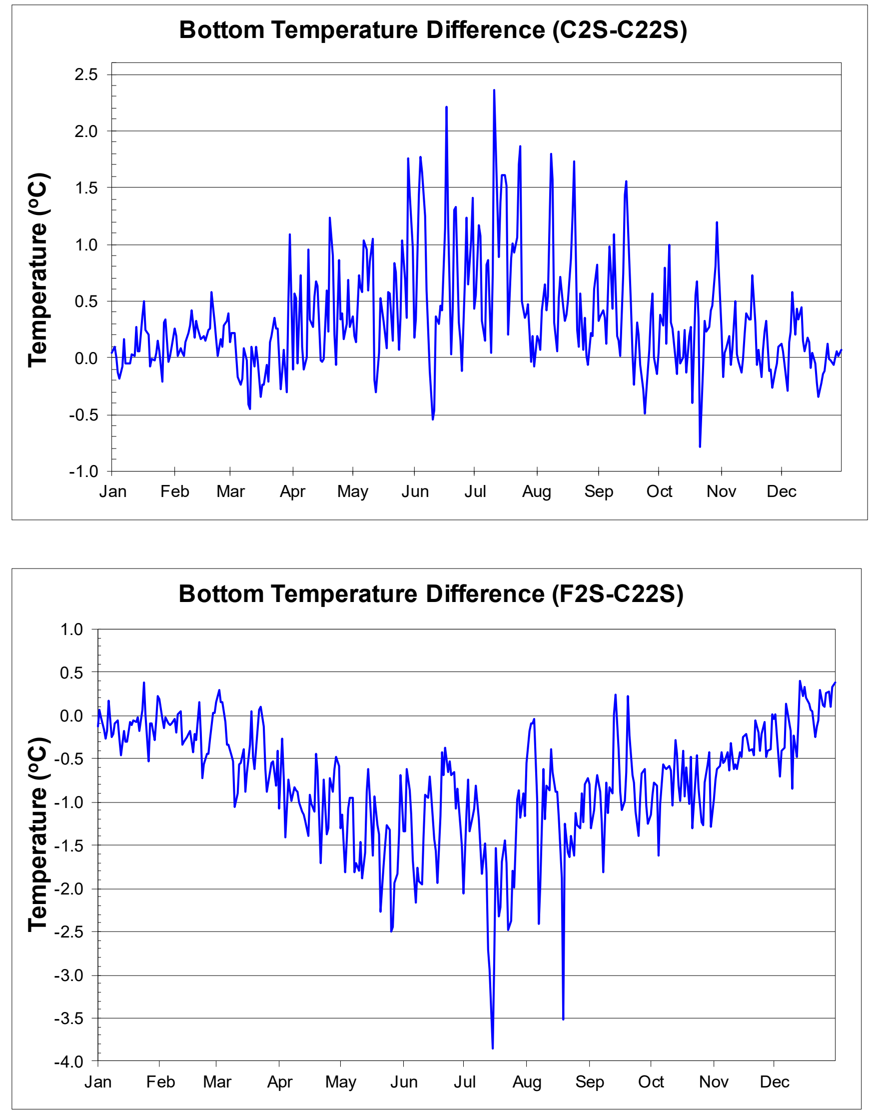


Figure 2-12. Daily mean bottom temperature differences between the reference Station (C22S) and the impact Stations (C2S and F2S) for 2021. (Note: vertical scale varies).

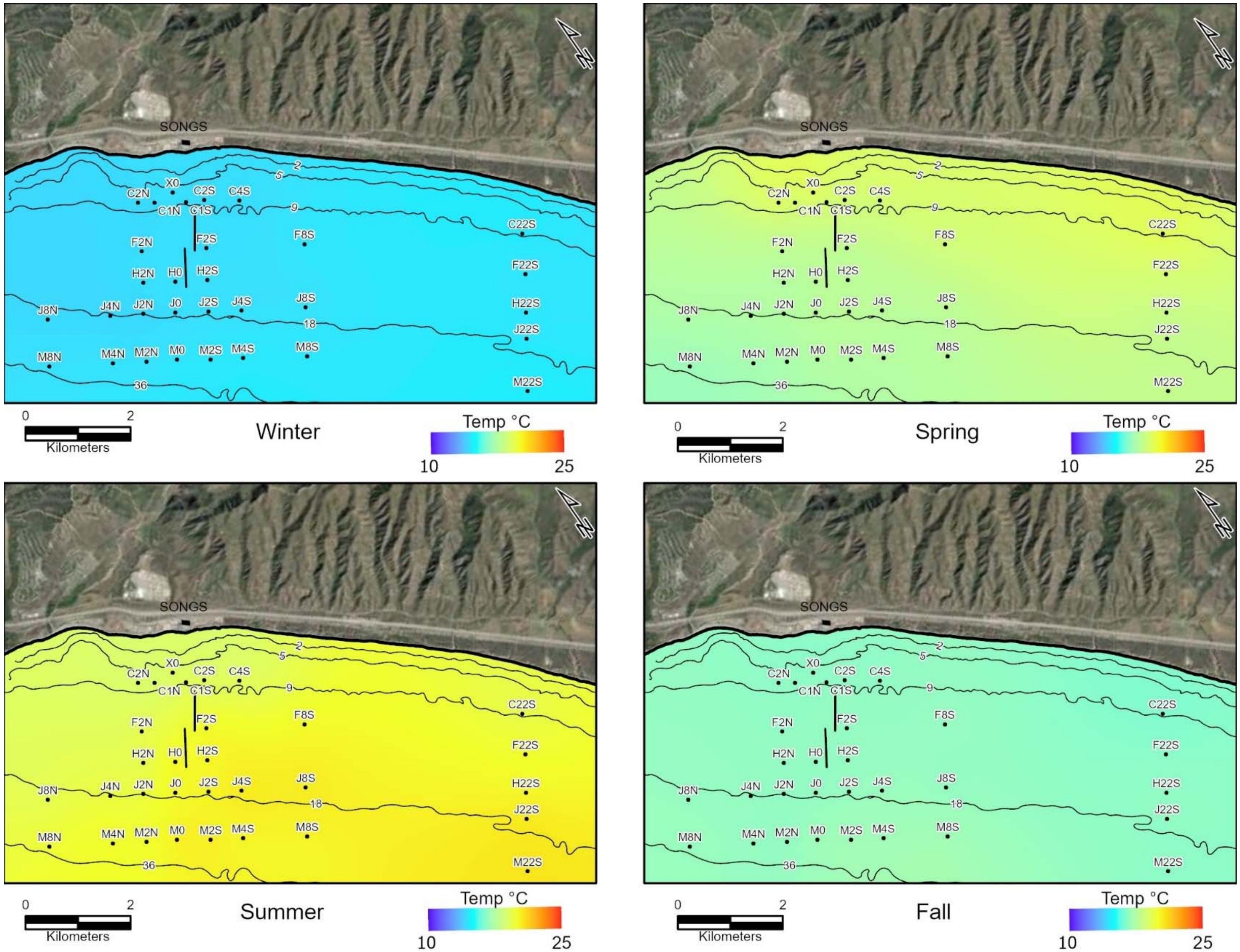


Figure 2-13. False-color surface water temperature contour plots recorded during quarterly water quality cruises in 2021.

First Quarter Cruise

On the morning of February 11, 2021, the skies were clear. In the morning, the wind was from the northeast and increased from 3 to 4 knots to 7 to 8 knots, decreasing to 3 to 4 knots from the northwest around noon. Seas were from the southwest at 0.3 to 0.6 m (1 to 2 ft). The water was slightly turbid at all stations. No red tide (phytoplankton bloom), or oil or grease was observed at any station. Drift giant kelp (*Macrocystis porifera*) was observed at nine of the 27 stations. Trash was observed floating on the surface at Stations H2S, J8S, and H2S. On the day of the survey, Unit 2 was at 2.0% of the design discharge flow of 1,218 MGD; Unit 3 had no flow.

Surface water temperatures varied from 14.23°C at Stations J8N, J4N, and J2N to 14.69°C at Station M22S (Data Appendix WQ-1). The average surface water temperature at the stations within the zone of initial dilution (ZID; Stations X0, H0, C1S, C2S, and F2S) was 14.34°C, slightly lower than the average at the downcoast reference stations (14.46°C). The false-color image shows uniform surface temperatures offshore of SONGS (Figure 2-13). The maximum surface-to-bottom temperature difference of 1.95°C in 2021 was above the maximum difference of 0.8°C reported during the first quarter survey of 2020 (SCE 2021). The overall average surface-to-bottom difference of 0.7°C in 2021 was greater than the mean difference of 0.3°C reported in 2020. Offshore water temperatures decreased gradually with depth at most stations. Temperatures decreased by less than 0.1°C per meter throughout the water column at all stations.

Second Quarter Cruise

On May 27, 2021, skies were overcast but cleared later in the day with winds from the southeast at 5 to 8 knots. Seas were from the northwest at 0.6 to 0.9 m (2 to 3 ft). No red tide, oil or grease was observed at any station. Floating bull kelp (*Nereocystis luetkeana*) was observed at Station J8N; giant kelp was observed at five of the 27 stations. Floating trash was observed at Station J4S. The water was slightly turbid at all stations. On the day of the survey, Unit 2 was at 1.9% of the design discharge flow; Unit 3 had no flow.

Surface water temperatures varied from 16.97°C at Station M8N to 19.28°C at Station C22S (Data Appendix WQ-2). The average surface water temperature at the reference stations was 0.05°C warmer than at ZID stations. The false-color image shows nearly uniform surface temperatures offshore of SONGS (Figure 2-13). Surface-to-bottom temperature differences were lower than those recorded during the first quarter survey, with an average difference at all stations of 5.55°C, which was lower than the 5.8°C recorded in 2020 (SCE 2021). In 2021, surface-to-bottom temperature differences were related to station depth, with smaller differences recorded at inshore stations (10 to 12 m depth) and the maximum surface-to-bottom difference (5.62 °C) reported at Station M22S (~34 m deep). A thermal gradient (thermocline) of 0.5 to 1.1°C/m decrease was present at most stations, occurring between 11 and 20 m depth.

Third Quarter Cruise

On September 9, 2021 skies were clear with winds from the west at 1 to 2 knots during the survey. Seas were from the southwest at 0.6 to 0.9 m (2 to 3 ft). Slight turbidity was noted at all stations; no red tide was noted at any station. Surfgrass was noted at C2N; no other floatables were observed. On the day of the survey, Unit 2 was at 1.9% of the design discharge flow, and there was no flow at Unit 3.

Surface water temperatures varied from 18.92°C at Station C1N to 20.75°C at Station M22S (Data Appendix WQ-3). Average surface water temperature at the reference stations was 0.69°C warmer than the average surface water temperature at ZID stations. Nearly uniform surface water temperatures were observed offshore of SONGS (Figure 2-13). Surface-to-bottom temperature differences were greater than those recorded during the second quarter survey with an average difference at all stations of 5.99°C, and were lower than the 7.0°C recorded in the third quarter of 2020 (SCE 2021). Surface-to-bottom temperature differences were related to station depth, with greater variability found at deeper stations. However, a thermal gradient of 0.5 to 1.7°C/m decrease was present at all stations between 4 and 12 m depth. Below the thermocline, temperatures continued to decrease to the bottom, with a maximum surface-to bottom change of 7.5°C at Station M0 (~27 m deep).

Fourth Quarter Cruise

On December 1, 2021 skies were overcast during the survey with winds from the south at 1-2 knots. Seas were southwest at 0.3 to 0.6 m (1 to 2 ft). There was slight turbidity at all stations, and no red tide was noted. No floatables, oil, or grease were observed. On the day of the survey, Unit 2 was at 1.4% of the design discharge flow; Unit 3 had no flow.

Surface water temperatures ranged from 16.32°C at Station C22S to 17.02°C at Station M8S (Figure 2-23, Data Appendix WQ-4). Average surface water temperature at the reference stations was 0.12°C cooler than average temperature at ZID stations. Nearly uniform surface water temperatures were observed offshore of SONGS (Figure 2-13). Thermal gradients were reduced compared to the third quarter survey. Average surface-to-bottom difference among all stations was 1.86°C, higher than the 0.6°C value reported in 2020 (SCE 2021). Surface-to-bottom temperature gradients were found at depths ranging from 11 and 30 m depth with the greatest difference of 0.07°C at Stations M2N, M4N, and F2S. Temperature profiles were mostly uniform.

WATER QUALITY AT FIXED MONITORING STATIONS

This section presents the results of the surface measurements of DO and pH concentrations at ten of the SONGS receiving water stations from the four quarterly cruises conducted in 2021 (Tables 2-4 and 2-5).

Eight impact stations (Stations C2S, C1S, X0, C1N, C2N, J2N, J2S, and J4S) were located near the circulating water system discharges, while the other two stations (reference Stations C22S and F22S) were about six kilometers (km) downcoast of SONGS, far enough to be removed from the influence of the discharges. The station locations are shown in Figure 2-2. The SONGS NPDES permit requires that DO concentrations in the receiving waters shall not be depressed more than 10% from that which occurs naturally, as compared to the reference stations. In addition, the generating station shall not cause the pH to vary by more than 0.2 units from that which occurs naturally.

Dissolved Oxygen

The mean surface DO concentrations at SONGS receiving water stations complied with requirements in the NPDES permit during all four quarterly surveys (Table 2-4). The saturation level of oxygen in the waters offshore SONGS is typically about 7 to 8 mg/L based on the water temperatures (Lewis 2006). The mean surface DO concentration over the four quarterly surveys for the impact stations was 8.36 mg/L and ranged from 7.52 mg/L in September to 9.06 mg/L in May. The mean surface DO concentration at the reference stations over the four quarterly surveys was 8.57 mg/L and ranged from 7.88 mg/L in September to 9.43 mg/L in May. All DO concentrations recorded in 2021 were above the level of biological concern of 5 mg/L (Kennish 2001).

Table 2-4. Summary of mean concentrations of dissolved oxygen (mg/L) at the surface during 2021 quarterly cruises.

Date	Impact Stations				Reference Stations (C22S and F22S)	NPDES Permit Limit*
	Mean	Min	Max	Std Dev	Mean	
2/11/2021	8.60	8.42	8.92	0.18	8.95	8.06
5/27/2021	8.78	8.43	9.06	0.21	9.12	8.21
9/9/2021	7.72	7.52	7.83	0.11	7.89	7.10
12/1/2021	8.34	8.34	8.35	0.01	8.33	7.50

* DO values cannot be depressed more than 10% with respect to reference stations.

Hydrogen Ion Concentration

The pH at SONGS receiving water stations complied with the requirements in the NPDES permit during all four quarterly cruises. The mean surface pH among all surveys ranged from 8.11 in September to 8.35 in December at the impact stations and 8.15 in September to 8.33 in December at the reference stations (Table 2-5). Surface pH varied by less than 0.2 among all stations during each quarterly cruise.

Table 2-5. Summary of mean pH values at the surface during 2021 quarterly cruises.

Date	Impact Stations				Reference Stations (C22S and F22S)	NPDES Permit Value Range*
	Mean	Min	Max	Std Dev	Mean	
2/11/2021	8.17	8.15	8.19	0.02	8.20	8.00 8.40
5/27/2021	8.24	8.19	8.28	0.04	8.26	8.06 8.46
9/9/2021	8.13	8.11	8.15	0.02	8.15	7.95 8.35
12/1/2021	8.34	8.34	8.35	0.01	8.33	8.13 8.53

* pH values must be within 0.2 pH units of the reference stations.

AERIAL PHOTOGRAPHIC SURVEYS

Aerial surveys of the coastal waters near SONGS were performed on March 28, July 16, and September 29, 2021, and on January 2, 2022; the latter survey, usually in December, was delayed due to inclement weather conditions. The area surveyed included the coastline from Dana Point (located approximately 16 km upcoast from San Onofre) to approximately 6 km downcoast from SONGS.

Photographic coverage of this coastal region allowed comparisons to be made between San Onofre and Dana Point, which are similar environments, with headlands (Dana Point and San Mateo Point) and streams (San Juan and San Onofre Creeks) present in both areas. The straight sections of beach up- and downcoast from San Onofre can be compared to similar beaches upcoast from San Clemente.

The aerial survey results were similar to those obtained in previous years (SCE 1990-2021). Turbid plumes visible in the paired Dana Point and SONGS photographs are similar, indicating no additional turbidity offshore of SONGS caused by plant operations. Examples of the comparison between San Onofre and Dana Point are shown in Figures 2-14 through 2-17.

a)

b)

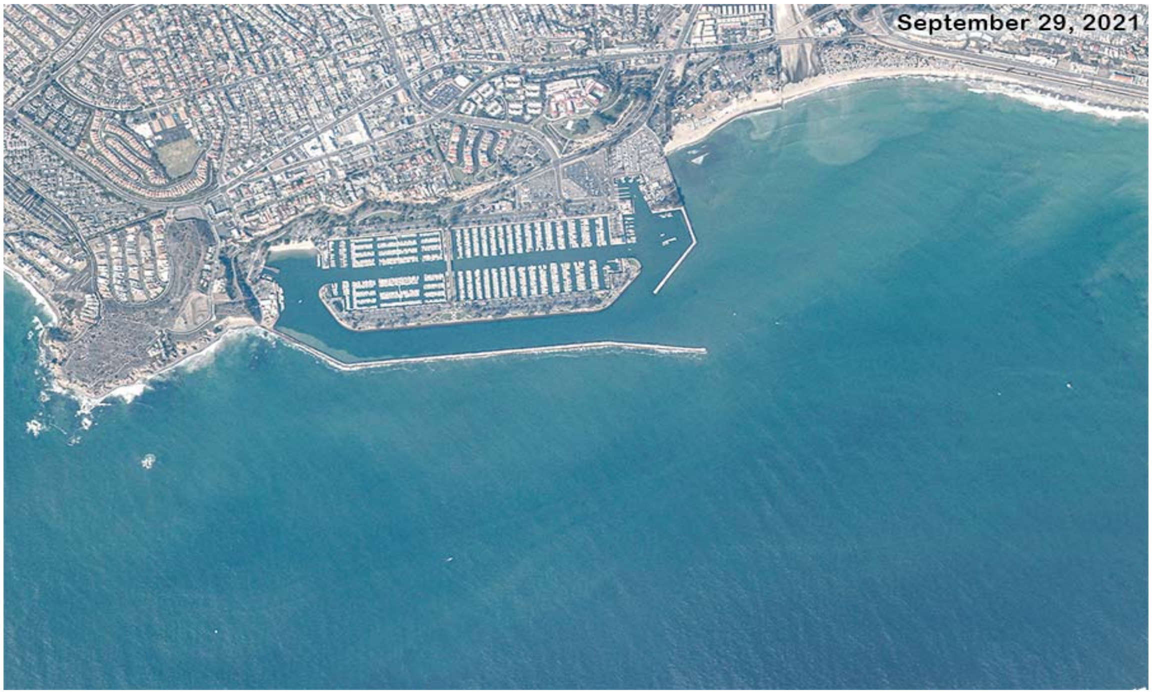
Figure 2-14. Aerial photographs showing turbidity near (a) Dana Point and (b) San Onofre, March 28, 2021.

a)

b)

Figure 2-15. Aerial photographs showing turbidity near (a) Dana Point and (b) San Onofre, July 16, 2021.

a)



b)

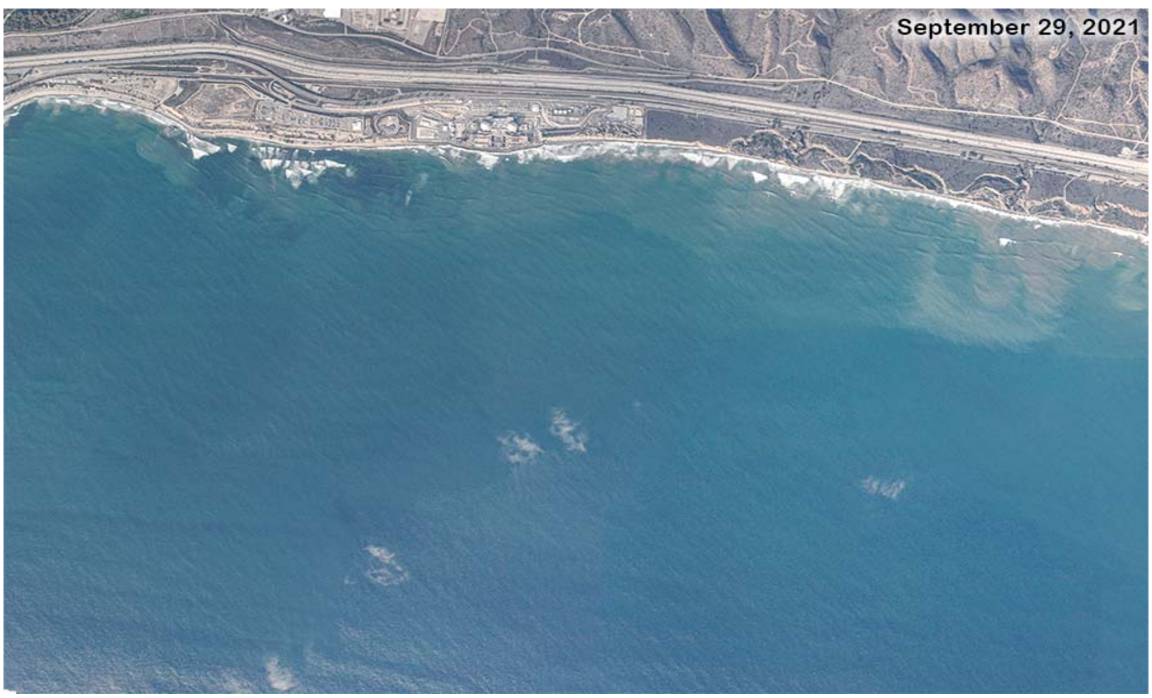


Figure 2-16. Aerial photographs showing turbidity near (a) Dana Point and (b) San Onofre, September 29, 2021

a)

b)

Figure 2-17. Aerial photographs showing turbidity near (a) Dana Point and (b) San Onofre, January 2, 2022.

LITERATURE & SOURCES CITED

Kennish, M.J. 2001. Practical Handbook of Marine Science, 3rd Edition, CRC Press, Boca Raton, FL. 876 p.

Lewis, M.E. 2006. Dissolved Oxygen, Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.2, accessed 4/25/2012 at: http://pubs.water.usgs.gov/twri9A6/.

NOAA. 2022. Coast Watch Browser. Oceanographic Data Access. U.S. Dept. of Commerce. Coast Watch. West Coast Regional Node. National Marine Fisheries Service, La Jolla, CA. https://coastwatch.pfeg.noaa.gov/erddap/griddap/jplMURSST41anommday.graph?sstAnom

NOAA-PFEG. 2022. Pacific Fisheries Environmental Laboratory. Upwelling indices: January to December 2020. Accessed 4/20/2022. Upwelling Index, 33N 119W, 6-hourly. https://coastwatch.pfeg.noaa.gov/erddap/tabledap/erdUI336hr.graph

SIO 2022. San Clemente and Dana Point shore station temperature data, May 1955 through December 2020. Shore Stations Program with current funding provided by the California Department of Parks and Recreation, Division of Boating and Waterways, Award# C1670003. Data are collected by marine safety personnel with the City of San Clemente, Marine Safety Department. Contact: shorestation@ucsd.edu. Internet site: https://shorestations.ucsd.edu/data-san-clemente/, accessed 4/20/22. Data ends December 2020.

Southern California Edison (SCE). 1990. 1989 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 90-RD-50.

_____. 1991. 1990 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 91-RD-10.

_____. 1992. 1991 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 92-RD-7.

_____. 1993. 1992 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company.

_____. 1994. 1993 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

_____. 1995. 1994 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

_____. 1996. 1995 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

_____. 1997. 1996 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

_____. 1998. 1997 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

_____. 1999. 1998 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

_____. 2000. 1999 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

_____. 2001. 2000 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ECOSystems Management, Ogden Environmental and Energy Services, and Southern California Edison.

_____. 2002. 2001 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ECOSystems Management, AMEC, and Southern California Edison.

_____. 2003. 2002 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by ECOSystems Management, AMEC, and Southern California Edison.

_____. 2004. 2003 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2005. 2004 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2006. 2005 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2007. 2006 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2008. 2007 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2009. 2008 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2010. 2009 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2011. 2010 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2012. 2011 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2013. 2012 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2014. 2013 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2015. 2014 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2016. 2015 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2017. 2016 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2018. 2017 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

_____. 2019. 2018 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

_____. 2020. 2019 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

_____. 2021. 2020 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

Sverdrup, H.U., M.W. Johnson, and R.H. Fleming. 1942. The oceans: their physics, chemistry, and general biology. Prentice-Hall, Inc., Englewood Cliffs, NY. 1,060 p. plus appendices.

Sverdrup, K.A., A.C. Duxbury, and A.B. Duxbury. 2003. An introduction to the world's oceans. McGraw-Hill Companies, Inc., New York, NY. 477 p. plus appendices.

Appendix 2-1. History of underwater temperature monitoring programs at San Onofre.

Unit	Temperature Studies	Type of Data	Date	Instrumentation	Frequency	Number of Stations	Depths Sampled
Marine Environmental Monitoring							
1	Preoperational	Depth profile	1963-68	Bathythermograph, thermometer	Bimonthly	32	Surface to bottom
1	Operational	Depth profile	1968-75	Bathythermograph, thermometer	Bimonthly	32	Surface to bottom
Environmental Technical Specifications and NPDES							
1	Operational	Depth profile	1975-76	Thermistor probe	Bimonthly	34	Surface to bottom
			976-80	Thermistor probe	Bimonthly	51	Surface to bottom
			1981	Thermistor probe	Bimonthly	50	Surface to bottom
			1985-97	Thermistor probe	Quarterly	29	Surface to bottom
		Intertidal	1975-77	Thermometer	Bimonthly	5/3 replicates	Surf zone
			1977-80	Thermometer	Bimonthly	11/3 replicates	Surf zone
			1981	Thermometer	Bimonthly	12/3 replicates	Surf zone
		Continuous	1975-97	Thermistor	Hourly	2 (C2S & C22S)	Surface, 5m and bottom
		Continuous	1975-80	Thermistor	Hourly	Inplant, intake and discharge	--------
2&3	Preoperational	Depth profile	1978-80	Thermistor probe	Bimonthly	23	Surface to bottom
		Continuous	1978-80	Thermistor	Hourly	1 (F2S)	Surface, 4m, 10m and bottom
		Continuous	1979-80	Thermistor	Hourly	5 PMP Hard bottom benthic stations	Bottom
2&3	Interim	Continuous	1981-84	Thermistor	Hourly	3 (C2S, C22S and F2S)	Surface, mid-depth, bottom (also 10 m at F2S)
2&3	Operational	Depth profile	1985-present	Thermistor probe	Quarterly	29	Surface to bottom
		Continuous	1984-present	Thermistor	At least Hourly	3 (C2S, C22S and F2S)	Surface, mid-depth, bottom (also 10m at F2S)

Appendix 2-2. History of water quality monitoring programs at San Onofre.

Unit	Temperature Studies	Type of Data	Date	Instrumentation	Frequency	# of Stations	Depths Sampled
Marine Environmental Monitoring							
1	Preoperational	Dissolved O_2	1967-69	Winkler Titration	Bimonthly	5	Surface
		Hydrogen Ion	1967-69	Polarographic pH meter	Bimonthly	5	Surface
		Coliform Bacteria	1967-69	Laboratory Incubation	Bimonthly	3	Surface
		Current	1967-69	Drogues	---	---	---
	Operational	Dissolved O_2	1968-72	Winkler Titration, Martek dissolved O_2 probe	Bimonthly	3	Surface
		Hydrogen Ion	1968-72	Polarographic pH meter, Martek pH probe	Bimonthly	3	Surface
		Coliform Bacteria	1968-72	Laboratory Incubation	Bimonthly	3	Surface
		Current	1968-72	Drogues and current meters	---	---	---
Environmental Technical Specifications and NPDES							
1	Operational	Dissolved O_2	1975-82	Martek dissolved O_2 probe	Bimonthly	3	Surface
		Hydrogen Ion	1975-82	Martek pH probe	Bimonthly	3	Surface
		Heavy Metals	1975-78	Grab and Scuba diver collection A.A. spectrophotometer	Quarterly	4	Mid-depth
			1978-80	Scuba diver collection, A.A. spectrophotometer	Bimonthly	4	Mid-depth & sediments
		Currents	1978-79	Current meters	Bimonthly	1 at C2N	1 m depth
		Mussel watch	1988-94	Diver collection	Semi-annual	6	10 ft
2&3	Preoperational	Dissolved O_2	1978-80	Martek dissolved O_2 probe	Bimonthly	4	Surface
		Hydrogen Ion	1978-80	Martek pH probe	Bimonthly	4	Surface
		Heavy Metals	1978-80	Scuba diver collection, A.A. spectrophotometer	Bimonthly	5	Mid-depth & sediments
		Current	1978-80	Current meters	Bimonthly	1 at H2N	1&7 m depths
2&3	Operational	Dissolved O_2	1988-96	Dissolved O_2 probe	Quarterly	10	Surface, mid-depth & bottom
		Dissolved O_2	1997-present	Dissolved O_2 probe	Quarterly	10	Surface
		Hydrogen Ion	1988-96	pH probe	Quarterly	10	Surface, mid-depth & bottom
		Hydrogen Ion	1997-present	pH probe	Quarterly	10	Surface
		Transmissivity	1985-2004	SeaTech Transmissometer	Quarterly	29	Surface to bottom
		Heavy Metals	1985-93	Scuba diver collection, A.A. Spectrophotometer	3/year	6	Mid-depth & sediments
		Total residual chlorine	1987-93	Amperometric Titration	3/year	12 per unit	Surface
SPECIAL STUDIES							
1	Operational	Total residual chlorine	1975-77	Amperometric Titration	Bimonthly	6 & Inplant	Surface
2&3	Preoperational	Total residual chlorine	1980	Amperometric Titration	3/year	8	Surface
2&3	Operational	Dissolved O_2	1985-87	Dissolved O_2 probe	Quarterly	4	Surface
		Hydrogen Ion	1985-87	pH probe	Quarterly	4	Surface

Appendix 2-3 History of turbidity monitoring programs by aerial photographs at San Onofre.

Unit	Turbidity Studies	Date	Instrumentation	Frequency
Environmental Technical Specifications and NPDES				
2&3	Operational	1975-77	35 mm SLR color camera	Quarterly
		1977-81	35 mm SLR color camera	Bimonthly
2&3	Preoperational	1982-83	High resolution airborne camera	Monthly
2&3	Operational	1984-85	High resolution airborne camera	Monthly
		1986-present	High resolution airborne camera	Quarterly

Appendix 2-4. SONGS receiving water monitoring stations for 2021.

Station	California Coordinates		Latitude	Longitude	Profiling* / Chemistry **
	x cal	y cal			
C1N	1598175	438077	33°21.826'	117°34.016'	P,C
C1S	1599799	436951	33°21.643'	117°33.694'	P,C
C2N	1597349	438649	33°21.918'	117°34.180'	P,C
C2S	1600827	436406	33°21.556'	117°33.491'	P,C
C22S	1615779	423196	33°19.408'	117°30.552'	P,C
F2N	1595776	436039	33°21.484'	117°34.482'	P
F2S	1599176	433872	33°21.134'	117°33.809'	P
F22S	1614475	420991	33°19.042'	117°30.773'	P,C
H0	1596375	433295	33°21.033'	117°34.358'	P
H2N	1594700	434397	33°21.211'	117°34.690'	P
H2S	1598085	432217	33°20.859'	117°34.019'	P
H22S	1613122	419032	33°18.716'	117°31.034'	P
J0	1595274	431726	33°20.772'	117°34.570'	P
J2N	1593587	432812	33°20.948'	117°34.904'	P,C
J2S	1596994	430573	33°20.586'	117°34.230'	P,C
J4N	1591838	433925	33°21.128'	117°35.251'	P
J4S	1598711	429423	33°20.400'	117°33.889'	P,C
J8N	1588505	435984	33°21.460'	117°35.911'	P
J8S	1602091	427263	33°20.051'	117°33.220'	P
J22S	1612198	417675	33°18.490'	117°31.212'	P
M0	1593662	429264	33°20.363'	117°34.881'	P
M2N	1592020	430263	33°20.524'	117°35.206'	P
M2S	1595368	428040	33°20.165'	117°34.543'	P
M4N	1590260	431396	33°20.707'	117°35.555'	P
M4S	1597060	426954	33°19.989'	117°34.208'	P
M8N	4586905	433534	33°21.053'	117°36.219'	P
M8S	1600406	424716	33°19.627'	117°33.545'	P
M22S	1610360	414952	33°18.038'	117°31.566'	P
X0	1599470	437947	33°21.807'	117°33.761'	P,C

* Profiling - Temperature Profiling Stations
** Chemistry - Dissolved Oxygen Concentration and Hydrogen Ion Concentration Statio

CHAPTER 3 KELP DENSITY STUDY

AN EVALUATION OF THE KELP AND SUBTIDAL HARD-BOTTOM HABITAT OFFSHORE OF SAN ONOFRE

INTRODUCTION

The evaluation of the nearshore kelp community and subtidal hard-bottomed habitat was conducted during 2021 to comply with environmental monitoring requirements for the NPDES permit (Order No. R9-2015-0073) for SONGS Units 2 and 3, established by the SDRWQCB. The purpose of the Kelp Density Study component of the Operational Program was to monitor the kelps, selected invertebrates, and subtidal substrate composition at six stations within the SOK, and at two stations within the San Mateo Kelp Forest (SMK) which serve as a reference for comparison to SOK. The data from 2021 were compared with historic data collected at the same stations during previous studies.

BACKGROUND

Biological Studies

Studies of the subtidal hard-bottom habitat offshore of San Onofre have been conducted since 1963 (Appendix 3-1). In addition to the yearly updates presented in annual reports, several special studies have evaluated the status of particular features of interest in the ecosystem offshore of San Onofre. For example, after completion of the Preoperational Monitoring Program in mid-1980, subtidal hard-bottom studies conducted from 1963 through 1981 were reviewed and the results compared to conditions present at hard-bottom communities in three kelp forests near San Onofre during 1981 (SCE 1982). Similarly, long-term effects of changes in substrate composition and stability on large benthic algae and invertebrates in SOK were evaluated in 1986 using data collected between 1978 and 1985 (SCE 1986, Chapter 5). Long-term databases have also been utilized to evaluate recruitment periods of giant kelp (*Macrocystis pyrifera*) and stalked kelp (*Pterygophora californica*), as well as to demonstrate notable differences in urchin densities within and between SOK and SMK over time (SCE 1987).

Present regulations for ocean discharge require that monitoring programs include a consistent sampling design over time. Ongoing monitoring of a specific community or population, such as that of kelp in a kelp forest community, is essential for evaluating changes that may result from anthropogenic factors, such as the operation of a discharge. To assist with evaluation of these factors, comparisons are frequently made with similar sites outside of the influence of the anthropogenic input. Conditions at these sites help determine whether community or population changes observed among years at areas within the influence of the discharge are a result of an impact by the discharge or if the differences represent naturally occurring variability throughout the region. Since it is unlikely that reference sites have identical characteristics to the discharge site, it is important to select a reference site that has as many similarities as possible under normal conditions (Stewart-Oaten et al. 1986). In addition, comparison to reference sites allows community changes near the discharge to be evaluated with respect to those that occur in a community outside of the influence of the discharge. The following presents the results of the ongoing NPDES study conducted for SONGS, a nuclear generating station located in southern

California that discharges seawater, previously used for cooling purposes but during decommissioning is only for dilution, into the nearshore coastal environment.

Physical Setting

The study area is located within the nearshore coastal area between San Clemente and Oceanside, California. It extends from SMK, approximately 6 km upcoast of the SONGS diffusers, to SOK, less than 1 km downcoast of the diffusers (Figure 3-1). The study area is within the Southern California Bight, a unique oceanographic environment between Point Conception and Punta Colnett, Baja California (Dailey et al. 1993). The study area is within the northern part of the Oceanside littoral cell, which extends from Dana Point to Point La Jolla (Kuhn and Shepard 1984; SCE 1986, Chapter 11). Two creeks, which normally only have flow during the rainy season, drain into the ocean just downcoast of San Mateo Point between SMK and SOK. San Onofre Creek is approximately 2 km, and San Mateo Creek about 4 km, upcoast of SONGS. Ocean currents and net sediment transport in this nearshore environment are downcoast, so a majority of terrestrial runoff from the creeks would more likely influence conditions at SOK than SMK. In addition, erosion of cliffs during winter storms can contribute a considerable amount of sediment to the nearshore environment (Kuhn and Shepard 1984).

STUDY APPROACH

The purpose of the current monitoring program was to determine the status of giant kelp and associated macrobiota and hard-bottom habitat characteristics at the six stations in SOK and two at SMK during 2021. Data were reviewed to describe changes in the long-term (1978 through 2021) distribution and abundance of species and substrate types, and to compare the kelp community at SOK with that at SMK. Species and substrate categories were chosen for evaluation during the study because their distribution and abundance can have a major influence on the community structure of southern California kelp forests (Rosenthal et al. 1974; Dayton et al. 1984; Foster and Schiel 1985) (Table 3-1). Hard-bottom habitat characteristics, as defined by the percent coverage of boulder, cobble, and sand at each study site, provide information on the physical similarity of stations within SOK, and between SOK and SMK. These substrate types are important aspects for kelp bed communities. Boulder provides a generally immobile surface optimal for attachment of giant kelp. Cobble consists of hard substrate which kelp can attach to, but because of its smaller size, it can be lifted from the bottom as the giant kelp grows and becomes more buoyant, allowing the cobble and attached kelp to drift away. Sand is unconsolidated sediment that is easily moved by bottom currents and surge and does not allow for kelp attachment. Sand can also scour other suitable substrate types and prevent or hinder algal attachment. In addition, oceanographic and physical parameters, such as wave height and duration, water temperature, and rainfall, are important to kelp communities. Oceanographic and physical information are useful for evaluating annual results at SOK and for making long-term comparisons. Environmental conditions that have occurred during decades of kelp studies at SONGS have included extremes in natural conditions such as periods of heavy rainfall, strong El Niños (ocean warming), mild El Niños, periods of ocean cooling (La Niña), severe storm events (1983, 1984, and 1988), and relatively calm conditions. Comparison of these data allows evaluation of changes at two similar kelp communities in relatively close proximity and provides additional insight regarding the impact of the operation of the generating station relative to natural changes.

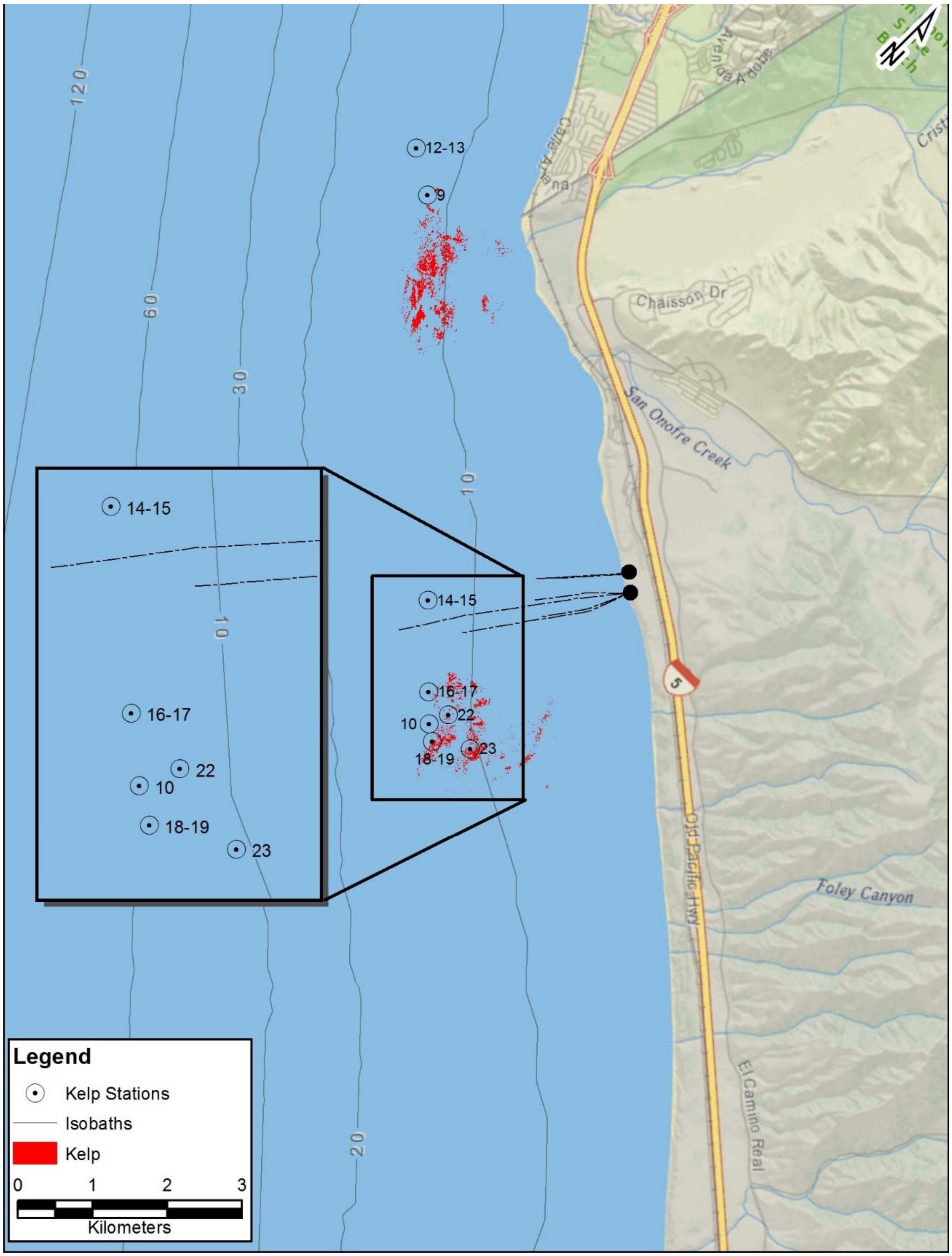


Figure 3-1. Location of sampling stations for the Kelp Density Study in San Onofre and San Mateo Kelp forests. Kelp beds depicted at maximum long-term extent.

METHODS

STUDY SITES

Six stations are located in SOK and two in SMK (Figure 3-1). Five of the six stations at SOK (Stations 10, 16-17, 18-19, 22, and 23) were located within the main SOK kelp bed downcoast of the Units 2 and 3 diffusers (main SOK) (Figure 3-1). Station 14-15 is sited upcoast of the diffusers in an area where a stand of kelp is periodically found.

SAMPLING

In 2021, the kelp density surveys were conducted in June, September, and November. Abundances and life stage of three kelps, presence of one other brown alga, proportions of substrate types and abundances of selected invertebrate species were recorded by biologist-divers (Table 3-1). Two sampling strategies were utilized to evaluate the biota on different scales. The first sampling strategy employed fixed quadrat sampling. Data were collected at Stations 9, 10, and 22 using a single 1 m x 10 m (10 m^2) fixed quadrat. At the remaining stations, a pair of 3 m x 2 m (6 m^2 each; 12 m^2 total) fixed quadrats was located approximately 10 m apart. Each square meter of the fixed quadrats provided replication for statistical analyses. Selected species were counted in each fixed quadrat without disturbing the habitat, and proportions of substrate types were estimated visually. In addition, the number of stipes on each giant kelp greater than 2-m tall was counted and recorded. The fixed quadrats allow a consistent evaluation of conditions that is comparable between years. However, because of the limited size of the quadrats, these conditions may not accurately characterize the overall status of the kelp forests in SOK or SMK.

The second sampling strategy, random quadrat sampling, was used to provide an assessment of the overall condition of the kelp forests. At each station, randomly placed quadrats were used to survey an area about 10 times greater than the size of that surveyed using the fixed quadrats. Proportions of the substrate types were estimated using a point contact method, and numbers and life history stages of giant kelp were counted within ten 10-m^2 circular areas randomly located within a 30-m radius of each station; measurements were recorded for four separate quadrants in each circular quadrat. Selection of 10 m^2 as the primary size for the sampling area was based on prior sampling experience and results of a previous study with similar objectives (Pearse and Hines 1979).

The random quadrats were sampled two times per year and the fixed quadrats were sampled three times per year. Random quadrats were sampled on the first and third surveys at the same time the fixed quadrat counts were conducted. The preferred sampling periods were (1) after the winter storms during periods of likely invertebrate and kelp recruitment (April-June), (2) during the warm-water summer months (July-September), and (3) prior to winter storms (November-December). Sampling was conducted as close to these periods as conditions allowed.

Table 3-1. Description of species sampled for this study including the size categories for kelp, invertebrates, and substrate types.

Species	Definition of Life Stage or Characteristic	Type of Sampling
KELP		
Macrocystis pyrifera (giant kelp) *	15-40 cm tall (Juvenile)	F & R
	41 cm-2 m tall (Subadult)	F & R
	>2 m tall (Adult)	F & R
Laminaria farlowii (oarweed)	>15 cm tall (Adult)	F
*Pterygophora californica**(stalked kelp)	>15 cm tall	F
Laminariales, unidentified**	<15 cm tall	
OTHER BROWN ALGA		
Cystoseira osmundacea (bladder chain kelp)	Presence	F
INVERTEBRATES		
Lytechinus pictus (white sea urchin)	All sizes	F
Patiria miniata (bat star)	All sizes	F
Pisaster spp (sea star)	All sizes	F
Strongylocentrotus [1] spp (sea urchin)	All sizes	F
Megastraea undosa (wavytop turban snail)	All sizes	F
Haliotis spp (abalone)	All sizes	F
SUBSTRATE		
Boulder	Immovable rock (stable substrate)	F & R
Cobble	Rock with a maximum linear dimension greater than 1 cm that can be moved because of physical or biological phenomena (movable substrate)	F & R.
Sand	Unconsolidated rock or shell debris with a maximum linear dimension of less than 1 cm	F & R.

* Life stage designated by length of the kelp measured from the top of the holdfast to the meristem of *Pterygophora* and to the meristem of the longest frond of *Macrocystis*.

** This group includes juvenile individuals of kelp species that were too small to be identified to the generic level in the field.

F Sampled in Fixed Quadrats

R Sampled in Random Quadrats

[1] *Strongylocentrotus franciscanus* is now *Mesocentrotus franciscanus;* grouping included for historical consistency.

DATA ANALYSIS

Proportions of substrate types and densities of species sampled at both fixed and random quadrats were evaluated for differences among stations within and between SOK and SMK kelp beds, and changes through time among stations and sites. The primary biological data used for analyses were from the random quadrats because of the larger area surveyed (100 m^2 for each station) and greater replication (10 quadrats for each station) using this technique. All species count data from the random and fixed quadrats are presented as densities (number of individuals per m^2).

As with the biological data, random quadrats were used in the analysis of the primary substrate type. The fixed quadrat substrate data were used to identify patterns and to follow changes occurring at these locations through time to evaluate differences. In addition, the line transect data, collected through 1987 and analyzed in earlier reports, were used to provide information on the substrate characteristics and patterns over a wider area.

On the time-series graphs (Figures 3-2 to 3-12), the first sampling event (usually June) indicates the beginning of each sample year; intervals between each year on the x-axis vary due to the different number of surveys conducted historically since the beginning of the monitoring program (Appendix 3-1).

RESULTS

The Kelp Density Study sampling year begins in spring (May-June) and ends in winter (December of the same year to March of the following year). In 2021, sampling for the Kelp Density Study random quadrat surveys was completed in June and November; fixed quadrat surveys were completed in June, September, and November.

The fixed and random sampling strategies allow the biological and physical variables to be evaluated on two spatial scales (large and small) and through time to provide different perspectives on changes in each kelp forest. Representative areas of the kelp forests were sampled using the stratified random design to evaluate large-scale change, while the permanent quadrats define areas for small-scale differences. The large-scale survey (random quadrat) evaluates an area of 600 m^2 in SOK (six stations) and 200 m^2 in SMK (two stations), while the small-scale survey (fixed quadrat) samples an area of 48 m^2 in SOK and 16 m^2 in SMK. The large-scale sampling provides an evaluation of changes in the overall dynamics of each kelp forest through time. The small-scale sampling provides a view of changes at specific locations only, though results can provide direct information to evaluate changes within the kelp forest communities.

BIOLOGICAL RESULTS

2021 SOK Random Quadrat Sampling

There was no giant kelp observed in random quadrats in SOK during either the June or November surveys (Table 3-2).

2021 SMK Random Quadrat Sampling

There was no giant kelp observed in random quadrats in SMK during either the June or November surveys (Table 3-3).

Table 3-2. Mean density (No./m²) of giant kelp in random quadrats sampled at six stations in San Onofre Kelp Forest (SOK) during 2021.

		Station						All Stations	
	Survey	14-15	16-17	18-19	10	22	23	Mean	SE
Giant Kelp (*Macrocystis pyrifera*)									
All Sizes Combined	Jun	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Size Categories									
Juvenile, 15-40 cm	Jun	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Subadult 41 cm – 2m	Jun	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Adult, >2m	Jun	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-

Note: "-" = none present

Table 3-3. Mean density (No./m²) of giant kelp in random quadrats sampled at two stations in San Mateo Kelp Forest (SMK) during 2021.

		Station		All Stations	
	Survey	9	12-13	Mean	SE
Giant Kelp (*Macrocystis pyrifera*)					
All Sizes Combined	Jun	-	-		-
	Nov	-	-		-
Size Categories					
Juvenile, 15-40 cm	Jun	-	-		-
	Nov	-	-		-
Subadult, 41cm-2m	Jun	-	-		-
	Nov	-	-		-
Adult, > 2m	Jun	-	-		-
	Nov	-	-		-

Note: "-" = none present

2021 SOK Fixed Quadrat Sampling

There was no giant kelp observed in random quadrats in SOK during either the June, September, or November surveys (Table 3-4).

Kelp recruits (unidentified Laminariales) were only present during September only at Station 22 and in November only at Station 23 (Table 3-4). Mean density was 0.02 kelp/m² in both surveys.

The brown understory algae bladder chain kelp (*Cystoseira osmundacea*) was observed during all surveys at Stations 14-15, 22, and 23 (Table 3-4). Overall mean density ranged from 1.60 kelp/m² in November to 2.43 kelp/m² in September. The highest density occurred at Station 23, with a peak density of 8.00 kelp/m² in June.

Table 3-4. Mean density (No./m^2) of giant kelp, understory kelp, other large brown algae, and macroinvertebrates in fixed quadrats sampled at six stations in the San Onofre Kelp Forest (SOK) during 2021.

		Station						All Stations	
	Survey	**14-15**	**16-17**	**18-19**	**10**	**22**	**23**	**Mean**	**SE**
Giant Kelp (*Macrocystis pyrifera*)									
All sizes combined									
	Jun	-	-	-	-	-	-	-	-
	Sep	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Size Categories									
Juvenile,	Jun	-	-	-	-	-	-	-	-
(15-40 cm)	Sep	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Subadult,	Jun	-	-	-	-	-	-	-	-
(41cm–2m)	Sep	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Adult,	Jun	-	-	-	-	-	-	-	-
(>2m)	Sep	-	-	-	-	-	-	-	-
	Nov	-	-	-	-	-	-	-	-
Understory Kelps									
Oarweed (*Laminaria farlowii*)									
	Jun	0.40	-	-	-	-	0.10	0.08	0.04
	Sep	-	-	-	-	0.50	0.20	0.12	0.04
	Nov	0.70	-	-	-	0.40	0.60	0.28	0.10
Stalked Kelp (*Pterygophora californica)*									
	Jun	0.50	-	-	-	0.60	-	0.18	0.10
	Sep	-	-	-	-	0.60	1.30	0.32	0.11
	Nov	0.90	-	-	-	1.90	1.90	0.78	0.20
Kelp Recruits (Laminariales, unident.)								-	-
	Jun	-	-	-	-	-	-	-	-
	Sep	-	-	-	-	0.10	-	0.02	0.02
	Nov	-	-	-	-	-	0.10	0.02	0.02
Brown Understory Algae									
Bladder chain kelp (*Cystoseira osmundacea*)									
	Jun	0.20	-	-	-	3.80	8.00	2.00	0.44
	Sep	0.10	-	-	-	7.90	6.60	2.43	0.48
	Nov	0.20	-	-	-	5.60	3.80	1.60	0.36
Macroinvertebrates - Sea Urchins									
Strongylocentrotus spp. Combined									
	Jun	2.20	-	1.70	0.50	-	-	0.73	0.20
	Sep	1.30	-	0.30	-	-	-	0.27	0.11
	Nov	9.20	0.80	0.30	0.90	-	-	1.87	0.61
Purple sea urchin (*Strongylocentrotus purpuratus*)									
	Jun	2.00	-	0.90	0.30	-	-	0.53	0.18
	Sep	1.20	-	0.20	-	-	-	0.23	0.10
	Nov	7.60	0.40	0.10	0.10	-	-	1.37	0.51
Red sea urchin (*Mesocentrotus [Strongylocentrotus] franciscanus*)									
	Jun	0.20	-	0.80	0.20	-	-	0.20	0.07
	Sep	0.10	-	0.10	-	-	-	0.03	0.02
	Nov	1.60	0.40	0.20	0.80	-	-	0.50	0.13

Table 3-4. Cont.

Survey	Station 14-15	16-17	18-19	10	22	23	All Stations Mean	SE
Macroinvertebrates - Sea Urchins (continued)								
White sea urchin (*Lytechinus pictus*)								
Jun	-	-	-	1.40	-	-	0.23	0.10
Sep	-	-	0.30	1.70	-	-	0.33	0.11
Nov	-	-	0.30	2.00	-	-	0.38	0.13
Macroinvertebrates - Sea Stars								
Bat star (*Pateria miniata*)								
Jun	0.20	-	0.30	0.10	-	-	0.10	0.04
Sep	-	-	0.20	0.20	-	-	0.07	0.03
Nov	-	-	0.20	0.70	-	-	0.15	0.12
Pisaster spp. Combined								
Jun	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-
Short-spined sea star (*Pisaster brevispinus*)								
Jun	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-
Giant-spined star (*Pisaster giganteus*)								
Jun	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-
Ochre star *(Pisaster ochraceus)*								
Jun	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-
Macroinvertebrates – Mollusks								
Wavytop turbansnail (*Megastraea undosa*)								
Jun	0.10	-	0.10	0.40	0.20	1.20	0.33	0.11
Sep	0.20	-	0.10	0.10	0.40	0.80	0.27	0.07
Nov	0.40	0.20	-	0.30	0.90	2.00	0.63	0.22
Abalone (*Haliotis* spp.)								
Jun	0.10	-	-	-	-	-	0.02	0.02
Sep	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-

Note: “-“ = none present

The purple sea urchin (*Strongylocentrotus purpuratus*) was the most abundant macroinvertebrate species observed, but its distribution was uneven. Purple sea urchin was present at three, two, and four stations in June, September and November, respectively; it was not recorded at either Station 22 or 23 (Table 3-4). Mean survey density ranged from 0.23 individuals/m^2 in September to 1.37 individuals/m^2 in November. The highest density (7.60 individuals/m^2) occurred in November at Station 14-15.

The second most abundant macroinvertebrate was the wavytop turbansnail (*Megastraea undosa*) which was recorded at five stations in all three surveys; overall mean density ranged from 0.27 individuals/m^2 in September to 0.63 individuals/m^2 in November (Table 3-4).

Red sea urchin (*Mesocentrotus* [formerly *Strongylocentrotus*] *franciscanus*), frequently one of the most abundant macroinvertebrates, was observed in the same pattern as was the purple sea urchin (Table 3-4). Mean density ranged from 0.03 individuals/m^2 in September to 0.50 individuals/m^2 in November. White sea urchin (*Lytechinus pictus*) was present only at two stations; Station 10 during all three seasons and Station 18-19 only in September and November. Mean density increased from 0.23 individuals/m^2 in June to 0.38 individuals/m^2 in November. Bat star (*Patiria miniata*) were observed at three stations in June and at two stations in September and November; mean density varied from 0.07 individuals/m^2 in September to 0.15 individuals/m^2 in November. One abalone (*Haliotis corrugata*) was observed at Station 14-15 in June. Short-spined sea star (*Pisaster brevispinis*), giant-spined star (*P. giganteus*), and ochre star (*P. ochraceus*) were not observed in fixed quadrats in SOK in 2021.

2021 SMK Fixed Quadrat Sampling

In the fixed quadrats at SMK, the only monitored algae observed were stalked kelp and bladder chain kelp; no giant kelp, oarweed, or kelp recruits were recorded at either station during any survey (Table 3-5). Stalked kelp occurred in all three surveys only at Station 9; station density increased from 0.10 kelp/m^2 in June to a peak of 0.60 kelp/m^2 in September. Bladder chain kelp was recorded only at Station 9 and only in September and November, with station density increasing from of 0.10 kelp/m^2 to 0.20 kelp/m^2.

Purple sea urchins and wavytop turban snails were the most abundant macroinvertebrates at SMK. Purple sea urchin was observed at Station 9 during all three surveys and at Station 12-13 only in September; overall mean density ranged from 0.30 individuals/m^2 in November to 0.45 in June (Table 3-5). Wavytop turbansnail was observed at both stations during all three surveys; mean survey density ranged from 0.60 in September to 1.35 individuals/m^2 in November. Red sea urchin was recorded at Station 9 only in September and at Station 12-13 in all three surveys; mean density ranged from 0.15 individuals/m^2 in November to 0.25 individuals/m^2 in both June and September. Bat star was observed at Station 9 during all three surveys and at Station 12-13 only in September; overall mean density ranged from 0.10 individuals/m^2 in June and November to 0.15 in September. No white sea urchin, any of the three Pacific sea star species, or abalone were observed during any survey at SMK in 2021.

SUBSTRATE COMPOSITION

2021 SOK Substrate Composition

Percentage of habitat available for algae and macroinvertebrates by substrate type (boulder, cobble, and sand) was evaluated both in the random and fixed quadrat sampling. In the random sampling in June and November, the mean proportion of boulder substrate reported at SOK increased slightly between the surveys, changing from a mean of 21.4% among all stations in June to 26.0% in November (Table 3-6). The proportion of boulder substrate at stations in June ranged from 7.50% to 33.8%, while in November it ranged from 11.3% to 38.1%. The mean proportion of cobble between surveys decreased from 38.7% in June to 36.4% in November. The proportion of cobble among stations varied more than that of boulder, ranging from 0.6% to 70.0% in June and from 9.4% to 63.1% in November. The mean proportion of sand increased from June to November, changing from 40.0% to 37.6%. By survey, boulder showed the greatest overall change in mean proportion, varying by 4.7% between surveys, followed by sand and cobble (2.4% and

Table 3-5. Mean density (No./m^2) of giant kelp, understory kelp, other large brown algae, and macroinvertebrates in fixed quadrats sampled at two stations in San Mateo Kelp Forest (SMK) during 2021.

		Station		All Stations	
	Survey	9	12-13	Mean	SE
Giant Kelp (*Macrocystis pyrifera*)					
All sizes combined					
	Jun	-	-		-
	Sep	-	-		-
	Nov	-	-		-
Size Categories					
Juvenile,	Jun	-	-		-
(15-40 cm)	Sep	-	-		-
	Nov	-	-		-
Subadult,	Jun	-	-		-
(41cm-2m)	Sep	-	-		-
	Nov	-	-		-
Adult,	Jun	-	-		-
(>2m)	Sep	-	-		-
	Nov	-	-		-
Understory Kelps					
Oarweed (*Laminaria farlowii*)					
	Jun	-	-		-
	Sep	-	-		-
	Nov	-	-		-
Stalked Kelp (*Pterygophora californica)*					
	Jun	0.10	-	0.05	0.05
	Sep	0.60	-	0.30	0.15
	Nov	0.40	-	0.20	0.12
Kelp Recruits (Laminariales, unident.)					
	Jun	-	-	-	-
	Sep	-	-	-	-
	Nov	-	-	-	-
Brown Understory Algae					
Bladder chain kelp (*Cystoseira osmundacea*)					
	Jun	-	-	-	-
	Sep	0.10	-	0.05	0.05
	Nov	0.20	-	0.10	0.07
Macroinvertebrates - Sea Urchins					
Strongylocentrotus spp. Combined					
	Jun	0.40	0.50	0.45	0.15
	Sep	0.10	0.60	0.35	0.13
	Nov	0.50	0.10	0.30	0.25
Purple sea urchin (*Strongylocentrotus purpuratus*)					
	Jun	0.40	-	0.20	0.12
	Sep	0.10	0.10	0.10	0.07
	Nov	0.30	-	0.15	0.15
Red sea urchin (*Mesocentrotus* [*Strongylocentrotus] franciscanus*)					
	Jun	-	0.50	0.25	0.12
	Sep	-	0.50	0.25	0.12
	Nov	0.20	0.10	0.15	0.11

Table 3-5. Cont.

	Station		All Stations	
Survey	9	12-13	Mean	SE
Macroinvertebrates - Sea Urchins (continued)				
White sea urchin (*Lytechinus pictus*)				
Jun	-	-	-	-
Sep	-	-	-	-
Nov	-	-	-	-
Macroinvertebrates - Sea Stars				
Bat star (*Asterina miniata*)				
Jun	0.20	-	0.10	0.07
Sep	0.20	0.10	0.15	0.08
Nov	0.20	-	0.10	0.07
Pisaster spp. Combined				
Jun	-	-	-	-
Sep	-	-	-	-
Nov	-	-	-	-
Short-spined sea star (*Pisaster brevispinus*)				
Jun	-	-	-	-
Sep	-	-	-	-
Nov	-	-	-	-
Giant-spined star (*Pisaster giganteus*)				
Jun	-	-	-	-
Sep	-	-	-	-
Nov	-	-	-	-
Ochre star *(Pisaster ochraceus)*				
Macroinvertebrates – Mollusks				
Wavytop turbansnail (*Megastraea undosa*)				
Jun	1.40	0.30	0.85	0.21
Sep	1.10	0.10	0.60	0.18
Nov	2.00	0.70	1.35	0.36
Abalone (*Haliotis* spp.)				
Jun	-	-	-	-
Sep	-	-	-	-
Nov	-	-	-	-

Note: "-" = none present

2.3%, respectively). Among stations, the greatest variability among all three substrate types occurred at Station 10, with cobble decreasing by 19.4% from June to November.

Proportions of substrate composition were also estimated in the fixed sampling quadrats during the June, September, and November surveys. The mean proportion of boulder substrate ranged from 21.2% in November to 26.6% in June (Table 3-6). The proportion of boulder within stations ranged from a low of 1.5% at Station 23 in November to a high of 57.0% at Station 18-19 in June. On average, the lowest proportion of boulder over the three surveys (12.7%) occurred at Station 16-17 and the highest (37.2%) occurred at Station 22. The lowest percentage of cobble (0%) was observed at Station 16-17 while the highest percentage (80.5%) occurred at Station 10. On average among surveys, the lowest proportion of cobble (0.2%) was at Station 16-17 and the highest (64.5%) at Station 14-15. The mean proportion of sand ranged from a low of 43.1% in June to a high of 52.9% in September. The proportion of sand ranged from a low of 5.5% at Station 14-15 in November to a high of 98.0% at Stations 16-17 in June. On average, the lowest sand proportion (7.3%) was at Station 14-15 and the highest (87.25%) at Station 16-17. Similar to results from the random sampling, during the fixed station sampling the proportion of sand was consistently high at Station 16-17 and low at Station 14-15.

Table 3-6. Mean proportions of substrate types in random and fixed quadrats sampled at six stations in the San Onofre Kelp Forest (SOK) during 2021.

	Survey	Station						All Stations	
		14-15	16-17	18-19	10	22	23	Mean	SE
Random Quadrats									
Boulder %	Jun	20.63	13.13	33.75	20.63	32.50	7.50	21.35	2.08
	Nov	28.13	22.50	24.38	31.88	38.13	11.25	26.04	2.17
Cobble %	Jun	66.88	0.63	23.75	70.00	19.38	51.25	38.65	3.71
	Nov	63.13	9.38	15.63	50.63	24.38	55.00	36.35	3.35
Sand %	Jun	12.50	86.25	42.50	9.38	48.13	41.25	40.00	3.78
	Nov	8.75	68.13	60.00	17.50	37.50	33.75	37.60	3.58
Fixed Quadrats									
Boulder %	Jun	36.50	2.00	57.00	31.00	28.50	4.50	26.58	3.43
	Sep	30.00	6.00	30.50	13.50	41.00	33.00	25.67	3.31
	Nov	18.00	30.00	22.00	13.50	42.00	1.50	21.17	2.64
Cobble %	Jun	56.50	-	24.00	55.00	4.00	42.50	30.33	3.67
	Sep	60.50	-	5.50	31.00	15.00	16.50	21.42	3.13
	Nov	76.50	0.50	4.00	80.50	10.50	39.00	35.17	4.61
Sand %	Jun	7.00	98.00	19.00	14.00	67.50	53.00	43.08	4.52
	Sep	9.50	94.00	64.00	55.50	44.00	50.50	52.92	4.22
	Nov	5.50	69.50	74.00	6.00	47.50	59.50	43.67	4.10

Note: "-" = none present

2021 SMK Substrate Composition

During random quadrat surveys at SMK, the highest mean proportion of substrate type recorded per survey was cobble, in June (47.5%) and November (61.30%); sand contributed the least during both surveys (Table 3-7). The highest percent contribution by boulder was at Station 9 in both June and November. The cobble percentage was highest at Station 9 in June and Station 12-13 in November. Sand contribution in June was same at both stations (6.9%) and in November was least at Station 12-13 (0%). Between surveys, mean coverage of all substrates varied from 4.7% for boulder to 13.8% for cobble.

Estimates of substrate composition in the fixed quadrat surveys were more variable than those from the random surveys (Table 3-7). In fixed quadrats, seasonal mean cover by boulder varied from a low of 43.8% in November to a high of 55.5% in June, while cobble varied from a low of 37.3% in June to a high of 55.5% in November. Percent sand was relatively low, with mean coverages ranging from 0.8% to 8.8% among the surveys. Overall, the mean concentrations in boulder, cobble, and sand substrate varied among surveys by 11.8%, 18.3%, and 8.0%, respectively. There was more fluctuation in mean substrate proportions for all three substrate types in the fixed quadrat surveys than in the random quadrat surveys.

Table 3-7. Mean proportions of substrate types in random and fixed quadrats sampled at two stations in the San Mateo Kelp Forest (SMK) during 2021.

Type	Survey	Station		All Stations	
		9	12-13	Mean	SE
Random Quadrats					
Boulder %	Jun	42.50	37.50	40.00	3.15
	Nov	38.75	31.88	35.31	2.88
Cobble %	Jun	50.63	44.38	47.50	4.14
	Nov	54.38	68.13	61.25	3.03
Sand %	Jun	6.88	18.13	12.50	2.13
	Nov	6.88	-	3.44	1.54
Fixed Quadrats					
Boulder %	Jun	62.00	46.00	54.00	5.75
	Sep	71.50	39.50	55.50	5.56
	Nov	51.00	36.50	43.75	5.27
Cobble %	Jun	35.00	39.50	37.25	5.68
	Sep	25.50	56.00	40.75	5.41
	Nov	47.50	63.50	55.50	5.38
Sand %	Jun	3.00	14.50	8.75	1.62
	Sep	3.00	4.50	3.75	0.80
	Nov	1.50	-	0.75	0.41

Note: "-" = none present

DISCUSSION

Long-term studies of southern California kelp forests have shown that kelp bed canopy areal extent is highly variable and that notable changes can occur over periods of only a few years (Schiel and Foster 1986; North and MBC 2001). On a regional basis, the persistence of giant kelp is tied very strongly to El Niño and La Niña oceanographic events (MBC 2020). Still, local differences in kelp bed community response to large-scale events of this type can be variable, and this local response may delay recovery of giant kelp when growing conditions improve. For example, at the Point Loma Kelp Forest, there was a rapid recovery following the 1982-1984 El Niño, while it took over five years for a recovery following the 1957-1959 El Niño (Tegner and Dayton 1987, 1991). Regionally, recovery following large El Niño events also varies. While giant kelp may recover well following an El Niño, this is not always the case. The 1982-1984 El Niño oceanographic condition resulted in poor giant kelp growth, canopy formation, and survival. This allowed understory kelps to become established, which out-competed giant kelp recruits when oceanographic conditions became more favorable and resulted in continued low abundances of giant kelp despite the improved growing conditions (Tegner et al. 1996, 1997). However, under the right conditions, giant kelp may competitively dominate understory kelps, and the colder, nutrient-rich nearshore water of the 1988-1989 La Niña led to an increase in giant kelp and a decrease of understory kelps, with considerable site-to-site variation (Dayton et al. 1992).

Because of the complexity of a kelp forest community, any review of the status of a particular bed requires information on potential variables which could result in a change in the kelp bed community structure. In this chapter, the status of the SOK is assessed by evaluating densities of giant kelp in distinct size categories and physical factors important to kelp's ability to recruit and persist on the seafloor throughout SOK. To do this, the distribution and abundance of kelp are compared to factors known to be important to kelp to investigate small- and large-scale changes through time. The long-term collection of this information in a consistent fashion is important to evaluate changes which would otherwise be difficult to assess.

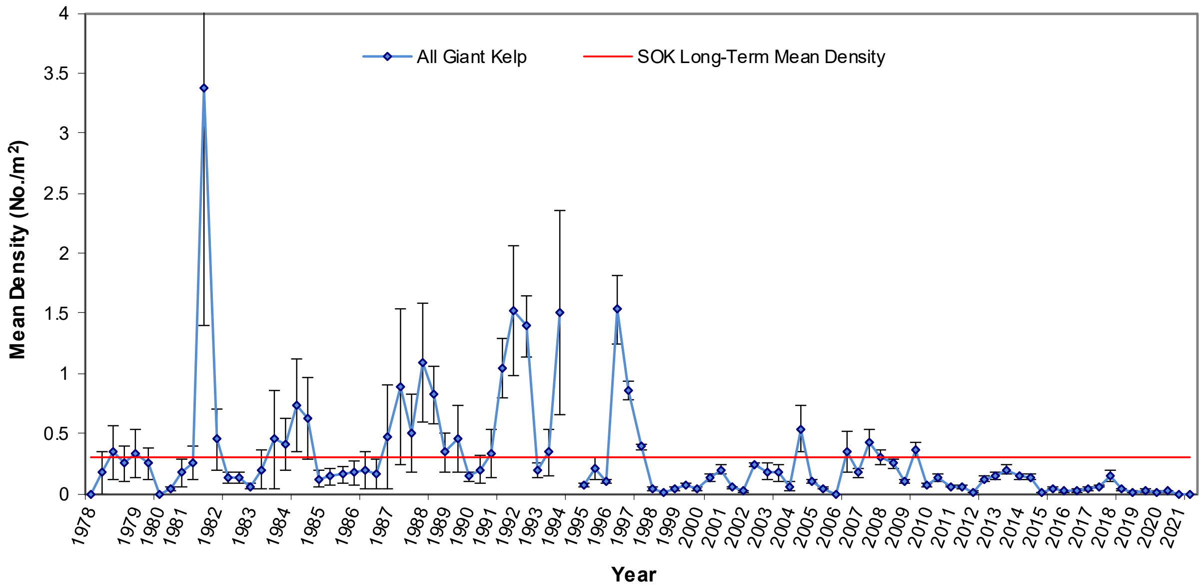
Factors affecting kelp development and distribution that were assessed by this study include: recruitment periods (periods of high densities of giant kelp and unidentified Laminariales); amount of stable substrate available for attachment (percent boulder versus cobble or sand); disturbance (percent sand); competition for space (densities of understory algae); herbivory (densities of sea urchin species); and predation on those herbivores (densities of sea stars). An additional environmental parameter which has an effect on kelp is nutrient availability, with temperature as a surrogate measure for nutrients. The following discusses the changes in these factors throughout the duration of this study and relates them to the densities of giant kelp.

GIANT KELP AT SOK

Mean density of giant kelp in SOK from 1978 through 2021 has been highly variable among surveys, as well as among stations within the kelp bed, as represented in Figures 3-2A and 3-3A. Historically, the greatest density of all giant kelp occurred late in the year during the 1981, 1992, 1994, and 1996 surveys, with the greatest overall density found in 1981 (Figure 3-2A). For adult giant kelp, mean densities were similar during the 1981 and 1992 surveys (Figure 3-2B), with high values also reported during the 1994, 1997, and 2007 surveys. During 1981, density was much higher at Station 14-15 (the station upcoast of the diffusers) than at the other stations, resulting in a large standard error around the mean (SCE 1982). During the 1992 peak, densities were similar among stations in main SOK (the stations in the main bed of SOK (Figure 3-3A, excluding Station 14-15) and the resultant standard error was relatively small (Figure 3-2A) (SCE 1993). All six stations in SOK have reached relatively high densities during only one period, from late-1988 through early-1990 (Figure 3-3A).

Conversely, giant kelp density was very low from 1998 to early-2004 with minor variation among sites (Figure 3-3A). By the end of 2004, mean densities of both smaller individuals and adult giant kelp increased to a level last seen in 1997. This period was followed by a general decline culminating in 2006 when giant kelp virtually disappeared. Between 2006 and 2009, juvenile and adult giant kelp densities increased, with overall mean annual densities of juvenile giant kelp remaining close to the 43-year mean of 0.31 giant kelp/m^2. Since 2009, however, overall mean densities decreased and remain below the 43-year mean. Adult densities reported between 2006 and 2009 were more variable than those observed for juveniles, shown by the large standard error bars. Adult giant kelp was notably more abundant at Station 16-17 by late-2007, while densities among the other five stations remained similar to those observed at the end of 2006 (SCE 2007, 2008). Since 2007, adult densities have remained below the long-term mean of 0.10 giant kelp/m^2, except for single surveys in 2013 and 2018. Kelp densities seen at monitoring stations do not always indicate the health or extent of a kelp bed. Although the densities from 2007 to 2013 remained below the long-term mean density, the kelp bed canopy (which fluctuates in size each year) attained the largest canopy areal coverage since 1989 during 2013 (Figure 3-4), before decreasing in size in 2014. Warmer-than-normal SSTs since 2014 have likely inhibited formation of larger canopies (SCE 2015–2022, this report Chapter 2).

A. All giant kelp



B. Adult giant kelp

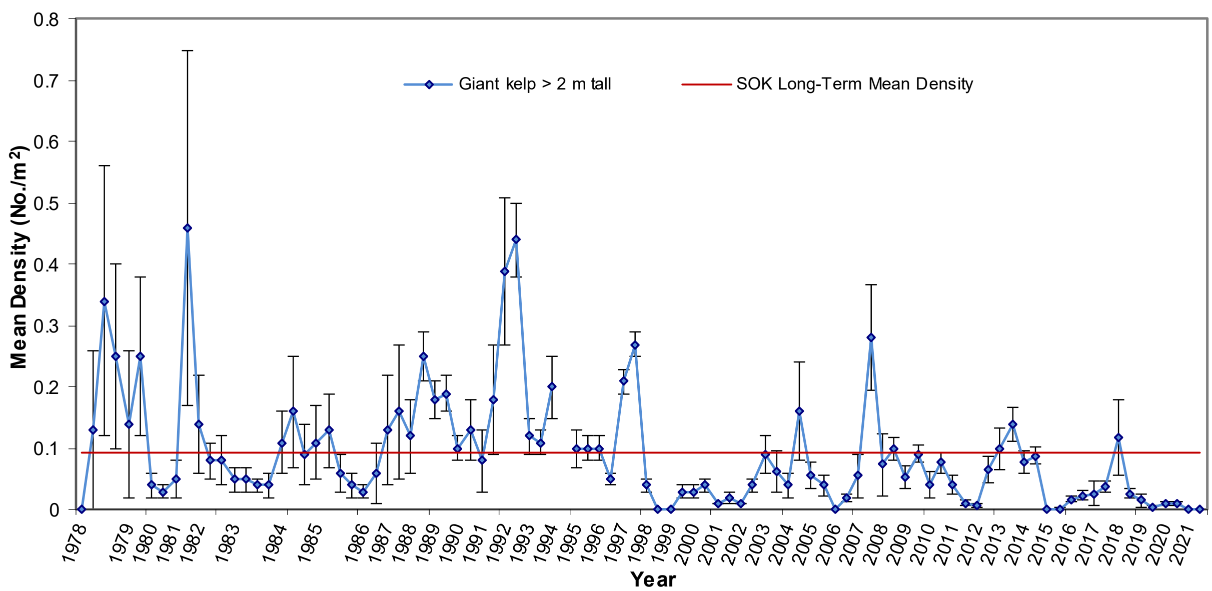
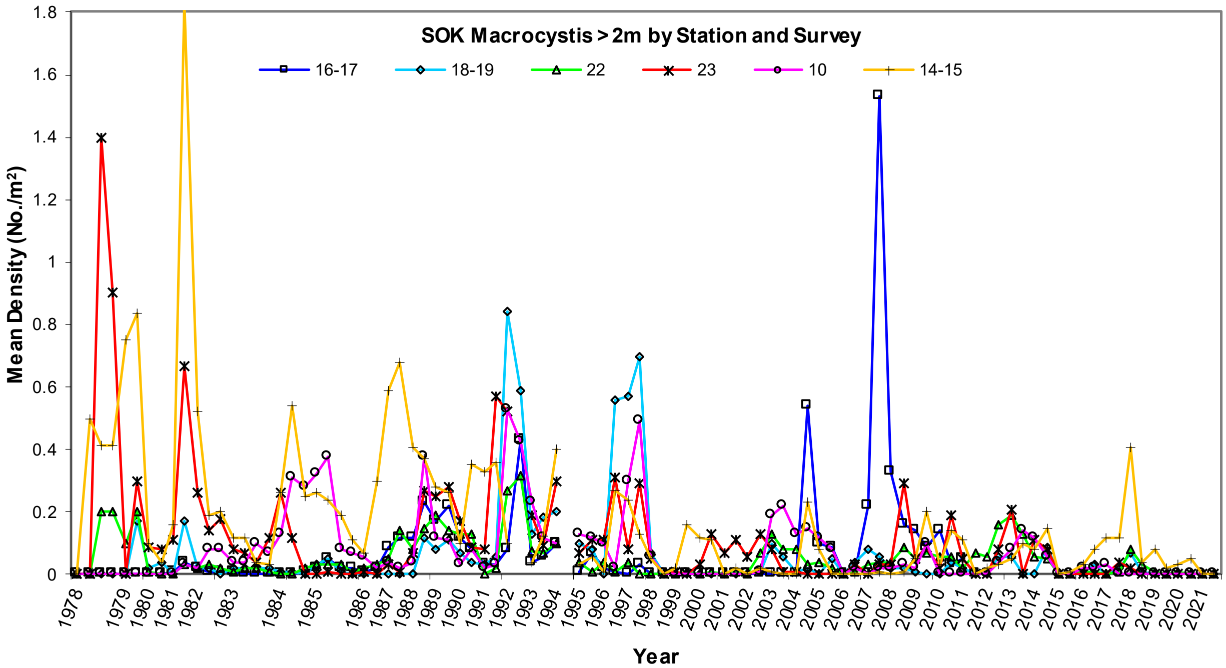


Figure 3-2. Mean (±1 standard error) and long-term densities of giant kelp (No./m^2) calculated from fixed and random quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted for the period 1978 through December 1980; random data for the period 1981 through 2021. Plot A is for the sum of all sizes of giant kelp; B is for adult giant kelp (>2-m tall).

A. San Onofre Kelp



B. San Mateo Kelp

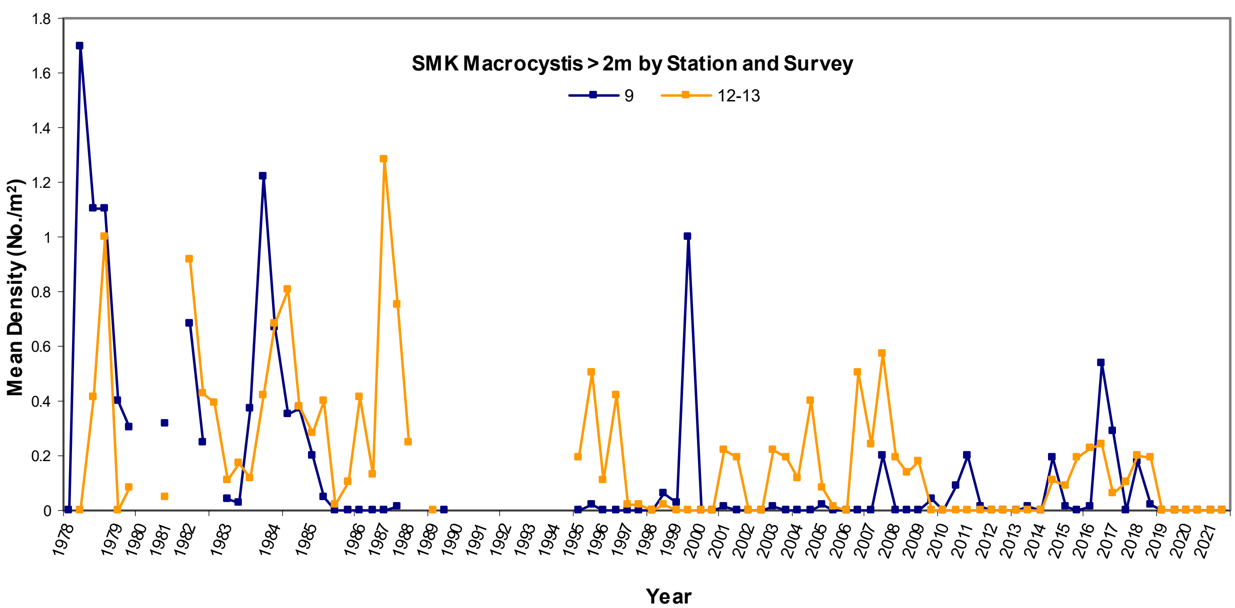


Figure 3-3. Variability in mean density of adult (> 2m tall) giant kelp (No./m^2) among the stations in A) San Onofre Kelp Forest (SOK) and B) San Mateo Kelp Forest (SMK). Fixed quadrat data were plotted for the period 1978 through December 1980; random quadrat data for the period 1981 through 2021.

Previous studies have determined that densities within SOK showed statistically significant differences among stations and through time (SCE 1992). Reduction in kelp densities in 1982-1983, 1986, 1993, and 1997 coincided with extended periods of higher-than-normal ocean temperatures associated with El Niño events (SCE 1984, 1987, 1994, 1998). However, increases in kelp density did not always correspond with cooler-than-normal temperature periods associated with La Niña years, and increases in kelp density (seen at most other southern California kelp beds in late 1989-1990) did not occur in SOK until 1991 (North and MBC 2001). Correlations between densities and three-month mean sea surface temperatures (the month of the survey and the two preceding months) showed little direct relationship. For example, higher-than-normal SSTs in 1981 and 1992 were followed by periods with high densities of giant kelp (in 1981 the increase in density occurred primarily at the station north of the discharge, but in 1992 it was more widespread), while after above-average SSTs in 1997 kelp recruitment was seen only at one station until 1999, when it became more widespread (Figure 3-3A). In 1992, this increase in giant kelp may have been due to prolonged upwelling in June with bottom temperatures below 14°C (57°F) during a year otherwise characterized by higher-than-average temperatures. In 2004, giant kelp densities increased after six years of low densities, the first notable recruitment event in SOK since the peak in 1996 (Figure 3-2). Even though densities decreased between 2005 and 2006, recruitment since the end of 2006 generally persisted, and giant kelp densities remained relatively stable through 2013. This disconnect between cooler temperatures and recruitment in SOK was evident in the 2010 through 2013 surveys. Temperatures in 2010 and 2011 were below the long-term average for the area (SCE 2011, 2012), while by mid-2012 they shifted back above the average (SCE 2013). During this period, although recruitment was evident at stations in SOK, overall densities did not increase to levels seen in prior recruitment episodes. With the relatively warm temperatures recorded since 2014, recruitment has dropped to very low levels and mean densities decreased to the current low levels.

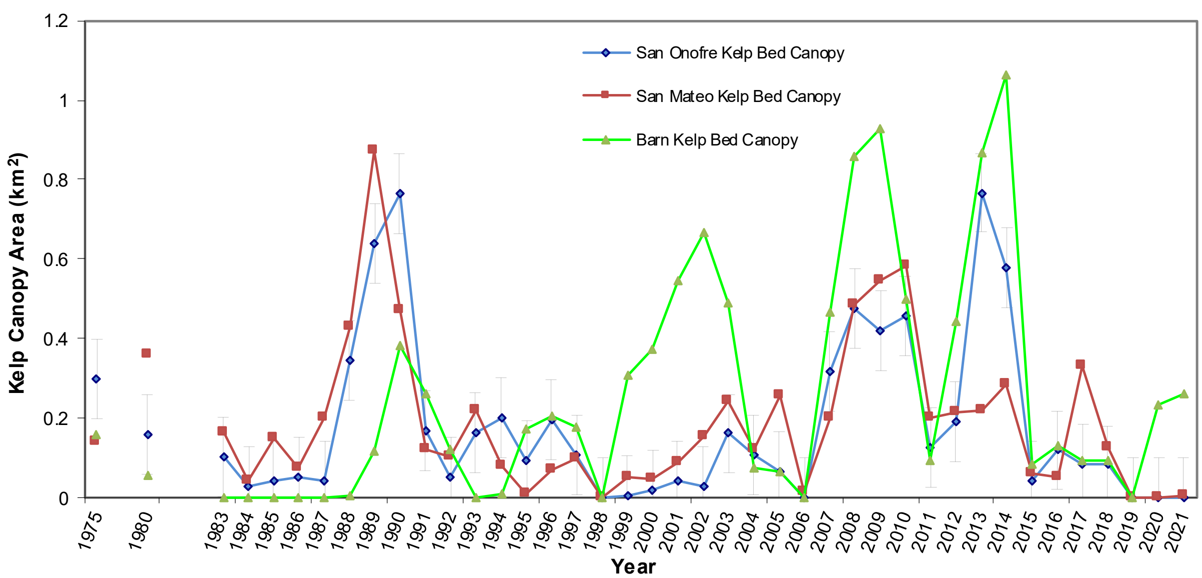


Figure 3-4. San Onofre Kelp, San Mateo Kelp, and Barn Kelp areal canopy coverage showing greatest canopy extent (km^2) during each calendar year, 1975 – 2021 (non-consecutively) (MBC 2022).

Episodic El Niño events can have a severe negative impact on the health of kelp beds in the Southern California Bight (Foster et al. 2013). Temperatures above 17°C (64°F) generally indicate water with very low nutrient content, with each one-degree centigrade (1.8°F) reduction in temperature approximately doubling the availability of nitrates to kelp (Haines and Wheeler 1978; Gerard 1982). Surface (and bottom) temperatures were above average during almost all of 2014 through 2019 (SCE 2015–2020); in 2020 and 2021 mean temperatures were cooler than in the 2015-2019 period (Table 2-1, Figures 2-6 through 2-8 this report), although warmer than the 2005 to 2013 period (SCE 2006-2014). Unusually warm north-Pacific Ocean temperatures were recorded in August and September of 2013 and remained above average in southern California from July of 2014 through April of 2019 (DiLorenzo and Mantua 2016, SCE 2014-2020) which reduced surface canopy and recruitment during that period. The kelp canopy in SOK, which increased in size from 2011 to a record value in 2013 (the largest recorded since 1983 when annual overflight monitoring was initiated [MBC 2020]), virtually disappeared in the last half of 2014 as the higher water temperatures persisted (SCE 2015); reductions were also seen at nearby kelp beds (Figure 3-4 [reflected in 2015, as canopy values graphed are from the greatest canopy extent during the calendar year]). The decline in canopy and mean density of giant kelp in SOK since 2014 is possibly a result of the unusually warm surface water temperatures observed in the northeast Pacific Ocean which reduces the availability of nutrients needed to sustain growth.

The periods of cooler bottom temperatures (<14°C, generally associated with increased nutrients [Dayton et al. 1999]) were infrequent and of short duration from 2014 through 2016 at continuous temperature Station F2S (SCE 2015–2017); however, cool bottom temperature was more frequent in 2017 and 2018, particularly during spring and early summer (SCE 2018, 2019), in March and April in 2019 (SCE 2020), and March through May this year (Chapter 2, this report). Since 2014, surface canopy decreased (Figure 3-4), and nutrient availability (based on temperatures each year) was low, although sporadic recruitment was noted in 2016, and juveniles and subadult kelp were observed at most stations during random surveys in 2017 and 2018, but not within the fixed quadrats. Although adult giant kelp was present sporadically in 2020 (SCE 2021), it was absent in SOK in 2021 during all fixed and random surveys. During 2021, bottom temperatures were below 14°C only in winter at Station F2S (Chapter 2, data appendix), and warm summer surface temperatures may have reduced surface canopy formation (Mabin et al. 2019). The variability in kelp beds among years can be seen in Figure 3-4, which shows canopy coverage among three adjacent kelp beds; SOK and SMK studied in this report, and an adjacent kelp bed downcoast of SONGS, Barn Kelp. Although all three kelp beds depicted show generally similar trends, they peak in different years. These three kelp beds have differing maximum bottom depths and substrates which may explain the variation in surface canopy based on the nutrient supply in deeper water and substrate stability (e.g. cobble versus boulder/rock bottom).

Historically, peak densities of adult giant kelp in main SOK generally showed dissimilar seasonal and annual timing among stations in random quadrat surveys, with peak densities reported at all five stations only in 1992 (Figure 3-3). Typically, these high densities are not consistent year to year, and lower densities between peaks tend to last several years. In 1988, density peaks occurred at four of the five SOK stations, with Station 22 reaching a peak in 1989. In 1992, individual stations reached their peak densities during different surveys; they were highest at the inshore, southern-most station (Station 23) in March 1992, and then were highest at more northern stations in SOK during the subsequent surveys. Since 1992, densities have peaked at three or more stations in main SOK during the same year only twice: in January 1998, after which densities decreased sharply, and in 2003 when maximum densities varied among stations by season. This indicates that the kelp bed is dynamic, with microhabitats likely a result of differing depth, sporophyll sources, bottom temperature, and substrate availability. These microhabitats affect recruitment success differently throughout the kelp bed and growing season. Previous reports have suggested that SOK and SMK are out of phase with each other in recruitment success (SCE 1991, 1993), and this appears to be true on the smaller scale of stations within SOK as well.

Station 14-15 also appears to fluctuate in a different pattern than the five stations in main SOK, with a different timing of peak densities, as well as relative measured densities (Figure 3-3). In both 1988 and 1992 when the other five SOK stations all reached their respective peak densities, kelp density at Station 14-15 decreased from its high value from the previous year. Between 1999 and 2005 high urchin densities appear to have regulated giant kelp densities at Station 14-15. After a decline of urchins began in 2007, it was noted that recruitment occurred for most monitored algal species including giant kelp, which peaked in density in June 2018; it was the only station with a consistent presence of giant kelp in 2020, and had the highest densities of subadult and adult giant kelp size categories throughout the year.

Using the fixed quadrat data, correlation analysis was performed in 1991 to evaluate changes in kelp densities on a small scale versus densities of potential herbivores (sea urchins), physical characteristics (percent sand), and competitors (stalked kelp, oarweed) in both SOK and SMK (SCE 1991). This failed to show expected relationships based on long-term data at SOK, revealing only a few possible direct relationships between densities of adult giant kelp and densities of sea urchins at Station 22 and between adult giant kelp and stalked kelp at Fixed Quadrats 18 and 22. In addition, the correlation between all giant kelp showed a possible relationship with stalked kelp at Fixed Quadrat 17.

COMPARISON WITH GIANT KELP AT SMK

Prior to 1989, giant kelp densities at SMK were consistently two to four times greater than those as SOK, except for late 1979 and mid-1986 (Figure 3-5). From 1989 to 1994 SMK was not monitored as a result of the removal of all kelp by urchins. Since monitoring resumed in 1995 after the kelp bed re-established, the kelp bed with the highest mean giant kelp densities has alternated between SOK and SMK, with SOK having greater densities per survey more frequently than SMK. From 2015 through 2018 SMK has had higher giant kelp densities than SOK, but SMK kelp has been absent since that time with none recorded in 2021.

From 1977 to the late 1980s, densities of adult giant kelp at SMK exhibited periods of extreme fluctuations similar to those noted at SOK (Figures 3-3B and 3-5). While the temporal patterns prior to 1986 were similar between SMK stations, they were not always synchronous, and generally reached peak densities during different surveys or years (SCE 1980, 1985). In 1986, however, sea urchin grazing virtually eliminated the kelp population at the shallow SMK station, Station 9. By 1988 these grazing impacts were evident at the deeper station, Station 12-13, with the virtual elimination of giant kelp by 1989 (SCE 1987, 1990). When monitoring resumed in 1995, however, giant kelp had returned to Station 12-13 while Station 9 remained a sea urchin barren. Prior to these urchin grazing events, density of giant kelp at Station 12-13 in SMK was generally higher than at the stations in SOK, and Station 12-13 typically ranked either first or second in density for all giant kelp size categories for either kelp bed.

The recruitment of giant kelp at Station 9 in 2009 continued into 2011, and then few giant kelp were recorded from 2012 through early 2013 (Figure 3-3 B). A recruitment pulse began in late-2013 and giant kelp were recorded into 2018. In 2019, no giant kelp of any size class were observed in either fixed or random quadrat surveys. Since 1995, Station 9 had previously only experienced two giant kelp recruitment periods—in 1999 and 2007—as sea urchin densities have fluctuated. Adult giant kelp densities have fluctuated from 2014 through 2018 with relatively low sea urchin densities during that time period (Figure 3-3 B).

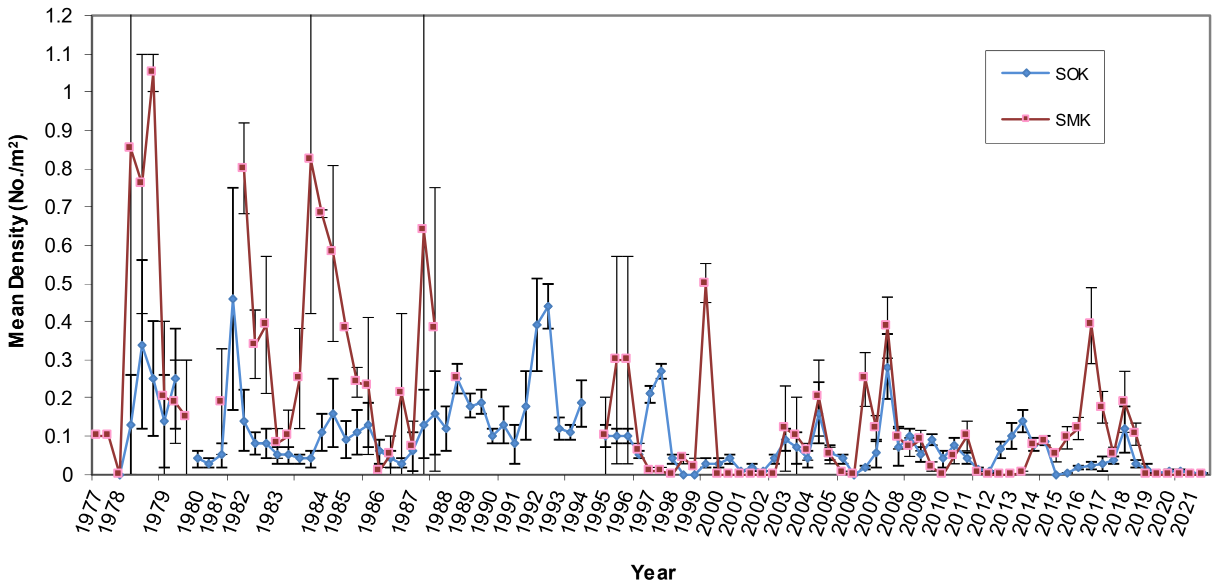


Figure 3-5. Mean density (No./m^2) (±1 standard error) of adult giant kelp (> 2 m tall) from fixed and random quadrat data from six stations in San Onofre Kelp Forest (SOK) and two in San Mateo Kelp Forest (SMK). Fixed data were plotted for the period 1978 through December 1980; random data for the period 1981 through 2021.

Giant kelp at Station 12-13 appeared to recover after 1997, concurrent with reductions in sea urchin densities of 75-90% (SCE 1998). Giant kelp densities fluctuated between 2000 and 2010, when densities fell to zero and remained there until recruitment was recorded in 2014, simultaneous with a decrease in sea urchin densities to fewer than 2 individuals/m^2. Although adult giant kelp densities have fluctuated since 2014, giant kelp has not been recorded during either fixed or random quadrat surveys since 2018. Sea urchin abundance has remained low at Station 12-13 since 2014, and although an increase was recorded in 2019, urchin densities decreased further in 2021 from the declining values seen in 2020 (SCE 2021).

SUBSTRATE

The six stations in SOK have consistently fit into two categories based on substrate composition: those with high proportions of sand (and corresponding low proportions of cobble and boulder), and those with low proportions of sand (Figure 3-6, SCE 1979-2021). Stations 16-17 and 22 are stations with substantial amounts of sand, where cobble generally accounts for less than 20% of the substrate. Low-sand stations are those with consistent contribution of 50% or more cobble (Stations 10, 14-15, 18-19, and 23). Substrate characteristics at stations within SOK have remained relatively stable through time with only occasional, usually short-term, changes in relative contributions. Long-term data, and the means-sampling-technique (SCE 1995), have consistently shown this difference.

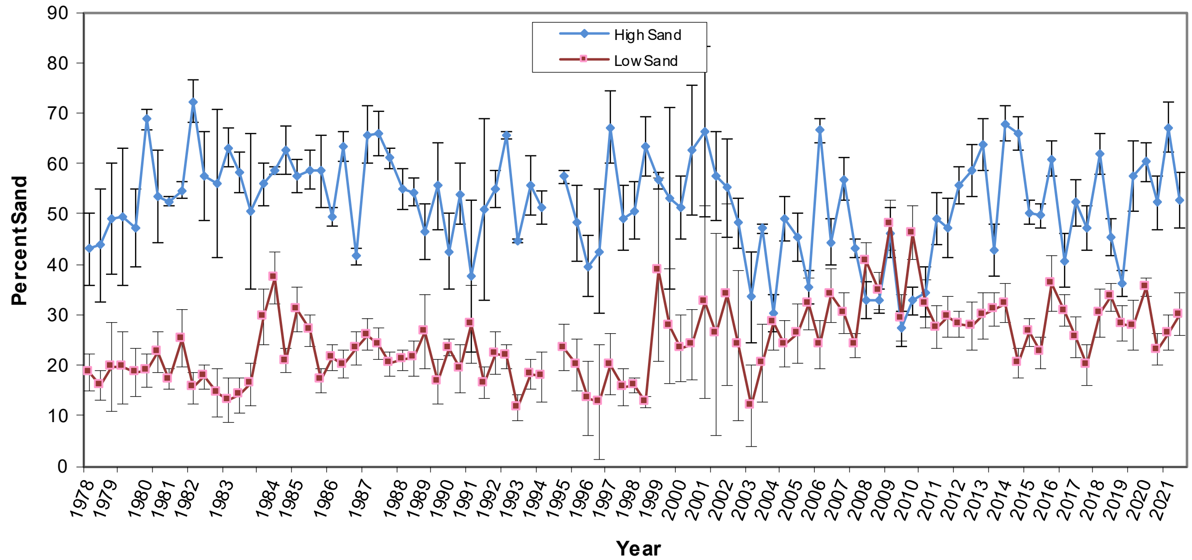


Figure 3-6. Mean (±1 standard error) proportions of sand in station categories with consistently high (N=2) and low (N=4) percentages of sand calculated from random and fixed quadrat data for six stations in the San Onofre Kelp Forest (SOK). Fixed data were plotted for the period from 1978 through December 1980; random data from 1981 through 2021.

An increase of sand coverage was observed during late-1985 and 1986 near Stations 16-17 and 22 as well as other areas of SOK and near the Unit 2 diffuser terminus (Murdoch et al. 1988, SCE 1989). Additional sand intrusions occurred at Station 14-15 in 1984; Station 16-17 in early 1992; Station 10 in 1981, 1984, 1985, and 1989; Station 18-19 in 1984, 2003, and 2008-2010; and Station 23 in 1984 and 1991. Some of the variability between stations may be explained by inherent differences in the specific locations surveyed through the use of randomly located quadrats. However, quantitative data collected by the line contact study (1980-1989) suggested that a sand lens slowly passed through Station 16-17 between 1980 and 1985, while another sand lens persisted at Station 22 (SCE 1991).

At Station 22 substrate composition changed in 1991 when the proportion of sand decreased to that characteristic of the “low sand” category rather than the “high sand” substrate typical of the station (SCE 1994, Chapter 3; Figure 3-6). This short-term trend reversed in 1992, and the proportion of sand increased to levels consistent with years prior to 1990. Interestingly, the proportion of sand in the fixed quadrat at Station 22 in 1992 did not show the same decreasing pattern noted in the random quadrat survey, demonstrating the presence of small-scale changes in sand cover in SOK (SCE 1992). From 1995 to 1997 the fixed quadrat at Station 22 was almost completely covered with sand (>90%) with a thickness estimated at 0.6 m (two feet), while the proportion of sand throughout the area represented by the random sampling was about 65%. Since then, sand cover at Station 22 has fluctuated from a high of 83% in 2001 to a low of 24% in 2009; in 2021 sand coverage averaged 49% among the fixed and random quadrat surveys.

Sand cover at Station 16-17 has fluctuated between a high of 63.8% in 2006 and a low of 17.5% in 2008. Station 16-17 has generally recorded lower random and fixed quadrat sand percentages than at Station 22. Percentages since 2000 have typically been less than 50%, with an average of 83% between the two survey types in 2021.

Sand cover at Station 18-19 has also been variable, with the normally cobble-dominated sediments buried in sand during 1999-2001, in 2005, and from 2008 to 2010; sand coverage decreased somewhat since then, but exceeded 50% coverage through mid-2014, and then decreased in 2015 to 44%. These shifts blurred the distinction between the low-sand and high-sand station categories since 2013, with the mean sand proportions varying 10% to 20% every few years. Mean sand proportion was 52% in 2021.

In 2021, differences between the two sand category groups were similar to values since 1989 (Figure 3-6). In contrast, sand percentage at SMK has remained relatively stable, with greater variability since 2007 compared to earlier years, but with no evidence of sand movement on the scale noted at SOK has occurred at the quadrats in SMK.

The proportion of sand has been more variable on both large and small scales at those stations with higher proportions of sand, and those stations nearest to the diffusers in main SOK. This sand movement has had considerable influence on the giant kelp community. For example, giant kelp densities were high in the fixed quadrat at Station 22 in 1989, but giant kelp was absent and the quadrat covered with sand during the following survey in mid-1990. This suggests that giant kelp is more likely to be disturbed and exhibit more population fluctuations in areas with high proportions of sand. This was substantiated by analysis that suggested that densities of adult giant kelp differed among areas with different proportions of sand cover (i.e., high sand [>50%], low sand [>10% and <30%], and very low sand [<10%]), and also differed through time (SCE 1991). Since the area nearest the diffusers typically has higher proportions of sand than other stations, the giant kelp population within SOK at stations closest to the diffusers were more likely to exhibit fluctuations than areas in SOK with lower proportions of sand, and at SMK which has very low sand coverage.

The amount of sand cover plays a key role in the availability of hard substrate for giant kelp recruitment, especially at SOK where sand movement is common on both small and large scales (Devinny and Volse 1978). Even in areas of SOK where large-scale sand movement has not been observed there has been some evidence of localized sand movement. At SMK, both amount of sand and variability in percent sand cover were considerably less than at SOK (Figure 3-7). Sand coverage in SMK has shown more variability since 2008 compared to the 1995-2007 period, but is similar to that seen in the 1980's. The amount and movement of sand affect the subtidal community, particularly one with giant kelp. At SOK, sand cover and movement are key factors determining availability of hard substrate, creating open space, scouring rock surfaces, and decreasing available light. At SMK, sand plays a smaller role within the kelp bed community.

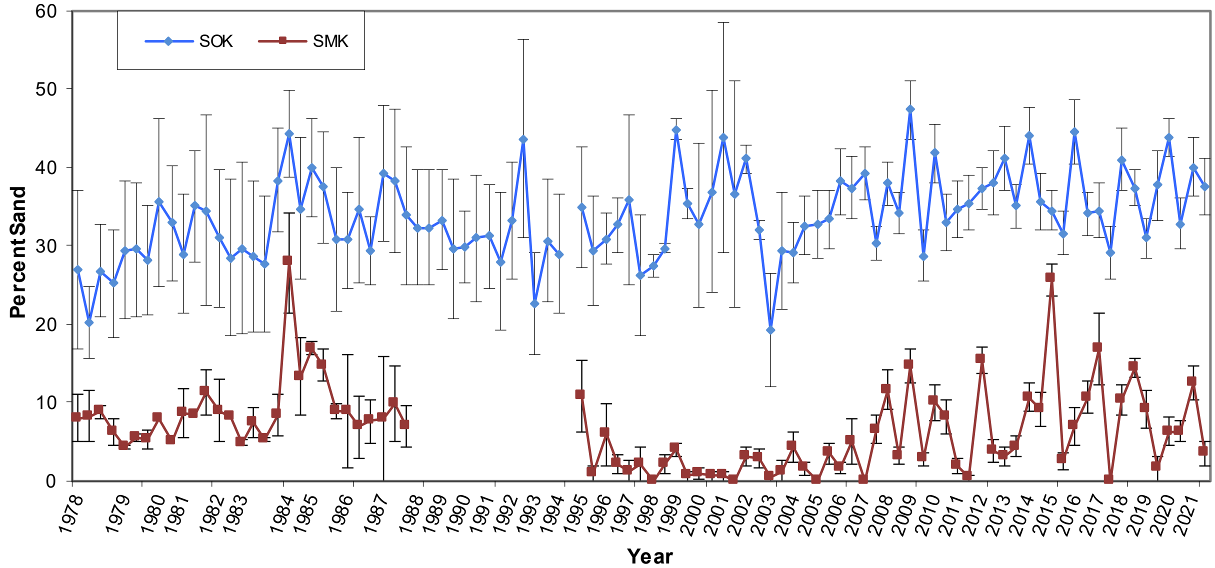


Figure 3-7. Mean (±1 standard error) proportions of sand at San Onofre Kelp and San Mateo Kelp calculated from random and fixed quadrat data for six stations in the San Onofre Kelp Forest (SOK) and two stations in San Mateo Kelp Forest (SMK). Fixed data were plotted for the period from 1978 through December 1980; random data from 1981 through 2021.

While sand cover has fluctuated at SOK, proportions of boulder have remained fairly constant and low (usually <30%) at each station. In contrast, the two SMK stations have similarly low proportions of sand (usually <10%) and high proportions of boulder and cobble (Tables 3-6 and 3-7; Figure 3-7). From 2003 to 2005, however, higher proportions of boulder were observed at most stations in SOK, including Stations 10, 16-17, and 22 (>30%). These stations are located adjacent to each other, offshore and downcoast of the diffusers, suggesting that substrate changes in the area would likely influence these stations similarly. In 2008, percentages of boulder at most stations returned to a typical level for SOK of less than 30%, and remained so through 2016, with higher values noted at individual stations on several surveys. The mean for the random surveys in 2020 for all stations was 23.7%, with percentages at two of the six stations the same or higher than the mean during both surveys and at two other stations during one survey. During this same period, proportions of cobble, boulders, and sand were relatively stable at the two stations in SMK, with slight differences depending on the measurement technique. Because stations closest to the diffusers had significantly higher proportions of sand before SONGS began operation, analysis comparing stations in SOK and SMK has shown that the effect of distance from the diffusers was indistinguishable from the effect of decreasing proportions of sand with distance from the diffusers (SCE 1991).

UNDERSTORY KELPS

Understory kelps may compete for attachment space with giant kelp and by shading or abrading newly recruited juvenile and subadult giant kelp, thus reducing the likelihood of giant kelp attachment and survival. There were two periods of notable recruitment of stalked kelp: in 1979, with a mean density peak of 6 kelp/m^2, and 1988, with a mean peak density of 3 kelp/m^2 (Figure 3-8). During the 16-year period from 1979 to 1994 stalked kelp was typically present at all stations during all surveys, and it was only absent from one station per survey during nine surveys. From 1995 to 2008 and 2012 to 2016, overall mean stalked kelp densities were recorded at less than 0.3 kelp/m^2, and it was only recorded at two or three stations during any survey. Historically, stalked kelp densities have been highest at Station 23 (1986 through 1989), Station 18-19 (single surveys in 1990 and 1991), Station 14-15 (late-1991 through October 1992), Station 10 (December 1992), and Station 14-15 (late-1995 to 1997) (SCE 1987-1993, 1996-1998). Stalked kelp densities of 1 to 2 kelp/m^2 occurred at station 23 in 2003, Station 14-15 in 2004, and at Station 22 in 2005 (SCE 2004-2006). From 2009 through 2011 stalked kelp was recorded at two to four stations per survey and density peaked in June 2011. In 2018, mean densities increased to a peak of 0.8 kelp/m^2, and in 2021 stalked kelp was recorded at two to three stations during the fixed surveys with a mean density of 0.4 kelp/m^2; mean density increased throughout the year, and highest survey density occurred at both Stations 22 and 23 in December (Table 3-4).

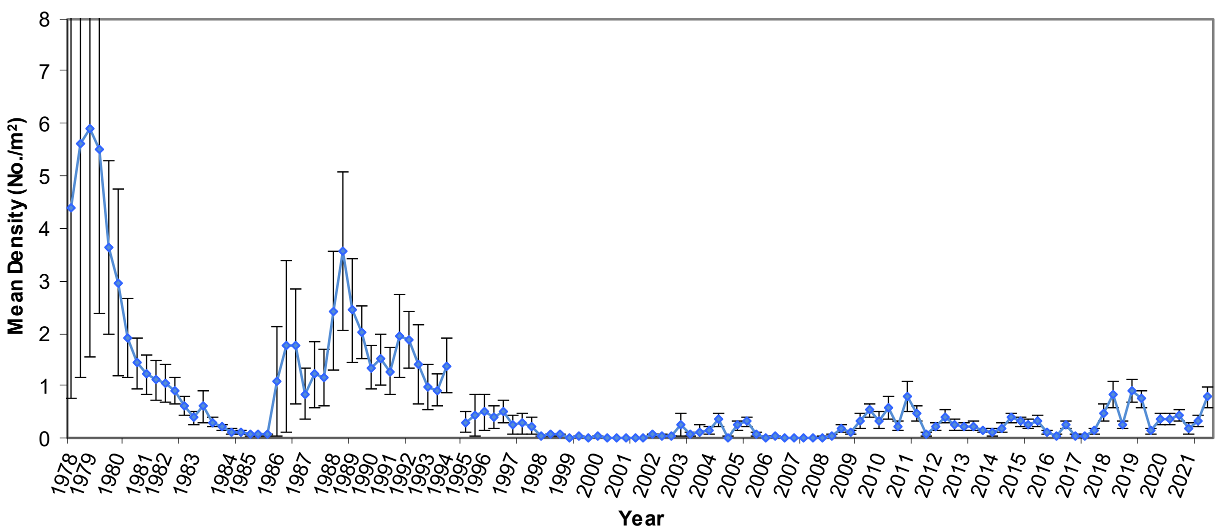


Figure 3-8. Mean (±1 standard error) density of stalked kelp (*Pterygophora californica)* per m^2 from random and fixed quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted from 1978 to December 1980 and from 1995 to 2021; random data from December 1980 through 1994.

Historically, oarweed occurred infrequently in surveys, with densities below 0.3 kelp/m^2 until 1994, when a density of 0.8 kelp/m^2 was reported at Station 14-15 (SCE 1995). Although mean survey densities of oarweed have typically remained about 0.3 kelp/m^2 since 1994, higher densities have been recorded at individual stations. Densities have trended downward over time, decreasing from a peak value of 6.0 kelp/m^2 at Station 14-15 in 1999 (SCE 2000); values in 2021 averaged 0.2 kelp/m^2 and peaked at 0.7 kelp/m^2 at Station 14-15.

Bladder chain kelp was generally present only at Station 23 (the shallowest station) in surveys prior to 2003, but that year moderate densities were noted at Stations 10 and 22, with highest densities of 5.5 kelp/m^2 reported at Station 23 (SCE 2004). Between 2004 and 2014 mean annual densities were less than 0.3 kelp/m^2, however, since 2016 densities have averaged equal or greater than 2.0 kelp/m^2. In 2021, bladder chain kelp averaged 2.0 kelp/m^2 and peaked at 7.9 kelp/m^2 at Station 22 during the September survey.

LARGE INVERTEBRATE SPECIES

Red and purple sea urchins are the primary invertebrate grazers on giant kelp in southern California (Dayton et al. 1984) so information on their abundance is important for this study. Mean densities of purple and red sea urchins in SOK have varied throughout the study period. When the study was initiated in 1978, mean densities were around 1 urchin/m^2 and then decreased steadily to less than 0.1 urchin/m^2 by 1983 (Figure 3-9). During this period urchins were generally present at all six SOK stations, but densities varied among stations. Up to 3.8 urchins/m^2 were recorded at Station 18-19, but densities at most other stations were between 0.1 and 0.5 urchin/m^2. From 1983 to 1989, urchin densities at all stations were generally between 0.1 to 0.5 urchin/m^2. Since 1990, urchin densities have shown a cyclical pattern, with densities peaking about every three to five years, followed by a decrease before increasing again. Peak mean densities were reached in 1992, 1996, 2001, 2004, and 2011, with the highest mean density of 5.9 urchins/m^2 in 2004. There was considerable variation among stations during these periods of high sea urchin abundances, and during these years highest densities occurred at different stations within SOK. Peak densities at each station were: Station 22 at 3.3 urchins/m^2 in 1992, Station 18-19 at 9.3 urchins/m^2 in 1996, Station 14-15 at 14.3 urchins/m^2 in 2001, Station 23 at 33.3 urchins/m^2 in 2004, and at Station 16-17 with 15.1 urchins/m^2 in 2011 (SCE 1993, 1997, 2002, 2005, 2012).

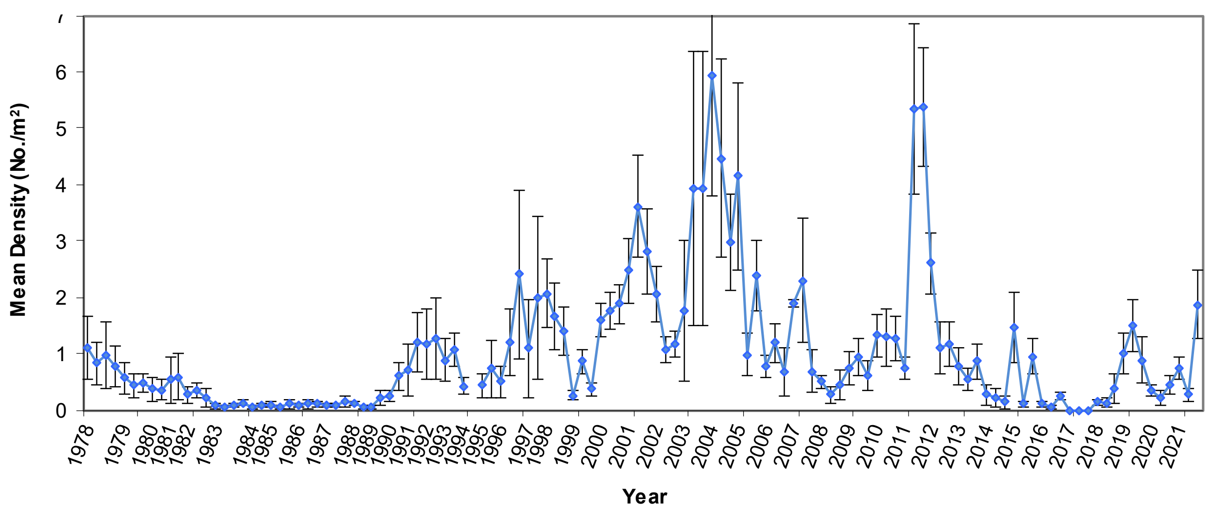


Figure 3-9. Mean (±1 standard error) density of purple and red sea urchins (*Strongylocentrotus* spp) per m^2 calculated from random and fixed quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted from 1978 to December 1980 and from 1995 to 2021; random data from December 1980 through 1994.

Other than the peak in 2011 there was a general decrease in purple and red sea urchin densities since 2004, with mean densities below 1 urchin/m^2 with periodic peaks for individual surveys greater than 1.0 urchins/m^2 (Figure 3-9). In 2021, mean densities increased above 0.5 urchin/m^2, with the highest station density at Station 14-15 in November with 9.2 urchins/m^2. Fluctuations in sea urchin density are common. The purple sea urchin aggregates, and high densities often precede an onset of feeding behavior that removes all algae from an area. Consequently, high densities may signal the beginning of a sea urchin feeding aggregation, such as the one that apparently depleted kelp at several stations throughout the 1980s and created an urchin barren in SMK (SCE 1987).

However, low densities observed in the past six years may be associated with a recent mortality episode for urchins (Hendler 2013).

White sea urchin, which also graze on giant kelp, peaked in density in SOK in 1986 with more than 15 urchins/m^2. Densities decreased to less than 0.1 urchins/m^2 from 1990 through 1991, and 1994 through 2020, with a slight increase in 2021 (Figure 3-10). The increase in mean density in the early 1980s was due primarily to high abundances at Station 18-19, where densities increased to 46 individuals/m^2 in 1986, and then decreased to near zero by 1990. Elevated densities of white sea urchin (approximately 15 individuals/m^2) were also observed at Stations 10 and 23 from 1985 through 1986. From 1990 to 2020, mean densities remained near zero, except for a slight increase in 1992. Since 2002, white sea urchin was observed sporadically at Stations 14-15, 16-17, and 23 in relatively low densities of less than 0.9 individuals/m^2. During 2021, white sea urchin mean density was 0.3 urchins/m^2 and they were observed at Stations 10 and 18-19.

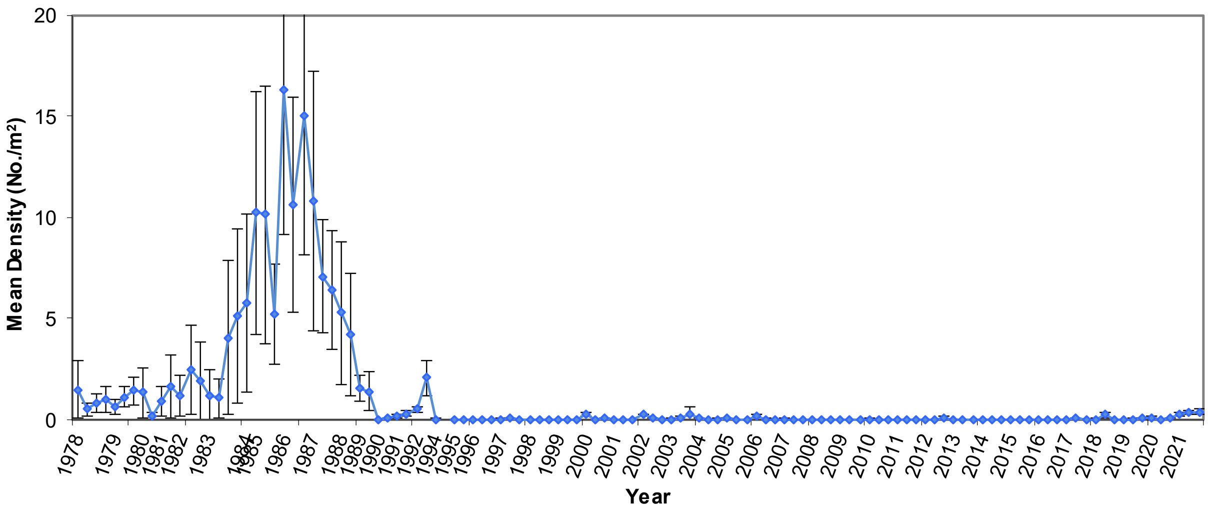


Figure 3-10. Mean density (±1 standard error) of white sea urchin (*Lytechinus pictus*) per m^2 from random and fixed quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted from 1978 to December 1986 and from 1995 to 2021; random data from 1987 through 1994.

Mean density of bat star, a white sea urchin predator, was approximately 1.5 individuals/m^2 in late-1978 in SOK. That survey was followed by a decrease in numbers over a four-year period, and mean densities have consistently been below 0.25 individuals/m^2 since 1982 (Figure 3-11). This decrease at SOK was similar to decreases documented throughout southern California during the same period (Schroeter et al. 1983; Dean et al. 1984). During 1990, 1991, 1992, and 2003, bat star densities of greater than 0.25 individuals/m^2 occurred at Station 14-15, but these were much lower than densities observed in 1981. During surveys in March 1992, bat stars were observed with a tissue-rot disease like that seen during the 1982-1984 El Niño. This may partially explain the decrease in density for the species to near zero from 1994 to 2001. From 2002 through 2013, a general increase in densities was noted, and bat star mean density fluctuated from about 0.05 to 0.25 individuals/m^2. In 2010 and 2011 bat star was recorded at most stations in SOK, reaching a mean density of 0.50 individuals/m^2, with a peak density of 1.40 individuals/m^2 at Station 14-15. From 2014 through 2020 mean densities declined to less than 0.1 individuals/m^2. In 2021 bat star densities increased slightly to 0.11 individuals/m^2 (it was recorded in a single survey at Station 14-15 and all three surveys at Stations 10 and 18-19).

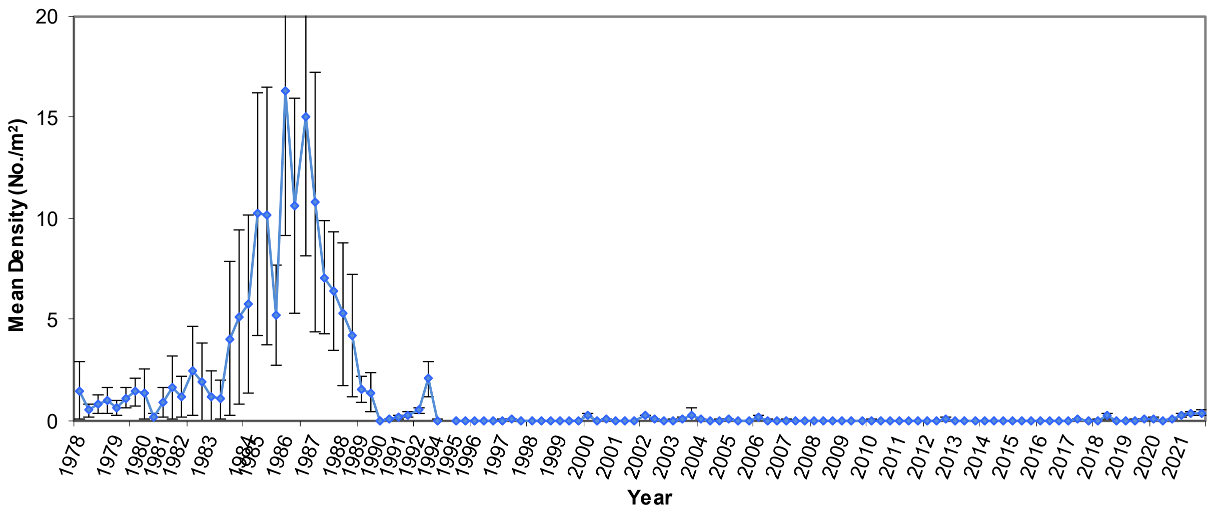


Figure 3-11. Mean (±1 standard error) density of bat star (*Patiria miniata*) per m^2 from random and fixed quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted from 1978 to December 1980 and from 1995 to 2021; random data from 1981 through 1994.

The larger Pacific sea stars (particularly, giant-spined star) were commonly observed off San Onofre at most stations in low densities (less than 0.05 individuals/m^2) until 1989. Between 1990 and 2013 Pacific sea stars were observed at fewer stations, but in generally higher densities (up to 0.30 individuals/m^2) than those reported prior to 1989 (Figure 3-12). Densities increased beginning in 1989 and peaked in August 1992 (mean of 0.22 individuals/m^2) and December 1996 (0.40 individuals/m^2). During 1996, no Pacific sea stars were present during the June survey, though by December they were present at all stations except for Station 22. The highest density in 1996 occurred at Station 23 with 1.0 individuals/m^2, while densities at the other stations ranged from 0.2 to 0.5 individuals/m^2.

From 1996 to 2013, giant-spined star was present at one or more station in every survey, except one survey each in 1997, 1999, and 2010. Mean densities in that period typically varied from 0.05 to 0.20 individuals/m^2 in SOK. In 2003, 2006, and 2011, mean densities of Pacific sea stars were similar to levels recorded in the early 1990s (>0.20 individuals/m^2) at SOK stations; during those years they occurred at three or more stations. Following the first survey in 2014 no Pacific sea stars have been observed, including in 2021. This corresponds to a decline in sea stars along the entire U.S Pacific coast associated with a disease referred to as Sea Star Wasting Syndrome which has affected multiple sea star families and reduced populations significantly (Jurgens et al. 2015).

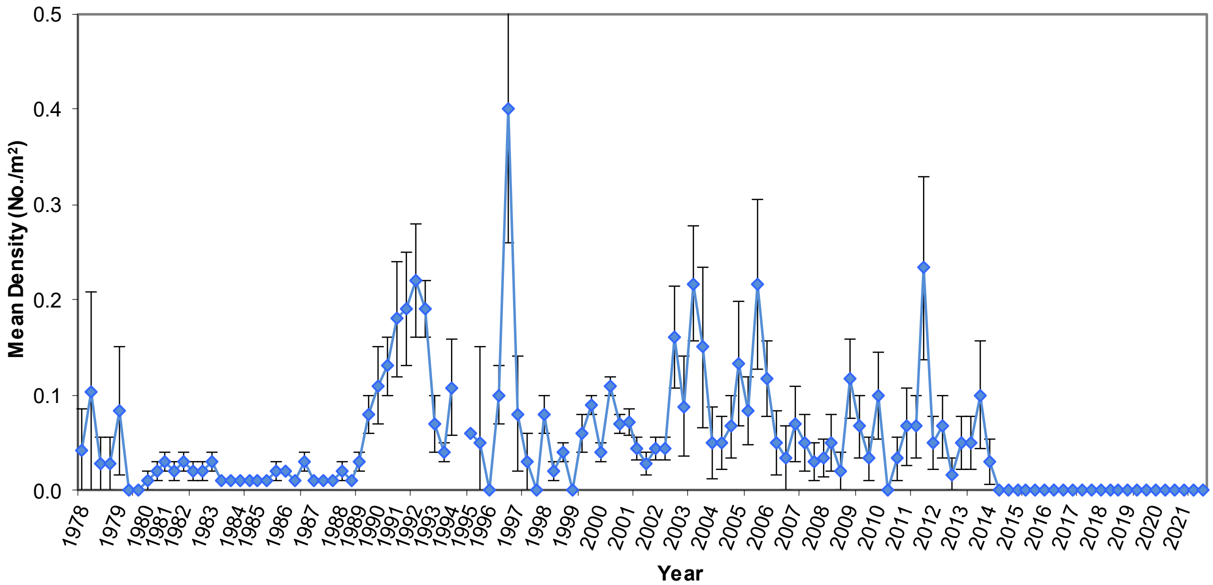


Figure 3-12. Mean (±1 standard error) density of *Pisaster* spp (mostly *P. giganteus*) per m^2 from random and fixed quadrat data from six stations in San Onofre Kelp Forest (SOK). Fixed data were plotted for 1978 to December 1980 and from 1995 to 2021; random data from 1981 through 1994.

CONCLUSIONS

Southern California giant kelp forests are not permanent and persist in an area only while physical and environmental conditions are favorable. Kelp forest size, condition, and even community structure can vary considerably over periods of months and years, particularly in areas of unstable substrate such as cobble (small, movable rocks) and sand as occurs at SOK (North and MBC 2001). Boulders, which are relatively permanent and provide a more stable attachment for giant kelp than cobble, cover only about 25–30% of the area at SOK stations. Although proportions of cobble and sand differ considerably among areas within SOK, the relatively high percentages of sand compared to other southern California giant kelp forests, and the shifting nature of sand, create a seafloor with a changing mosaic of substrate constituents including variable areas of hard substrate, relatively elevated levels of sand scour, and generally more turbid water (SCE 1988). Sand movement is a very important factor in the ability of giant kelp to attach, establish, and survive. If an area that normally has suitable hard substrate is covered by sand, it will not support giant kelp. In addition to sand, the predominant hard substrate at SOK is cobble, which is also prone to movement by bottom surge, particularly when giant kelp is attached (because giant kelp becomes more buoyant as it grows, large kelp can cause cobble-sized stones to float off the bottom and be carried away by currents). In contrast, the higher proportion of boulders and relatively little sand results in a more stable hard-substrate habitat at SMK.

While the changing substrate components affect the distribution and persistence of giant kelp, so do biological factors such as competition for space, presence of grazers, and presence or absence of predators on the grazers. The negative effects of sea urchin grazing on kelp are apparent in the current monitoring program by: (1) low densities of giant kelp at Station 18-19 when sea urchin densities were high; (2) the virtual elimination of kelp at Stations 9 and 12-13 in SMK between

1986 and 1989 by an active feeding front of sea urchins that left much of the kelp forest substrate barren; and (3) the shift to a sea urchin barren at SOK Station 14-15 where historically giant kelp was relatively persistent, and now showing algal growth with the recent decrease in urchins. Contrary to the expected response, however, numbers of native sea urchin predators did not increase in response to the increased number of urchins.

In 2021, in SOK there was a continuing increase in competing understory kelps, while giant kelp was not observed during any survey; it was last recorded in November 2019. At SMK in 2021, giant kelp was not observed during any survey; it was last recorded in 2018. In SMK, the understory kelps showed a variable pattern among the different species monitored, but their combined coverage increased from 2020. Urchin density increased at SOK and decreased at SMK from the prior year. However, the urchin density at both kelp beds in 2021 was well below values recorded in SOK in 2011 and at SMK when Stations 9 and 12 were both urchin barrens in 2008 and 2009, respectively. The unusually warm water temperatures observed the past six years are likely to have been strong influence on the kelp density for both kelp beds by reducing the available nutrients.

LITERATURE CITED

Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). 1993. Ecology of the Southern California Bight. Los Angeles: Univ. Calif. Press. 926 p.

Dayton, P.K., V. Currie, T. Gerrodette, B.D. Keller, R. Rosenthal, and D.V. Tresca. 1984. Patch dynamics and stability of some California kelp communities. Ecological Monographs: 54(3) 253-289.

Dayton, P.K., M.J. Tegner, P.E. Parnell, and P.B. Edwards. 1992. Temporal and Spatial Patterns of Disturbance and Recovery in a Kelp Forest Community. Ecological Monographs 62(3): 421-445.

Dayton, P.K., M.J. Tegner, P.B. Edwards and K.L. Riser. 1999. Temporal and spatial scales of kelp demography: the role of oceanographic climate. Ecological Monographs, 69(2): 219-250.

Dean, T.A., S.C. Schroeter, and J.D. Dixon. 1984. Effects of grazing by two species of sea urchins (S. franciscanus and L. anamesus=pictus) on recruitment and survival of two species of kelp (M. pyrifera and Pterygophora). Marine Biology 78: 301-313.

DiLorenzo, E.D. and N Mantua. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Climate Change 6:1042-1047.

Devinny, J.A. and L.A. Volse. 1978. Effects of sediments on the development of Macrocystis pyrifera gametophytes. Marine Biology 48: 343-348.

Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: A community profile. U. S. Fish and Wildlife Service Biological Report 85. 152 p.

Foster, M.S., D.C. Reed, M.H. Carr, P.K. Dayton, D.P. Malone, J.S. Pearse, and L. Rogers-Bennett. 2013. Kelp Forests in California. Smithsonian Contributions to the Marine Science. 39:115-132,

Gerard, V.A. 1982. In situ rates of nitrate uptake by giant kelp, Macrocystis pyrifera (L.) C Agardh: tissue differences, environmental effects, and predictions of nitrogen limited growth. J. Exper. Mar. Biol. Ecol., 62:211-224.

Hendler, G. 2013. Recent mass mortality of *Strongylocentrotus purpuratus* (Echinodermata: Echinoidea) at Malibu and a review of purple sea urchin kills elsewhere in California. Bull. S. Cal. Acad. Sci. Vol. 112:19-37. Available at: http://scholar.oxy.edu/scas/vol112/iss1/2

Haines, K.C. and P.A. Wheeler. 1978. Ammonium and nitrate uptake by the marine macrophytes Hypnea musciformes (Rhodophyta) and Macrocystis pyrifera (Phaeophyta). J. Phycol. 14:319-324.

Jurgens L.J., L Rogers-Bennett, P.T. Raimondi, L.M. Schiebelhut, M.N. Dawson, R.K.Grosberg, B. Gaylord (2015) Patterns of Mass Mortality among Rocky Shore Invertebrates across 100 km of Northeastern Pacific Coastline. PLoS ONE 10(6): e0126280. 21 p. doi: 10.1371/journal.pone. 0126280.

Kuhn, G.G. and F.P. Shepard. 1984. Sea Cliffs, Beaches, and Coastal Valleys of San Diego County, California. University of California Press. Berkeley. 175 p.

Mabin, C.J.T., C.R. Johnson, and J.T. Wright. 2019. Physiological response to temperature, light, and nitrates in the giant kelp *Macrocystis pyrifera* from Tasmania, Australia. Mar. Ecol. Prog. Ser . Vol. 614: 1–19.

MBC Aquatic Sciences. 2020. Status of the Kelp Beds in 2020: Orange and San Diego Counties. August 18, 2020. Prepared for the Region Nine Kelp Survey Consortium. 54 p. plus appendices.

MBC Aquatic Sciences. 2022. Status of the Kelp Beds in 2021: Orange and San Diego Counties. In Prep.

Murdoch, W.W., B.J. Mechalas, and R.C. Fay. 1988. Final technical report to the California Coastal Commission. B: Cohesive sediments in the San Onofre kelp forest. Unpublished draft copy of a Marine Review Committee Document prepared by S. C. Schroeter and John Reitzel. Encinitas, CA. 58 p.

North, W.J. and MBC Applied Environmental Sciences. 2001. Status of the Kelp Beds of San Diego and Orange Counties for the years 1990 to 2000. Prepared by MBC Applied Environmental Sciences. Costa Mesa, CA. 86 p. + appendices.

Pearse, J.S. and A.H. Hines. 1979. Expansion of a central California kelp forest following the mass mortality of sea urchins. Marine Biology 51: 83-91.

Rosenthal, R.J., W.D. Clarke, and P.K. Dayton. 1974. Ecology and natural history of a stand of giant kelp, Macrocystis pyrifera, off Del Mar in a southern California kelp forest. Oecologia 56: 141-147.

Schiel, D.R. and M.S. Foster. 1986. The Structure of Subtidal Algal Stands in Temperate Waters. Oceanography and Marine Biology Annual Review 24: 265-307.

Schroeter, S.C., J. Dixon, and J. Kastendiek. 1983. Effects of the starfish Patiria miniata on the distribution of the sea urchin Lytechinus anamesus=pictus in a southern California kelp forest. Oecologia 56: 141-147.

Southern California Edison Company (SCE). 1979. Annual Operating Report for the San Onofre Nuclear Generating Station. Vol. IV. Biological, sedimentological, and oceanographic data analysis. January-December 1978. Prepared by Brown and Caldwell, Lockheed Center for Marine Research, and Marine Biological Consultants, Inc. 79-RD-54. 300 p.

_____. 1980. Annual Operating Report, San Onofre Nuclear Generating Station, Volume V, Biological and Oceanographic Data Analysis - 1979, Environmental Technical Specifications – Unit 1, Preoperational Monitoring Program – Units 2 and 3. Prepared by Brown and Caldwell, Lockheed Center for Marine Research, and Marine Biological Consultants, Inc. 80-RD-100.

_____. 1981. Oceanographic and Biological Annual Operating Report, San Onofre Nuclear Generating Station. Volume III: Marine Environmental Analysis and Interpretation, Environmental Technical Specifications Unit 1, National Pollutant Discharge Elimination

System Units 1, 2, and 3; Construction Monitoring Program Units 2 and 3; and Preoperational Monitoring Program Units 2 and 3. Prepared by Brown and Caldwell, Lockheed Environmental Sciences, and Marine Biological Consultants, Inc. 81-RD-9.

_____. 1982. Oceanographic and Biological Annual Operating Report, San Onofre Nuclear Generating Station. Volume III: Marine Environmental Analyses and Interpretation, Environmental Technical Specifications Unit 1; National Pollutant Discharge Elimination System - Units 1, 2, and 3; and Preoperational Monitoring Program - Units 2 and 3. Prepared by Brown and Caldwell, Lockheed Ocean Science Laboratories, and Marine Biological Consultants, Inc. 82-RD-51.

_____. 1983. Report on 1982 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Lockheed Ocean Science Laboratories; Brown and Caldwell; MBC Applied Environmental Sciences; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Occidental College; Tekmarine, Inc.; and Southern California Edison Company. 83-RD-10.

_____. 1984. Report on 1983 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by WESTEC Services, Inc.; EcoSystems Management; Kinnetics Laboratories; Natural History Museum of Los Angeles County; W.J. North; Occidental College; Tekmarine, Inc.; and Southern California Edison Company. 84-RD-63.

_____. 1985. Report on 1984 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by WESTEC Services, Inc.; EcoSystems Management; Kinnetics Laboratories; Natural History Museum of Los Angeles County; W.J. North; Occidental College; Tekmarine, Inc.; and Southern California Edison Company. 85-RD-37.

_____. 1986. Report on 1985 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by WESTEC Services, Inc.; Natural History Museum of Los Angeles County; W.J. North; Tekmarine Inc.; and Southern California Edison Company. 86-RD-26.

_____. 1987. Report on 1986 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by WESTEC Services, Inc.; Brown and Caldwell; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Occidental College; Tekmarine, Inc.; and Southern California Edison Company. 87-RD-31.

_____. 1988. Report on 1987 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by WESTEC Services, Inc.; Brown and Caldwell; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Occidental College; Tekmarine, Inc.; and Southern California Edison Company. 88-RD-35.

_____. 1989. Report on 1988 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 89-RD-11.

______. 1990. Report on 1989 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; Natural History Museum of Los Angeles County; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 90-RD-50.

______. 1991. Report on 1990 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 91-RD-10.

______. 1992. Report on 1991 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company. 92-RD-7.

______. 1993. Report on 1992 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by ERC Environmental and Energy Services Company; EcoSystems Management; W.J. North; Tekmarine, Inc.; and Southern California Edison Company.

______. 1994. Report on 1993 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

______. 1995. Report on 1994 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

______. 1996. Report on 1995 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; W.J. North; MBC Applied Environmental Sciences; and Southern California Edison Company.

______. 1997. Report on 1996 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 1998. Report on 1997 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 1999. Report on 1998 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 2000. Report on 1999 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 2001. Report on 2000 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 2002. Report on 2001 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 2003 Report on 2002 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by Ogden Environmental and Energy Services Company; EcoSystems Management; and Southern California Edison Company.

______. 2004 Report on 2003 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2005 Report on 2004 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2006 Report on 2005 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2007 Report on 2006 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2008 Report on 2007 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2009 Report on 2008 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2010 Report on 2009 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2011 Report on 2010 Data, Marine Environmental Analysis and Interpretation, San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison Company.

______. 2012. 2011 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

______. 2013. 2012 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2014. 2013 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2015. 2014 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2016. 2015 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2017. 2016 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences and Southern California Edison.

_____. 2018. 2017 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Applied Environmental Sciences.

_____. 2019. 2018 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

_____. 2020. 2019 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

_____. 2021. 2020 Annual Marine Environmental Analysis and Interpretation - San Onofre Nuclear Generating Station. Prepared by MBC Aquatic Sciences.

Stewart-Oaten, A., W.R. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67:929-940.

Tegner, M.J. and P.K. Dayton. 1987. El Niño effects on southern California kelp forest communities. Advances in Ecological Research 17: 243-274.

_____. 1991. Sea urchins, El Niño, and the long-term stability of southern California kelp forest communities. Marine Ecology Progress Series 77: 49-63.

Tegner, M.J., P.K. Dayton, P.E. Edwards, and K.L. Riser. 1996. Is there evidence for long-term climatic change in southern California kelp forests? CalCOFI Report 37: 111-126.

_____. 1997. Large-scale, low-frequency oceanographic effects on kelp forest succession: a tale of two cohorts. Marine Ecology Progress Series 146: 117-134.

Appendix 3 -1. Synopsis of SCE hard-bottom subtidal studies conducted offshore of San Onofre, 1963 through 2021.

Program	Total No of Surveys	No of Samples per year	No of Stations	Sampling Area (m^2)	No of Sampling Areas / Station	Types of Data Collected
MARINE ENVIRONMENTAL MONITORING (MEM) PROGRAM						
Preliminary Survey 1963	1	*	*	*	*	A
Unit 1 Preoperational Benthic Sampling 1964-1966	6	1-2	9	*	*	A
Unit 1 Transitional Benthic Sampling 1966-1967	2	2	4-6	*	*	A
Unit 1 Operational Benthic Sampling 1968-1975	12	2	7-9	1	3	B
SAND DISPOSAL MONITORING PROGRAM (SDMP) 1974-1976	9	4	5	4	2 random 2 fixed	B
ENVIRONMENTAL TECHNICAL SPECIFICATIONS (ETS) 1975-1981	25	4	11(3)	10	10 fixed	C
CONSTRUCTION MONITORING PROGRAM (CMP) 1976-1980	15	4	2(2)	10	10 fixed	C
PREOPERATIONAL MONITORING PROGRAM (PMP) mid-1978 to mid-1980	8	4	10(8)	6, 0.125	1 fixed, 4 random	D
BENTHIC SENSING PACKAGES (BSP) mid-1979 to mid-1980	NA	Continuous	5**	NA	NA	E
MARINE REVIEW COMMITTEE (MRC)						
Kelp Transect Studies 1979-1981	10	4	13	300	NA	F
Pendleton Artificial Reef Studies	5	3	9	200,5,5	20 random, 6 fixed, 4 random	G
INTERIM KELP PROGRAM (IKP) 1980-1984	10	3	8(8)	960,36,3	12 random, 6 fixed, 3 fixed	H
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)						
mid-1981	1	1	11(3)	10	10 fixed	C
mid-1981 TO 1984	11	3	8(8)	960,36,3	12 random, 6 fixed, 3 fixed	H
OPERATIONAL NPDES PROGRAM						
1984 to 1994	33	3	8§(8§)	960,36,3	12 random, 6 fixed, 3 fixed	H
1995 to present	9	3	8(8)	800,24,4	10 random, 4 fixed, 4 fixed	I

* Undefined

** At PMP Stations

A Qualitative observations with estimates of abundance of flora and fauna to species level over an unidentified area.

B Visual estimates of % cover or abundance of flora and fauna to species level in a defined area.

C Quantitative estimates of % sand, % rock, % cover of flora and fauna to species level, and abundance of solitary invertebrates and kelp by visual estimation, also temperature and visibility estimates.

D Quantitative estimates of % sand, % rock, % cover of flora and fauna to species level, and abundance of kelp and macroinvertebrates by point contact technique (300 points in fixed, 60 points in random). Also, temperature and visibility estimates.

E Estimates of total organic carbon and sediment deposition, temperature, and light penetration.

F Estimates of kelp and concomitant grazer abundance, nutrients, temperature, light penetration, and sedimentation rates at San Onofre Kelp.

G Quantitative estimates of % sand, % rock, % cover of flora and fauna to species level, and abundance of select invertebrates and kelp by point contact and visual estimation techniques, also temperature, depth, and visibility estimates.

H Estimates of % sand, % cobble, % boulder, abundance of dominant kelp and grazer species at San Onofre Kelp and San Mateo Kelp (12 random 10 m2 circular plots sampled at each site; 2 fixed 6 m2 quadrats at each old PMP site; and 3 fixed 10 m2 transects at old ETS and CMP sites). Done to meet NPDES requirements beginning mid-1981. Fixed areas sampled 3 times per year throughout study; random sampled 3 times per year through 1987, thereafter sampling was done twice per year. § SMK stations not sampled after 1989.

I Estimates of % sand, % cobble, % boulder, abundance of giant kelp at San Onofre Kelp and San Mateo Kelp (10 random 10 m2 circular plots sampled at each site; 1 fixed 6 m2 quadrat at each old PMP site; and 1 fixed 10 m2 quadrat at old ETS and CMP sites). Fixed areas sampled 3 times per year throughout study; random sampled 2 times per year. Fixed sampling also includes counts of other kelps, sea urchins, and sea stars. Done to meet NPDES requirements.

( ) Number in parentheses denotes number of kelp bed stations ( )

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CHAPTER 4 IN-PLANT FISH ASSESSMENT

INTRODUCTION

In-plant fish monitoring at the SONGS is a component of the NPDES requirements. Impingement monitoring is conducted by observing number of organisms trapped on the onshore traveling screens. The term "impingement" refers to entrapped fish caught on traveling screens in the SONGS screenwells. However, impingement monitoring requires the operation of two circulating water intake pumps to provide pressure to wash traveling screens. In addition, the fish return systems integral to the Units 2 and 3 circulating water systems also require a circulating water pump to provide the water stream needed to return entrained organisms back to the ocean. Since shutdown of Unit 2 and 3 these features are no longer in use and the intake flows are the result of the operation of saltwater dilution pumps from both Units 2 and 3 intake structures that discharge through the Unit 2 outfall.

In 2021, the intake water average daily use (10.4 MGD) was approximately 99% lower compared to operational conditions (1,218 MGD). The lower intake volumes from the dilution pumps reduce intake flow velocities and likely allow fishes to avoid entrainment into the onshore circulating water system. The forebays are inspected on a monthly basis; no fish have been observed in the water during these inspections.

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CHAPTER 5 FISH POPULATION MONITORING

INTRODUCTION

SCE is required to monitor and assess the annual and long-term effects of the operation of SONGS on the marine environment surrounding the discharges. The fish population study includes fish trawls over soft-bottom habitat using sampling methods consistent with other NPDES ocean monitoring programs conducted throughout southern California, including the Bight Regional Monitoring Program (Walther et al. 2017). The NPDES permit issued in 2015 (Order No. R9-2015-0073, effective in 2016) reduced the trawl survey frequency from quarterly to semiannual. In compliance with NPDES permit requirements, and as described by the Interim Monitoring Program (SCE 1982), the semiannual trawl surveys were conducted in the receiving waters offshore of SONGS and at reference stations located (1) upcoast from SONGS at San Mateo Point, and (2) downcoast at Don Light (Figure 5-1). The spatial distribution of fishes was analyzed using both data collected this year and data collected previously in the area to determine any potential effect on fish distribution from the discharge of water from SONGS. It should be noted that both SONGS units were taken offline in January 2012 with some cooling water pumps operated through May 2013. All circulating water pumps were turned off when SONGS was permanently closed in June 2013. Since the closure, only saltwater dilution pumps, rather than the larger capacity circulating water pumps, have remained operational for dilution needs as SONGS proceeds through the decommissioning phase. The current seawater intake at each unit is less than one percent of design-flow pumping capacity.

METHODS

STUDY SITES

In April (spring) and December (fall) 2021 otter trawl surveys were conducted at three sites established for the Interim Monitoring Program (SCE 1982): San Onofre (SO), San Mateo Point (SM), and Don Light (DL) (Figure 5-1). San Mateo (northern reference site) and Don Light (southern reference site) are located approximately 5 km north and 8.5 km south of SONGS, respectively. All three sites are characterized by soft-bottom seafloor, with rocky reefs in the vicinity of San Mateo and San Onofre. The trawl stations at San Mateo are situated on the east and west sides of the SONGS mitigation reef project, while at San Onofre the middle isobath is close to natural rock reef structure. Stations were labeled by depth from offshore to nearshore. Stations on the 18.3-m (60-ft) isobath were designated by the Number 1 (Stations SM1, SO1 and DL1). Stations SM2, SO2, and DL2 were located on the 12.2-m (40-ft) isobath, and Stations SM3, SO3, and DL3, were on the 6.1-m (20-ft) isobath.

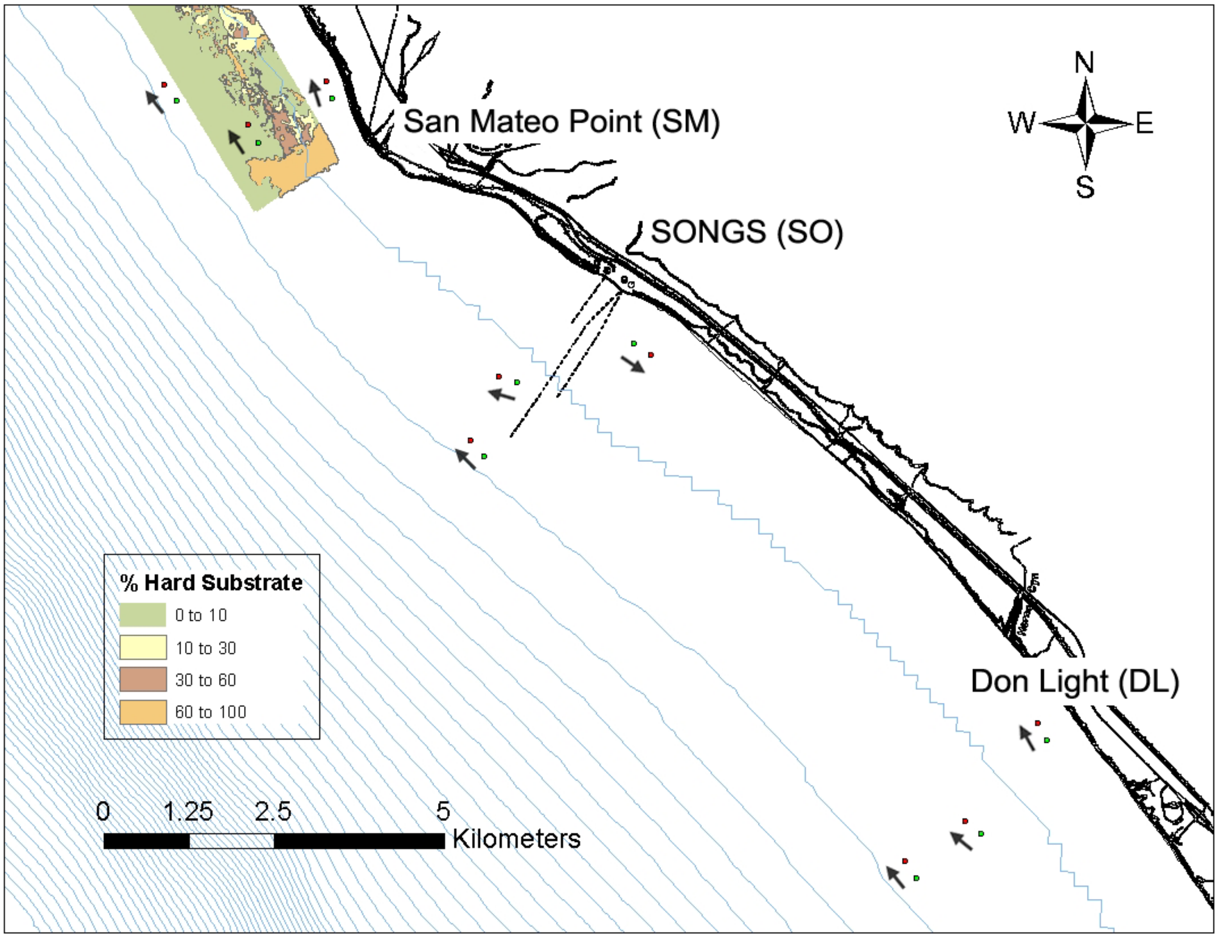

Figure 5-1. Location of three trawling sites (each site with three sampling stations) offshore of San Mateo Point, San Onofre Nuclear Generating Station (SONGS), and Don Light. Blue lines represent 10-m depth contours. Green and red dots represent the start and end locations of each trawl, respectively, with an arrow indicating the direction of the tow.

SAMPLING

Sampling was completed using a 7.6–m semi-balloon otter trawl net towed at a speed of 1.5–2.5 knots for five minutes. Two tows were conducted at each station. Fishes caught in each replicate tow were sorted, identified, enumerated, and weighed to the nearest 0.01 kilogram (weight data not presented). The standard length (SL) of each fish was measured to the nearest millimeter for up to 125 individuals of each species; if more than 125 individuals of the same species remained, those fish were batch-weighed and their remaining abundance was derived by estimation. For species represented by fewer than 125 individuals in a single tow, all individuals were measured and weighed. Where possible, sex was also determined for up to 50 measured individuals for a select group of species. Historically, White Croaker (*Genyonemus lineatus*), Northern Anchovy (*Engraulis mordax*), and Queenfish (*Seriphus politus*) smaller than 30 millimeters (mm) SL were counted, but these individuals were excluded from abundance totals due to the poor sampling efficiency of the net for small individuals of these species. In 2021, there were no fish from these three species caught that measured less than 30 mm SL. Data collected since 1995 were included in this report for a historic perspective.

ANALYSIS

Comparisons of fish abundances were made between stations for all species by depth, season, and total annual catch. Replicate tows at each location were combined for the abundance comparisons. Species richness was visualized through generation of species accumulation curves on non-transformed abundance data. Richness examined differences by sampling station location and by depth; a final analysis of the annual differences between San Mateo, San Onofre, and Don Light, irrespective of depth was also performed. Shannon-Wiener diversity indices (H') were calculated for each site and are reported along with abundances in Table 5-1 (Shannon and Weaver 1962). Historical abundance comparisons (since 1995) were made by area and depth for the whole community; data collected prior to 2016 was excerpted by season to match semiannual trawl effort since 2016 as compared to quarterly effort previously. Long-term abundance trends for the three most commonly observed species overall were examined by isobath to identify potential patterns related to the SONGS discharges. Length-frequency histograms of the three most abundant species were presented as the frequency of individuals per 10-millimeter (mm) size class. Common and scientific names of fishes caught during the 2021 surveys are listed in Appendix 5-1. Catch data by season for the 2021 trawls are presented in Appendix 5-2 and by station are presented in Appendix 5-3.

RESULTS

2021 FISH CATCH

A total of 2,233 fish of 27 species were caught in the 2021 demersal fish trawls (Table 5-1). In spring, 1,031 fish representing 19 species were caught, and in fall 1,202 fish representing 22 species were caught. For all stations combined overall diversity for the year was 1.47; in spring the diversity was greatest at San Mateo and lowest at Don Light, while in fall the diversity was greatest at San Onofre and lowest at Don Light. Diversity for all stations combined was higher in spring (1.40) than during the fall survey (1.08). Overall in 2021, the greatest number of individuals were caught at San Mateo during the spring survey, and at Don Light during the fall survey; the greatest number of species was at San Onofre in spring and at both San Onofre and Don Light in fall. The most abundant species in 2021 were Northern Anchovy (40.9%), Speckled Sanddab (*Citharichthys stigmaeus*, 39.9%), and Queenfish (7.8%); the remaining species each individually contributed 2% or less to the catch (Appendix 5-2).

Table 5-1. Location, abundance, number of species, and Shannon-Wiener diversity indices for demersal trawl catch by season, 2021.

Season	Area	Abundance	Species Count	Diversity (H´)
Spring	SM	619	14	1.39
	SO	183	17	1.33
	DL	229	9	0.87
	Total	**1,031**	**19**	**1.40**
Fall	SM	112	9	1.13
	SO	145	15	1.58
	DL	945	15	0.66
	Total	**1,202**	**22**	**1.08**
Annual Total		**2,233**	**27**	**1.47**

Overall, the species accumulation curves showed Don Light and San Mateo were similar in species diversity both seasons, while abundances varied between all three locations. Species richness at San Onofre was highest in spring, while San Onofre and Don Light both had the highest in fall (Figure 5-2). Catch distributions were patchy across locations, depths and seasons, as is common with trawl surveys.

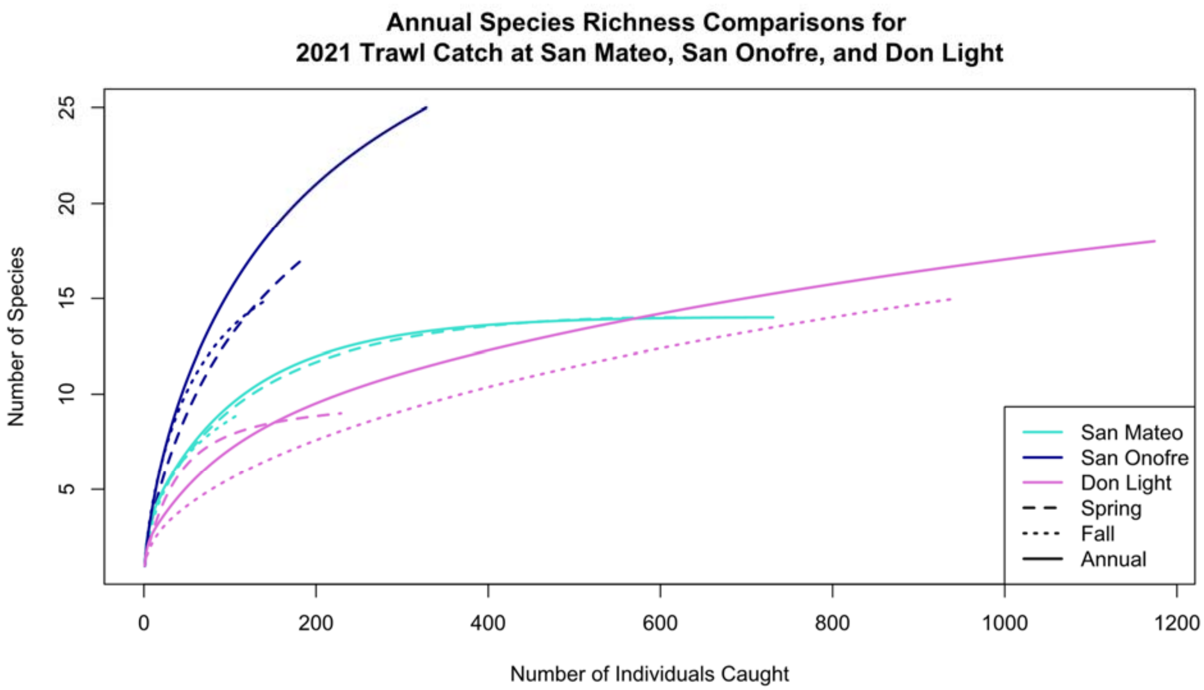

Figure 5-2. Species accumulation curves for all three trawl locations by season and overall, irrespective of depth in 2021.

On the 6.1-m isobath, annually Northern Anchovy was the most abundant species caught, followed by Queenfish and Speckled Sanddab; these three species contributed 91% to the combined total catch for this depth. Combined seasonal diversity was higher overall in the spring (1.39) than in the fall (0.58). Of the 27 species observed across all depths and locations in 2021, 17 of those species were collected on the 6.1-m isobath and 9 of those were uniquely observed at this depth (Appendix 5-2). In spring, the greatest abundance and number of species were caught offshore of San Mateo (Figure 5-3, Table 5-2). Of the nine species observed at this depth in spring, only four were collected at all three locations: Northern Anchovy, Speckled Sanddab, Kelp Pipefish (*Syngnathus californiensis*), and Walleye Surfperch (*Hyperprosopon argenteum*). Queenfish was the most abundant species comprising 42% of the catch in spring, with most caught off San Mateo, followed by Northern Anchovy, which was most abundant off San Mateo. Diversity was highest at Don Light (1.24) and lowest at San Mateo (0.97). During the fall survey at the 6.1-m depth, the greatest number of individuals were caught at Don Light and the greatest number of species at San Onofre. Of the 16 species caught at this depth in fall, only Northern Anchovy was observed at all three locations. In fall, Northern Anchovy had the highest abundance (88% of the total), with most individuals caught off Don Light (Table 5-2). Species diversity was highest at San Onofre (1.87) and lowest at Don Light (0.31).

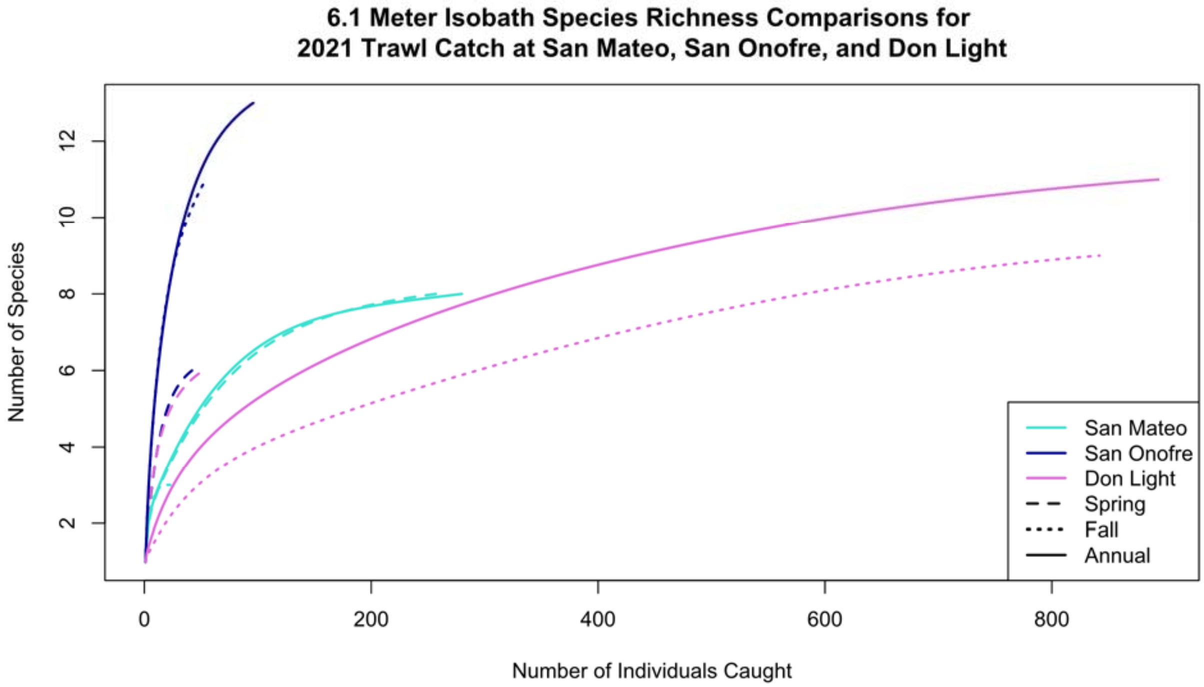

Figure 5-3. Species accumulation curves for three trawl locations by season and overall along the 6.1-m isobath in 2021.

On the 12.2-m isobath, annually Speckled Sanddab was the most abundant species caught comprising 85.5% of the total catch, followed by Vermilion Rockfish (*Sebastes miniatus*) and California Lizardfish (*Synodus lucioceps*), which both contributed about 7% to the overall total. In contrast to the pattern observed for the 6.1-m isobath, diversity at this depth was higher in fall (1.18) than in spring (0.54) (Table 5-2). Of the 27 species observed across all depths and locations in 2021, 15 of those were collected along the 12.2-m isobath, with two species uniquely caught at this depth: Barred Sand Bass (*Paralabrax nebulifer*) and Ocean Whitefish (*Caulolatilus princeps*) (Appendix 5-2). In spring, the greatest abundance occurred at San Mateo and the greatest number of species was taken at both San Mateo and San Onofre (Table 5-2; Figure 5-4). Nine species were observed in spring, with Speckled Sanddab, Vermilion Rockfish, and California Lizardfish (*Synodus lucioceps*) collected at all three locations. Speckled Sanddab was the most abundant species, comprising almost 89% of the catch; diversity was highest at San Onofre (0.84) and lowest at both San Mateo and Don Light (0.42). During the fall survey, nine species were taken, with the greatest abundance and species richness at Don Light. Of the species caught along this isobath in fall, only Speckled Sanddab was collected at all three locations. Speckled Sanddab comprised over 69% of the catch with highest number of individuals taken at Don Light. Species diversity was highest off San Mateo (1.14) and lowest at San Onofre (0.79). The fall catch was more similar among locations than the spring (Figure 5-4).

Table 5-2. Demersal trawl catch distribution at San Mateo (SM), San Onofre (SO), and Don Light (DL) by isobath and season, annual totals, and percent species composition, 2021.

Species	Spring 2021				Fall 2021				Annual	Percent
	SM	SO	DL	Tot.	SM	SO	DL	Tot.	Total	Total
6.1 m (20 ft))										
Northern Anchovy	71	27	4	102	15	5	788	808	910	71.9%
Queenfish	166	-	-	166	5	3	-	8	174	13.8%
Speckled Sanddab	3	4	31	38	-	6	21	27	65	5.1%
Slough Anchovy	-	-	-	-	-	22	23	45	45	3.6%
Kelp Pipefish	5	5	9	14	-	-	2	2	16	1.3%
California Lizardfish	1	-	5	6	-	-	-	-	6	0.5%
Deepbody Anchovy	2	-	-	2	3	4	-	7	9	0.7%
White Croaker	5	1	-	6	-	6	-	6	12	0.9%
Walleye Surfperch	4	3	1	8	-	1	-	1	9	0.7%
California Corbina	-	2	2	4	-	-	1	1	5	0.4%
Shiner Perch	-	-	-	-	-	3	-	3	3	0.2%
Round Stingray						1	2	3	3	0.2%
Thornback	-	-	-	-	-	2	-	2	2	0.2%
California Halibut	-	-	-	-	-	-	2	2	2	0.2%
California Tonguefish	-	-	-	-	-	-	2	2	2	0.2%
Jacksmelt	-	-	-	-	-	1	-	1	1	0.1%
Fantail Sole	-	-	-	-	-	-	1	1	1	0.1%
Total	257	42	52	346	23	54	842	919	1,265	
Number of Species	8	6	6	9	3	11	9	15	17	
Diversity (H′)	0.97	1.18	1.24	1.39	0.88	1.93	0.33	0.58	1.05	
12.2 m (40 ft)										
Speckled Sanddab	174	36	93	303	10	10	25	45	348	85.5%
Vermilion Rockfish	4	2	11	17	-	-	-	-	17	4.2%
California Lizardfish	3	4	2	9	-	1	1	2	11	2.7%
California Halibut	-	2	-	2	5	-	-	5	7	1.7%
Kelp Pipefish	-	-	-	-	-	1	5	6	6	1.5%
Pacific Sanddab	4	-	-	4	-	-	-	-	4	1.0%
Longfin Sanddab	3	-	-	3	-	-	-	-	3	0.7%
Northern Anchovy	-	-	-	-	3	-	-	3	3	0.7%
Longspine Combfish	2	-	-	2	-	-	-	-	2	0.5%
Ocean Whitefish	-	-	-	-	-	-	1	1	1	0.2%
White Croaker	-	-	-	-	1	-	-	1	1	0.2%
Barred Sand Bass	-	-	-	-	-	-	1	1	1	0.2%
Specklefin Midshipman	-	-	-	-	-	1	-	1	1	0.2%
California Tonguefish	-	1	-	1	-	-	-	-	1	0.2%
Fantail Sole	-	1	-	1	-	-	-	-	1	0.2%
Total	190	46	106	342	19	13	33	65	407	
Number of Species	6	6	3	9	4	4	5	9	15	
Diversity (H′)	0.42	0.84	0.42	0.54	1.14	0.79	0.81	1.18	0.73	

Table 5-2. Continued.

Species	SM	Spring 2021 SO	DL	Tot.	SM	Fall 2021 SO	DL	Tot.	Annual Total	Percent Total
18.3 m (60 ft)										
Speckled Sanddab	144	82	60	286	66	68	59	193	479	86.2%
Pacific Sanddab	10	2	4	16	1	1	4	6	22	4.0%
California Lizardfish	3	-	2	5	2	7	5	14	19	3.4%
Longfin Sanddab	7	4	5	16	-	-	-	-	16	2.9%
Hornyhead Turbot	3	1	-	4	-	-	1	1	5	0.9%
Kelp Pipefish	2	1	-	3	1	1	-	2	5	0.9%
California Halibut	2	2	-	4	-	-	-	-	4	0.7%
Specklefin Midshipman	-	-	-	-	-	1	1	2	2	0.4%
Spotted Turbot	-	1	-	1	-	-	-	-	1	0.2%
Plainfin Midshipman	-	1	-	1	-	-	-	-	1	0.2%
Vermilion Rockfish	1	-	-	1	-	-	-	-	1	0.2%
Longspine Combfish	-	1	-	1	-	-	-	-	1	0.2%
Total	172	95	71	338	70	78	70	218	556	
Number of Species	8	9	4	11	4	5	5	6	12	
Diversity (H′)	0.72	0.66	0.59	0.71	0.28	0.50	0.62	0.49	0.66	

Note: "-" = not present

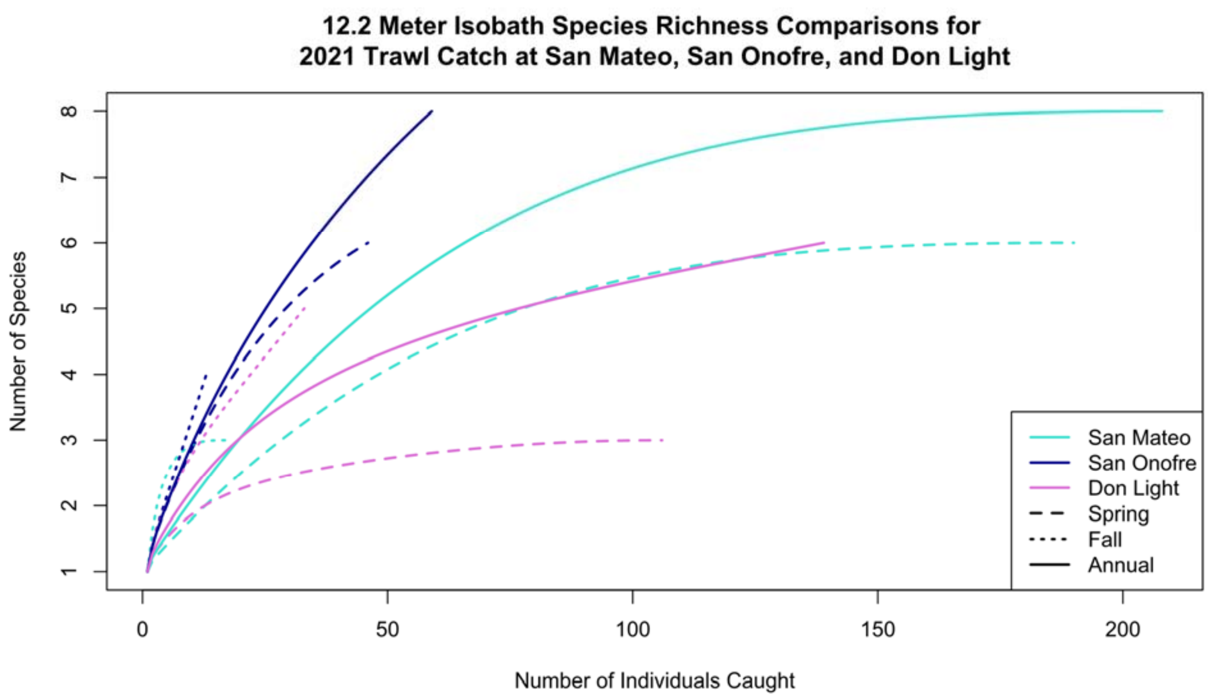

Figure 5-4. Species accumulation curves for all three trawl locations by season and overall along the 12.2-m isobath in 2021.

On the 18.3-m isobath, annually Speckled Sanddab was the most abundant species caught, accounting for 86% of the total catch, followed by Pacific Sanddab (*Citharichthys sordidus*) and California Lizardfish, which contributed 4% and 3%, respectively, to the total. Similar to the shallowest depth, diversity was greater in spring (0.71) than in fall (0.49), and 0.66 overall (Table 5-2). Twelve species were collected, with three species unique, at this depth (Appendix 5-2). There was less variability in number of species and abundance between stations and seasons than at the other two depths (Figure 5-5). In spring, eight species were taken at San Mateo, nine species at San Onofre and four species at Don Light (Table 5-2; Figure 5-5). Eleven species were observed in spring, with Speckled Sanddab, Pacific Sanddab, and Longfin Sanddab (*Citharichthys xanthostigma*) collected at all three locations; all three were most abundant at San Mateo. Speckled Sanddab was the most abundant species in spring, comprising 85% of the catch. Species diversity was highest at San Mateo (0.72) and lowest at Don Light (0.59). During the fall survey, Speckled Sanddab abundance was greatest at San Onofre. Five species were taken at both San Onofre and Don Light. Of the six species caught at this depth, Speckled Sanddab, Pacific Sanddab, and California Lizardfish were collected at all three locations. Speckled Sanddab comprised almost 89% of the catch; California Lizardfish and Pacific Sanddab were the second and third most numerous species caught, contributing 3% and 6% to the seasonal total, respectively. Diversity was highest off Don Light (0.62) and lowest at San Mateo (0.28) in fall.

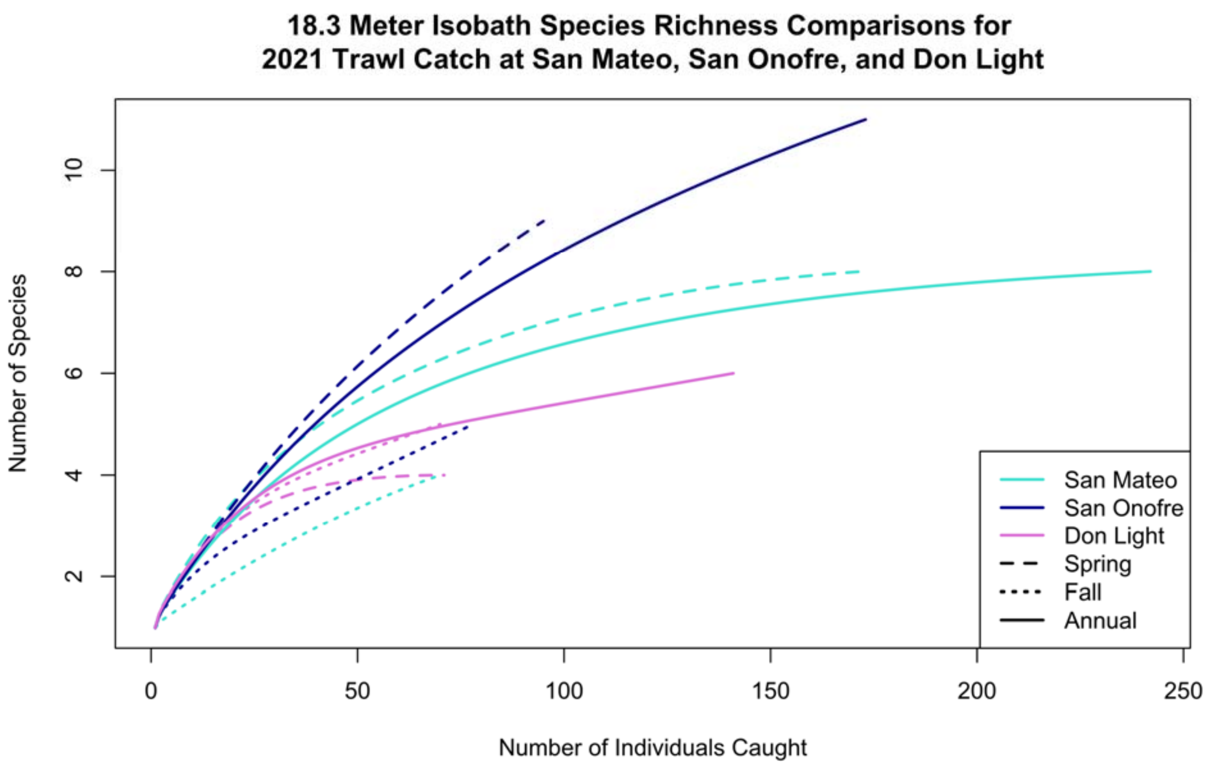

Figure 5-5. Species accumulation curves for all three trawl locations by season and overall along the 18.3-m isobath in 2021.

LIFE HISTORY ANALYSIS

Nine fish species were examined to determine their sex in 2021 (Table 5-3). Of the 47 individuals examined, 31 were female and 16 were male. Queenfish was the most commonly examined species with 17 females and 6 males. California Halibut (*Paralichthys californicus*) had 3 females and 3 males. White Croaker had 3 females and two males. Fewer than 5 individuals of each of the remaining species were able to have sex determined.

Length, or length ranges, of each species by isobath is/are presented for each species taken in 2021 in Table 5-4. In addition, the lengths for the three most abundant species overall were examined for patterns in their distribution among the three isobaths in 2021.

Table 5-3. Number of individuals of each sex identified during trawl surveys during 2021, by species.

Species	F	M	Total
Shiner perch	1	2	3
Northern anchovy	3	-	3
White croaker	3	2	5
Walleye surfperch	-	1	1
California halibut	3	3	6
Thornback	1	1	2
Queenfish	17	6	23
Kelp Pipefish	-	1	1
Round Stingray	3	-	3
Total	31	16	47

Table 5-4. Annual species catch distribution by isobath in 2021, with fish length ranges presented as standard length (SL) unless noted as total length (TL) or disc width (DW).

Species	6.1-m Isobath	12.2-m Isobath	18.3-m Isobath
Barred Sand Bass	-	160	-
California Corbina	75-238	-	-
California Halibut	204-226	195-300	247-310
California Lizardfish	87-102	80-103	76-140
California Tonguefish	125-128	84	-
Deepbody Anchovy	65-97	-	-
Fantail Sole	172	195	-
Hornyhead Turbot	-	-	52-202
Jacksmelt	214	-	-
Kelp Pipefish	133-236	180-258	170-236
Longfin Sanddab	-	134-156	125
Longspine Combfish	-	112-121	106-140
Northern Anchovy	30-96	120-121	-
Ocean Whitefish	-	58	-
Pacific Sanddab	-	111-131	89-157
Plainfin Midshipman	-	-	131
Queenfish	45-153	-	-
Round Stingray	72-235 TL 130 – 155 DW	-	-
Shiner Perch	83-90	-	-
Slough Anchovy	53-99	-	-

Table 5-4. Continued.

Species	6.1-m Isobath	12.2-m Isobath	18.3-m Isobath
Speckled Sanddab	23-115	35-106	35-100
Specklefin Midshipman	-	64	80-81
Spotted Turbot	-	-	56
Thornback	135-256	-	-
Vermilion Rockfish	-	37-47	47
Walleye Surfperch	43-96	-	-
White Croaker	81-147	110	-

Northern Anchovy, the most abundant species overall, had all but three individuals taken on the 6.1-m isobath, where 99.7% of all individuals were taken; length frequency analysis is only presented for the 6.1-m isobath. Distribution was unimodal, with lengths ranging from the 40- to 100-mm size classes, peaking at the 80-mm size class (Figure 5-6). Northern Anchovy spawn all year, with a peak from February to April (Leet et al. 2001). They mature at one to two years and 80 to 130 mm SL (Hunter and Macewicz 1980). Most of the individuals in 2021 were taken in December and were young-of-the-year. Three individuals were taken on the 12.2-m isobath and ranged from 120-121 mm SL; no individuals were taken on the 18.3-m isobath.

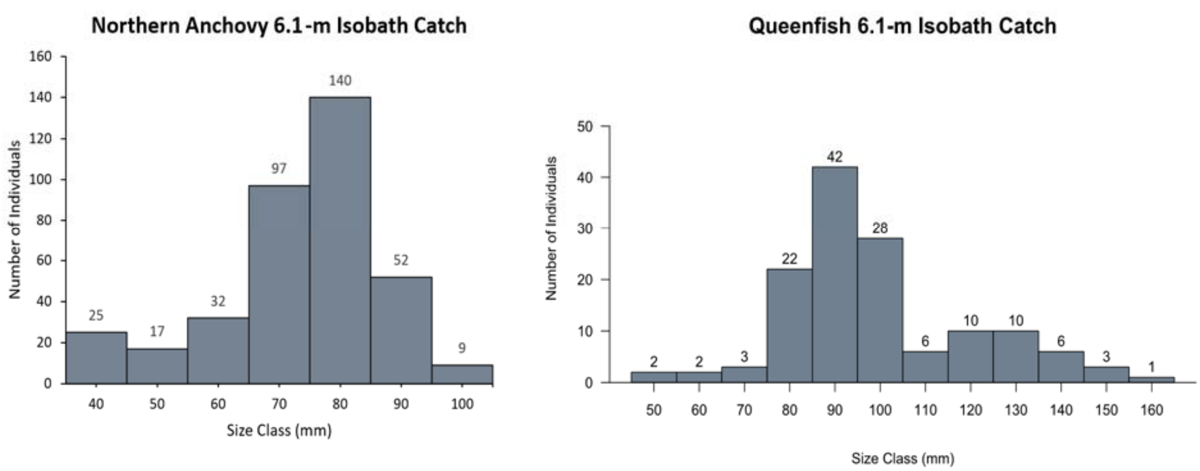

Figure 5-6. Length frequency distribution for Northern Anchovy (left, n = 372) (only presented for the 6.1-m isobath) and for Queenfish (right, n = 135, only present on the 6.1-m isobath) in 2021.

Speckled Sanddab, the second most abundant species, was caught along all three isobaths. The lengths on the 6.1-m and 12.2-m isobaths had a bimodal distribution, the 6.1-m isobath with peaks at the 80-mm and 100-mm size classes and the 12.2-m isobath with peaks at the 60-mm and 90-mm size classes (Figure 5-7). The 18.3-m isobath size classes had a unimodal distribution with a peak at the 70-mm size class. The 6.1-m isobath was only represented by 65 individuals (7.3% of the catch), with the 12.2-m and 18.3-m isobaths with 348 individuals (39%) and 479 individuals (53.7%), respectively. Lengths on the 6.1-m isobath ranged from the 30- to 120-mm size classes, while the 12.2-m and 18.3-m isobaths had similar ranges from the 40- to 110-mm and 40- to 100-mm size classes, respectively. The majority of fish taken along the deepest isobaths were found in the 60- to 90-mm size classes. Speckled sanddab is a small flatfish that is believed to live four years and reach maturity at 90 to 100 mm SL or two years old (Love 2011).

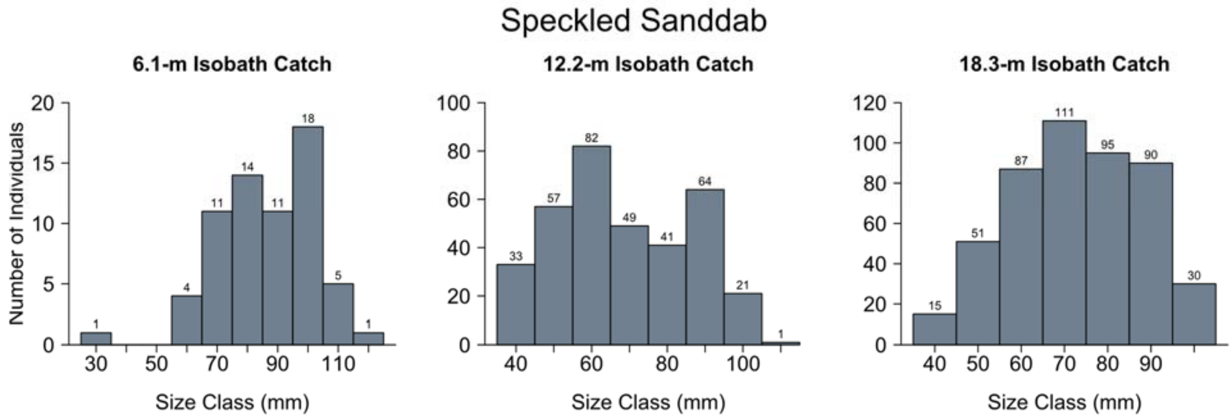

Figure 5-7. Length frequency distribution by isobath (6.1, 12.2, and 18.3 m) for Speckled Sanddab, where n = 65, 348, and 479, respectively, in 2021.

Queenfish, the third most abundant species, was taken only at the 6.1-m isobath. Distribution was bimodal, with peaks at the 90-mm and 120/130-mm size classes; sizes ranged from the 50- to 160-mm size classes (Figure 5-6). Queenfish are nocturnal and tend to occur inshore during the day in resting schools, and move offshore at night (Love 2011). Queenfish mature at about one year and approximately 110 mm SL (DeMartini and Fountain 1981).

HISTORIC ABUNDANCES

Since 1995, the mean catch per trawl among the stations along the 6.1-m isobath has been variable, but often more abundant, than mean catches reported on the 12.2- and 18.3-m isobaths (Figure 5-8). Along the 6.1-m isobath, the catch offshore of San Mateo increased in 2013 compared to previous years, remained somewhat level from 2013 through 2015, and spiked to the highest catch on record in 2016 due to a high number of Northern Anchovy; the catch was variable since then, until another spike of Northern Anchovy in 2020. The catch at Don Light followed the same trend as the catch for San Mateo until 2013, when the Don Light 6.1-m isobath catch decreased to a lower abundance relative to San Mateo. The Don Light catch remained at a lower level from 2013 through 2018, and in 2019 it spiked to the highest catch on record due to a large number of Northern Anchovy. In 2020 abundance fell to a level similar to low values seen in 2016 and 2018, and in 2021 it increased to the third highest abundance since 1995 for that depth. The catch offshore San Onofre along the 6.1-m isobath in 2013 was the highest on record since 1995 for that depth, with a large catch of White Croaker, but has since fallen to levels seen prior to 2013. The catch in 2021 was the lowest on record since 1995 for that depth. In 2020, abundance along the 6.1-m isobath at San Mateo was above its long-term average for the area since 1995, but fell back near the long-term average in 2021. Mean catch at San Onofre was below its long-term mean while Don Light was above its long-term mean in 2021.

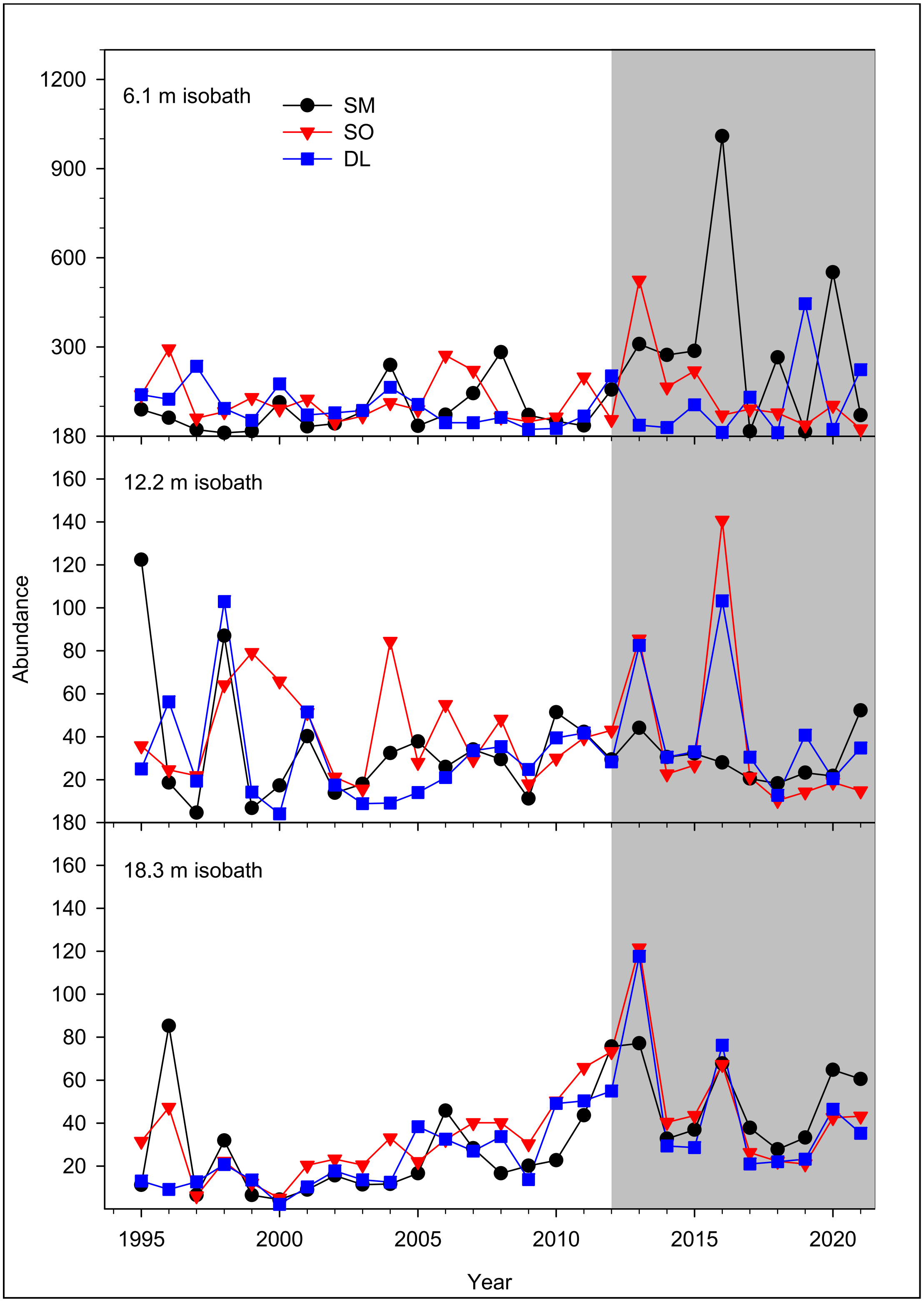

Figure 5-8. Mean catch per trawl along each isobath sampled among San Mateo, San Onofre, and Don Light 1995–2021. The shaded area represents the period since SONGS was taken offline. Note: abundance scales differ for each isobath.

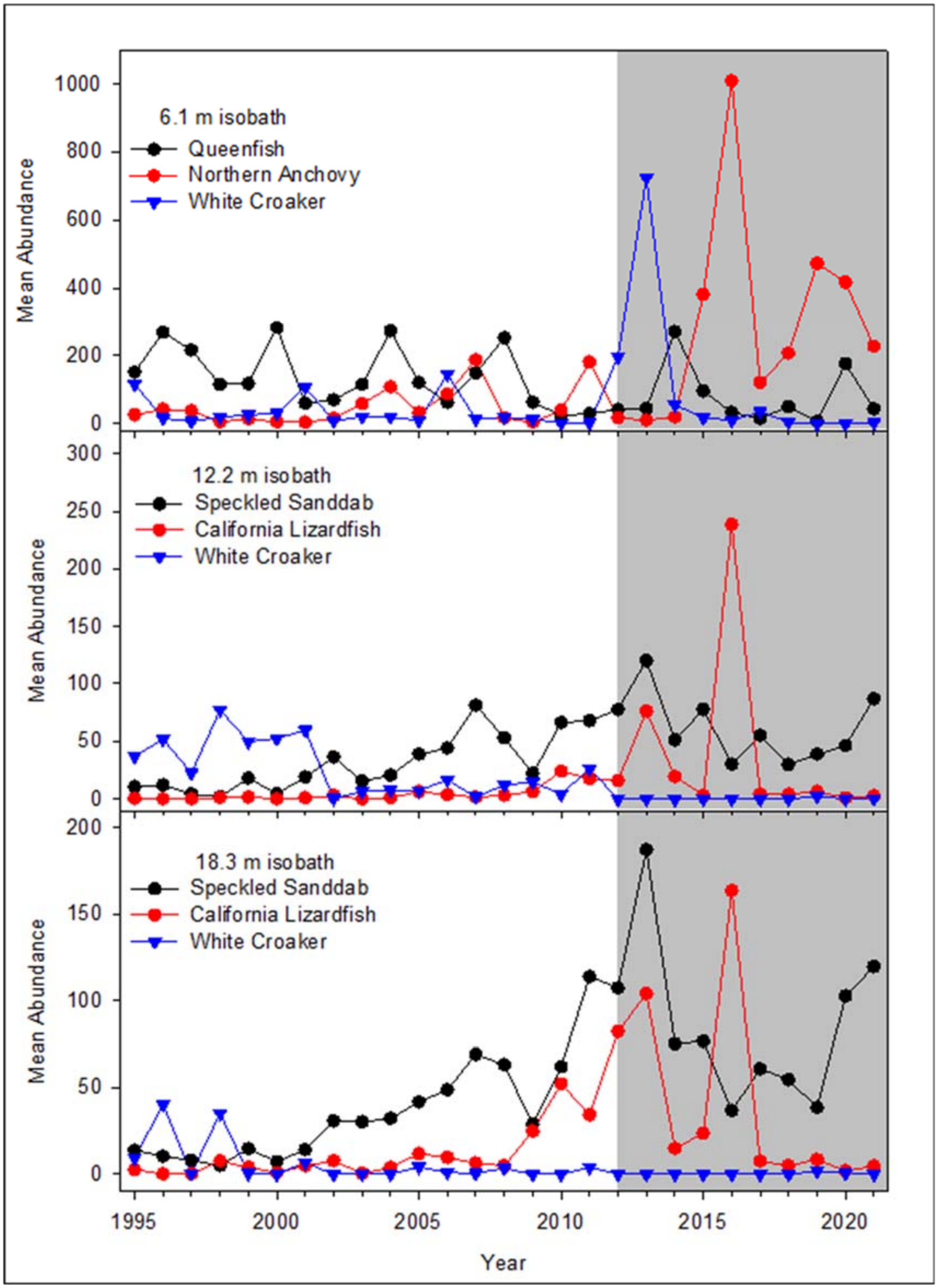

Figure 5-9. Mean catch per trawl of three long-term commonly caught species during demersal fish sampling along the 6.1-, 12.2-, and 18.3-m isobaths, 1995–2021. Data combined from stations offshore of San Mateo, San Onofre, and Don Light. Note: abundance scales differ for each isobath. The shaded area represents the period since SONGS was taken offline.

In general, all three locations have trended in a similar manner, with occasional large catches at one or another site, as seen at Don Light in 2019 and San Mateo in 2020. Catches at San Mateo have generally shown an increase since 2012, possibly due to the placement of the Wheeler North Artificial Reef modules adjacent to the tow paths at that location. The catch at San Onofre has been the middle or highest catch of the three sites for 25 of the 27 surveys since 1995, indicating there has been no unusual change in the fish population due to generating station operations.

Mean catches per trawl along the 12.2- and 18.3-m isobaths were similar among all three areas throughout most of the long-term record examined, although there was some divergence in 2013 and 2016 between San Mateo and the other sites (Figure 5-8); large catches of a single species were noted in both of those years at San Onofre and Don Light. In 2021, mean abundances at San Mateo exceeded the long-term means at these isobaths and were also highest for the year compared to the other sites. Mean abundances in 2021 were near the long-term mean at the 12.2-m isobath, and greater on the 18.3-m isobath, at all three sites. Over time, catches at San Onofre tend to be more similar to those taken at Don Light in terms of average abundance and species composition. Abundance on the 12.2-m isobath has generally increased over time at Don Light, with slight decreases at San Onofre and San Mateo, but there has been great variability in the year-to-year catch at all three locations. On the 18.3-m isobath, abundance has generally increased, beginning in 2000 when catches at all three locations reached their lowest level.

On the 6.1-m isobath, Queenfish abundance increased in 2020 to levels not seen in the past five years, but in 2021 decreased below peak levels seen periodically prior to 2013 (Figure 5-9). Northern Anchovy abundance decreased the last two years, although mean abundance was still higher than measured prior to 2015. White Croaker abundance peaked in 2013 and has since remained near the long-term average.

Between 1995 and 2001 White Croaker was a dominant species along the 12.2-m isobath (Figure 5-9). In 2002, the community shifted from dominance by White Croaker to dominance by Speckled Sanddab and later, by California Lizardfish with a large catch observed in 2016. In most years since 2011, few or no White Croaker were taken during trawls at the two deeper isobaths, except for a small increase in 2017 at the 18.3-m isobath. Speckled Sanddab and California Lizardfish have come to dominate the two deepest isobaths, although California Lizardfish abundance has decreased since 2017. Speckled Sanddab has shown an overall increase in abundance as the dominant species taken at these two deeper isobaths since 2017.

CONCLUSION

Semi-annual otter trawl sampling in 2021 documented seasonal variations in the fish communities near San Mateo, San Onofre, and Don Light for spring and fall. Overall, in 2021 the mean abundance fluctuated within the range of observations made throughout the historical period of record since 1995, particularly for the most commonly encountered fish along each isobath. Currently, there is no apparent trend to suggest a community response to the decommissioning of active power generation for SONGS.

Of the 27 species observed in 2021, Northern Anchovy, Speckled Sanddab, and Queenfish dominated the catch; Northern Anchovy and Speckled Sanddab each with about 40%, and Queenfish about 8%, of the overall catch. The remaining 24 species contributed less than 3% each to the overall catch. The top species caught in 2021 were consistent with the long-term results, and the top three species in 2021 are among the top five species collected since 1995. Since 2009, California Lizardfish was notably abundant at each sampling location at various depths, but in 2021 it contributed less than 2% to the annual catch total. Queenfish and White Croaker, which have had large contributions to the overall abundance (accounting for over 25% and 16% percent of the catch total since 1995), respectively, have both decreased throughout the Southern California Bight (Miller et al. 2011; Miller and McGowan 2013). In 2021 Queenfish accounted for almost 8% of the total and White Croaker accounted for less than 1% of the total. Most of the individuals in 2021 were taken along the 6.1 m isobath, consistent with the historical catch pattern.

Northern Anchovy, the most abundant species in 2021, has a well-documented history of episodic abundance cycles that fluctuate on both annual and decadal scales and on regional (Jacobson et al. 2001) and local scales (Figure 5-9). The pelagic nature of Northern Anchovy in addition to its wide biogeographic range further complicates assessing its population size based on localized demersal trawl surveys. The Northern Anchovy's dense schooling behavior (Love 2011) results in the large variation in catches as either the trawl net passes through the school and captures large numbers of individuals or it misses the school and, at most, captures a few individuals. Nevertheless, Northern Anchovy were substantial contributors to the 2021 catch along the 6.1-m isobath, especially offshore of Don Light in the fall. The majority of the individuals caught were young-of-the-year (≤80 mm SL, Hunter and Macewicz 1980).

Speckled Sanddab was the second most abundant species; it is a small flatfish largely restricted to shallow (<30 m depth) soft-bottom habitats (Love 2011; Miller and Schiff 2012). Speckled Sanddab had similar abundances along the 12.2-m and 18.3-m isobath but was less abundant at the shallower depth. Speckled Sanddab age classes were similarly distributed at the two deeper depths, with slightly larger fish dominating on the shallower depth. Estimated ages ranged from recent recruits less than one year old (< 60 mm) to over two-year-old fish (> 100 mm) (Rackowski and Pikitch 1989).

Queenfish was the third most abundant species; it is considered a habitat generalist and is very abundant over soft substrate such as that present offshore of SONGS (Allen and DeMartini 1983). This nocturnal species schools during the day and moves into the water column and feeds at night (Love 2011). It has most commonly been taken along the 6.1-m isobath. Estimated ages ranged with the majority of the individuals from young-of-the-year to Year-1 (110 mm SL) or older (DeMartini and Fountain 1981).

SONGS ceased power generation in January 2012 and was permanently closed in June 2013. Discharge volume decreased when power generation was stopped, but the greatest decrease in discharge volume occurred after the closure in June 2013. If the SONGS discharges were adversely affecting fish populations by reducing the numbers of fishes, then the predicted response after plant shutdown would be an increase in abundance at the stations offshore of SONGS. At nine years post-shutdown, a dramatic change has not occurred in the nearshore fish community. Inshore of the intakes and discharges for Units 2 and 3, the community composition and annual abundances continue to be highly variable, as they were when SONGS was operational. At depths similar to the intake and discharge depths, the fish communities remain stable in abundance and composition, consistent with records from when SONGS was operational. These data suggest no effect of the SONGS discharge on the surrounding fish community. There have been recent sharp increases at different sites, but these are attributable to the variability of catch with nearshore fish species schools, especially Northern Anchovy, which are naturally patchy in distribution.

LITERATURE CITED

Allen, L.G., and E.E. DeMartini. 1983. Temporal and spatial patterns of nearshore distribution and abundance of the pelagic fishes off San Onofre-Oceanside, California. Fish. Bull. 81(3):569-586.

DeMartini, E.E. and R.K. Fountain. 1981. Ovarian cycling frequency and batch fecundity in the Queenfish, *Seriphus politus*: attributes representative of serial spawning fishes. Fish. Bull. 79(3): 547-560.

Jacobson, L.D., J.A.A. De Oliveira, M. Barange, M.A. Cisneros-Mata, R. Felix-Uraga, J.R. Hunter, J.Y. Kim, Y. Matsuura, M. Niquen, and C. Porteiro. 2001. Surplus production, variability, and climate change in the great sardine and anchovy fisheries. Canadian Journal of Fisheries and Aquatic Sciences 58:1891-1903.

Hunter, J.R. and B. Macewicz. 1980. Sexual maturity, batch fecundity, spawning frequency, and temporal pattern of spawning for the northern anchovy, *Engraulis mordax*, during the 1979 spawning season. CalCOFI rep. Vol. 21. 139-149.

Leet, W.S., Dewees, C.M., R. Klingbeil, and E.J. Larson. 2001. California's Living Marine Resources: A Status Report. The Resources Agency, California Dept. of Fish and Game. 591 p.

Love, M.S. 2011. Certainly more than you want to know about the fishes of the Pacific Coast, a postmodern experience. Really Big Press, Santa Barbara, CA. 649 p.

Miller, E.F., D.J. Pondella II, D.S. Beck, and K. Herbinson. 2011. Decadal-scale changes in southern California sciaenids under differing harvest pressure. ICES Journal of Marine Science: Journal du Conseil. 68: 2123-2133.

Miller, E.F. and J.A. McGowan. 2013. Faunal shift in southern California's coastal fishes: A new assemblage and trophic structure takes hold. Estuarine, Coastal and Shelf Science. 127: 29-36.

Miller, E.F. and K. Schiff. 2012. Descriptive trends in Southern California Bight demersal fish assemblages since 1994. Calif. Coop. Oceanic Fish. Invest. Rep. 53: 107-131.

Rackowski, J.P. and E.K Pikitch. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest): Pacific and Speckled Sanddabs. U.S. Fish and Wildlife Service Biological Report. 82.

Shannon, C.H. and W. Weaver. 1962. The Mathematical Theory of Communication. Univ. of Illinois Press, Urbana, IL. 117 p.

Southern California Edison Co. (SCE). 1982. San Onofre Nuclear Generating Station 1981 Annual Report. Marine Environmental Analysis and Interpretation. Prepared by Brown and Caldwell, Lockheed Ocean Science Laboratories, and MBC Applied Environmental Sciences. Report Number 82-RD-51.

Walther, S.M., J.P. Williams, A. Latker, D.B. Cadien, D.W. Diehl, K. Wisenbaker, E. Miller, R. Gartman, C. Stransky, and K. Schiff. 2017. Southern California Bight 2013 Regional Monitoring Program: Volume VII. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Costa Mesa, CA.

Appendix 5-1. Scientific and common fish names, 2021.

Phylum / Class / Family / Species	Common Name
Chordata	
Chondrichthyes	
Platyrhinidae	
Platyrhinoidis triseriata	Thornback
Urobatidae	
Urobatis halleri	Round Stingray
Actinopterygii	
Atherinidae	
Atherinopsis californiensis	Jacksmelt
Porichthys myriaster	Specklefin Midshipman
Porichthys notatus	Plainfin Midshipman
Branchiostegidae	
Caulolatilus princeps	Ocean Whitefish
Cynoglossidae	
Symphurus atricaudus	California Tonguefish
Embiotocidae	
Cymatogaster aggregata	Shiner Perch
Hyperprosopon argenteum	Walleye Surfperch
Engraulidae	
Anchoa compressa	Deepbody Anchovy
Anchoa delicatissima	Slough Anchovy
Engraulis mordax	Northern Anchovy
Hexagrammidae	
Zaniolepis latipinnis	Longspine Combfish
Actinopterygii (cont'd.)	
Paralichthyidae	
Citharichthys sordidus	Pacific Sanddab
Citharichthys stigmaeus	Speckled Sanddab
Citharichthys xanthostigma	Longfin Sanddab
Paralichthys californicus	California Halibut
Xystreurys liolepis	Fantail Sole
Pleuronectidae	
Pleuronichthys ritteri	Spotted Turbot
Pleuronichthys verticalis	Hornyhead Turbot
Sciaenidae	
Genyonemus lineatus	White Croaker
Menticirrhus undulatus	California Corbina
Seriphus politus	Queenfish
Scorpaenidae	
Sebates miniatus	Vermilion Rockfish
Serranidae	
Paralabrax nebulifer	Barred Sand Bass
Syngnathidae	
Syngnathus californiensis	Kelp Pipefish
Synodontidae	
Synodus lucioceps	California Lizardfish

Appendix 5-2. Abundance of fishes caught each survey and overall in 2021.

Species	Common Name	Sampling Month		Total	Percent Total
		April	December		
Engraulis mordax	Northern Anchovy	102	811	913	40.9%
Citharichthys stigmaeus	Speckled Sanddab	627	265	892	39.9%
Seriphus politus	Queenfish	166	8	174	7.8%
Anchoa delicatissima	Sough Anchovy	-	45	45	2.0%
Synodus lucioceps	California Lizardfish	20	16	36	1.6%
Syngnathus californiensis	Kelp Pipefish	22	10	32	1.4%
Citharichthys sordidus	Pacific Sanddab	20	6	26	1.2%
Citharichthys xanthostigma	Longfin Sanddab	19	-	19	0.9%
Sebastes miniatus	Vermilion Rockfish	18	-	18	0.8%
Genyonemus lineatus	White Croaker	6	7	13	0.6%
Paralichthys californicus	California Halibut	6	7	13	0.6%
Anchoa compressa	Deepbody Anchovy	2	7	9	0.4%
Hyperprosopon argenteum	Walleye Surfperch	8	1	9	0.4%
Menticirrhus undulatus	California Corbina	4	1	5	0.2%
Pleuronichthys verticalis	Hornyhead Turbot	4	1	5	0.2%
Cymatogaster aggregata	Shiner Perch	-	3	3	0.1%
Porichthys myriaster	Specklefiin Midshipman	-	3	3	0.1%
Symphurus atricaudus	California Tonguefish	1	2	3	0.1%
Urobatis halleri	Round Stingray	-	3	3	0.1%
Zaniolepis latipinnis	Longspine Combfish	3	-	3	0.1%
Platyrhinoidis triseriata	Thornback	-	2	2	0.1%
Xystreurys liolepis	Fantail Sole	1	1	2	0.1%
Atherinopsis californiensis	Jacksmelt	-	1	1	0.0%
Caulolatilus princeps	Ocean Whitefish	-	1	1	0.0%
Paralabrax nebulifer	Barred Sand Bass	-	1	1	0.0%
Pleuronichthys ritteri	Spotted Turbot	1	-	1	0.0%
Porichthys notatus	Plainfin Midshipman	1	-	1	0.0%
Total Abundance		1,031	1,202	2,233	
Number of Species		19	22	27	
Diversity		1.40	1.08	1.47	

Note: “-“ = not present; “0.0” = <0.05.

Appendix 5-3. Abundance of fishes caught at each site, depth, and season in 2021.

San Mateo Point 18.3 m (SM1)

Species	Sampling Month April	December	Total
Citharichthys stigmaeus	144	66	210
Citharichthys sordidus	10	1	11
Citharichthys xanthostigma	7	-	7
Synodus lucioceps	3	2	5
Pleuronichthys verticalis	3	-	3
Syngnathus californiensis	2	1	3
Paralichthys californicus	2	-	2
Sebastes miniatus	1	-	1
Total	172	70	242
Diversity	0.72	0.28	0.62

San Mateo Point 12.2 m (SM2)

Species	Sampling Month April	December	Total
Citharichthys stigmaeus	174	10	184
Paralichthys californicus	-	5	5
Citharichthys sordidus	4	-	4
Sebastes miniatus	4	-	4
Citharichthys xanthostigma	3	-	3
Engraulis mordax	-	3	3
Synodus lucioceps	3	-	3
Zaniolepis latipinnis	2	-	2
Total	190	18	208
Diversity	0.42	0.98	0.58

San Mateo Point 6.1 m (SM3)

Species	Sampling Month April	December	Total
Seriphus politus	166	5	171
Engraulis mordax	71	15	86
Anchoa compressa	2	3	5
Genyonemus lineatus	5	-	5
Syngnathus californiensis	5	-	5
Hyperprosopon argenteum	4	-	4
Citharichthys stigmaeus	3	-	3
Synodus lucioceps	1	-	1
Total	660	1,544	2,204
Diversity	0.68	0.14	0.86

Note: “-“ = not present

Appendix 5-3. Continued

San Onofre 18.3 m (SO1)

Species	Sampling Month April	Sampling Month December	Total
Citharichthys stigmaeus	82	68	150
Synodus lucioceps	-	7	7
Citharichthys xanthostigma	4	-	4
Citharichthys sordidus	2	1	3
Paralichthys californicus	2	-	2
Syngnathus californiensis	1	1	2
Pleuronichthys ritteri	1	-	1
Pleuronichthys verticalis	1	-	1
Porichthys myriaster	-	1	1
Porichthys notatus	1	-	1
Zaniolepis latipinnis	1	-	1
Total	95	78	173
Diversity	0.66	0.50	0.66

San Onofre 12.2 m (SO2)

Species	Sampling Month April	Sampling Month December	Total
Citharichthys stigmaeus	36	10	46
Synodus lucioceps	4	1	5
Paralichthys californicus	2	-	2
Sebastes miniatus	2	-	2
Symphurus atricaudus	1	-	1
Xystreurys liolepis	1	-	1
Porichthys myriaster	-	1	1
Syngnathus californiensis	-	1	1
Total	46	13	59
Diversity	0.84	0.79	0.91

Note: “-“ = not present

Appendix 5-3. Continued.

San Onofre 6.1 m (SO3)

Species	Sampling Month April	Sampling Month December	Total
Engraulis mordax	27	5	32
Anchoa delicatissima	-	22	22
Citharichthys stigmaeus	4	6	10
Genyonemus lineatus	1	6	7
Syngnathus californiensis	5	-	5
Anchoa compressa	-	4	4
Hyperprosopon argenteum	3	1	4
Cymatogaster aggregata	-	3	3
Seriphus politus	-	3	3
Menticirrhus undulatus	2	-	2
Platyrhinoidis triseriata	-	2	2
Atherinopsis californiensis	-	1	1
Urobatis halleri	-	1	1
Total	42	54	96
Diversity	1.18	1.93	2.02

Don Light 18.3 m (DL1)

Species	Sampling Month April	Sampling Month December	Total
Citharichthys stigmaeus	60	59	119
Citharichthys sordidus	4	4	8
Synodus lucioceps	2	5	7
Citharichthys xanthostigma	5	-	5
Pleuronichthys verticalis	-	1	1
Porichthys myriaster	-	1	1
Total	71	70	141
Diversity	0.59	0.62	0.64

Don Light 12.2 m (DL2)

Species	Sampling Month April	Sampling Month December	Total
Citharichthys stigmaeus	93	25	118
Sebastes miniatus	11	-	11
Syngnathus californiensis	-	5	5
Synodus lucioceps	2	1	3
Caulolatilus princeps	-	1	1
Paralabrax nebulifer	-	1	1
Total	106	33	139
Diversity	0.42	0.81	0.61

Note: “-“ = not present

Appendix 5-3. Continued.

Don Light 6.1 m (DL3)			
Species	**Sampling Month** **April**	 **December**	**Total**
Engraulis mordax	4	788	792
Citharichthys stigmaeus	31	21	52
Anchoa delicatissima	-	23	23
Syngnathus californiensis	9	2	11
Synodus lucioceps	5	-	5
Menticirrhus undulatus	2	-	2
Paralichthys californicus	-	2	2
Symphurus atricaudus	-	2	2
Urobatis helleri	-	2	2
Hyperprosopon argenteum	1	-	1
Menticirrhus undulatus	-	1	1
Xystreurys liolepis	-	1	1
Total	52	842	894
Diversity	1.24	0.33	0.53

Note: “-“ = not present