Ecology, 94(11), 2013, p. 2654

A multi-decade time series of kelp forest community structure at San Nicolas Island, California (USA)

Ecological Archives E094-244

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Abstract. San Nicolas Island is surrounded by broad areas of shallow subtidal habitat, characterized by dynamic kelp forest communities that undergo dramatic and abrupt shifts in community composition. Although these reefs are fished, the physical isolation of the island means that they receive less impact from human activities than most reefs in Southern California, making San Nicolas an ideal place to evaluate alternative theories about the dynamics of these communities. Here we present monitoring data from seven sampling stations surrounding the island, including data on fish, invertebrate, and algal abundance. These data are unusual among subtidal monitoring data sets in that they combine relatively frequent sampling (twice per year) with an exceptionally long time series (since 1980). Other outstanding qualities of the data set are the high taxonomic resolution captured and the monitoring of permanent quadrats and swaths where the history of the community structure at specific locations has been recorded through time. Finally, the data span a period that includes two of the strongest ENSO events on record, a major shift in the Pacific decadal oscillation, and the reintroduction of sea otters to the island in 1987 after at least 150 years of absence. These events provide opportunities to evaluate the effects of bottom-up forcing, top-down control, and physical disturbance on shallow rocky reef communities.

Key words: *California Channel Islands; long-term monitoring; rocky reef ecology; sea otters.*

The complete data sets corresponding to abstracts published in the Data Papers section of the journal are published electronically in *Ecological Archives* at http://esapubs.org/archive (the accession number for each Data Paper is given directly beneath the title).

Manuscript received 22 March 2013; revised 25 June 2013; accepted 15 July 2013. Corresponding Editor: W. K. Michener.
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2013. *Ecology* XX: XX-XX

INTRODUCTION

Reefs at San Nicolas Island are an ideal location for studying the dynamics of shallow subtidal communities. San Nicolas is the most remote of California's Channel Islands, and its relative isolation somewhat protects it from the terrestrial runoff and recreational use faced by other reefs in Southern California. Although the island is small, its gently sloping subtidal shelf provides substantial shallow area for kelp forests and other rocky reef communities. Further, reefs at San Nicolas Island have been the focus of more than three decades of ecological monitoring, and the resulting data represent a valuable tool for understanding kelp forest community dynamics.

The data presented here come from a monitoring program that was initiated in 1980 in anticipation of the potential reintroduction of sea otters (Rathbun et al. 1990, Rathbun and Benz 1991). San Nicolas Island had been identified as a potential site for the establishment of a new breeding population of sea otters (sea otters from central California were translocated to the island starting in 1987). Subtidal monitoring was initiated in autumn of 1980 at six sampling stations positioned around the island to capture communities exposed to a range of wave exposures and other oceanographic conditions (Table 1). One additional station was added in 1986 (chosen to add a location where the bottom had very little physical relief). The intent of this monitoring was to provide baseline information on ecological community structure in order to better evaluate the effects of sea otter introduction. Each station has been sampled twice a year (with a few exceptions). This period of monitoring covers substantial variability in environmental conditions, including two of the strongest El Nino's on record, years with high and low waves, and major shifts in the Pacific decadal oscillation.

In this paper, we present time-series data on the abundance of more than 200 species of fish, algae and invertebrates. These data were collected at each permanent sampling station using a combination of swath counts and point-contact sampling. In addition, we present measurements of the sizes of *Macrocystis pyrifera* (giant kelp), a key foundation species. The long time series and biannual sampling make these data appropriate for exploring ecological dynamics on multiple time scales. The high taxonomic resolution of the sampling provides a detailed picture of community structure over time, and the fact that fixed quadrats and swaths have been sampled repeatedly means that changes in the community can be examined without the obscuring effects of sampling error. Taken together, these characteristics make these data valuable for investigating the ecology of giant kelp forests, particularly with respect to patterns and drivers of community dynamics across a wide range of physical and biological conditions

METADATA CONTENTS

Class I. Data set descriptors

I.A. Data set identity: Rocky reef community structure at San Nicolas Island, California

I.B. Data Set Identification Code: KennerEtAl2013-SNI

I.C. Data set description

I.C.1. Data set originators

Individual: James A. Estes
Role: Initial principal investigator
Organization: University of California, Santa Cruz
Position: Professor of Ecology and Evolutionary Biology
Address: Long Marine Lab, 100 Shaffer Road, Santa Cruz, CA 95060
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Individual: Michael C. Kenner
Role: Chief field biologist
Organization: University of California Santa Cruz
Position: Biologist
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Email: mkenner@ucsc.edu

Individual: M. Tim Tinker
Role: Current principal investigator
Organization: US Geological Survey, Western Ecological Research Center
Position: Research Biologist
Address: Long Marine Lab, 100 Shaffer Road, Santa Cruz, CA, 95060
Phone: 831-459-2357
Email: ttinker@usgs.gov

I.C.2. Abstract:

San Nicolas Island is surrounded by broad areas of shallow subtidal habitat, characterized by dynamic kelp forest communities that undergo dramatic and abrupt shifts in community composition. Although these reefs are fished, the physical isolation of the island means that they receive less impact from human activities than most reefs in Southern California, making San Nicolas an ideal place to evaluate alternative theories about the dynamics of these communities. Here we present monitoring data from seven sampling stations surrounding the island, including data on fish, invertebrate and algal abundance. These data are unusual among subtidal monitoring datasets in that they combine relatively frequent sampling (twice per year) with an exceptionally long time series (since 1980). Other outstanding qualities of the dataset are the high taxonomic resolution captured and the monitoring of permanent quadrats and swaths where the history of the community structure at specific locations has been recorded through time. Finally, the data span a period that includes two of the strongest ENSO events on record, a major shift in the Pacific decadal oscillation and the reintroduction of sea otters to the island in 1987 after at least 150 years of absence. These events provide opportunities to evaluate the effects of bottom up forcing, top down control and physical disturbance on shallow rocky reef communities.

I.E. Key words: *long-term monitoring, California Channel Islands, rocky reef ecology, sea otters*

Class II. Research origin descriptors

A. **Project description**
   1. **Objectives**
   2. **System description**
   3. **Guidelines for use of data**

II.A.1. Objectives: In the early 1980s, as part of the United States Fish and Wildlife Service's research program on southern sea otters, it was decided that a breeding population of sea otters should be established at San Nicolas Island to reduce the species' vulnerability to extinction caused by increasing threats from human activities. San Nicolas was selected because of its isolation and high availability of suitable habitat. In anticipation of the establishment of a new population, the U.S. Fish and Wildlife Service and the University of California, Santa Cruz established six permanent subtidal sampling stations around San Nicolas Island in 1980. One additional station was set up in 1986. It was chosen because the site had virtually no bottom relief and thus kelp, when present, would represent the only three dimensional structure affecting fish density. The study was designed to examine the possible impact of a translocated sea otter population on the local reef communities. The project is currently conducted by the U.S. Geological Survey - Western Ecological Research Center, U.C. Santa Cruz Field Station.

II.A.2. System description: San Nicolas Island (Ventura County, CA, USA) is the most remote of southern California's Channel Islands, both from shore and from the nearest neighboring island, lying approximately 140 km west-south-west of Los Angeles (~110 km offshore, 33°15' N, 119°30' W). San Nicolas is influenced both by the cold southward flowing California Current and the warmer northward edge of the California counter-current; consequently, its kelp forest communities contain biota characteristic of both more northern and more southern regions. The island itself is relatively small (less than 60 km^2 in area) but because of its gently sloping shelf of low-relief soft-sedimentary rock, it has the greatest area of kelp beds of any of the Channel Islands (30% of the total kelp coverage throughout the islands; Engle 1994). San Nicolas is located far from the wave shadows of other islands and the shape of its coastline provides little protection from the swell, so most of its shallow-water habitats are exposed to wave disturbance. Because of its isolation from the populated mainland, shallow subtidal communities at San Nicolas are less exposed to human influences than communities on many reefs in Southern California. However, reefs surrounding the island are the focus of several active commercial fisheries (particularly for sea urchins, lobster and rockfish), modest recreational fishing pressure (particularly for rockfish, ocean whitefish and sheephead) and are potentially impacted by the US Navy's operations on the island.

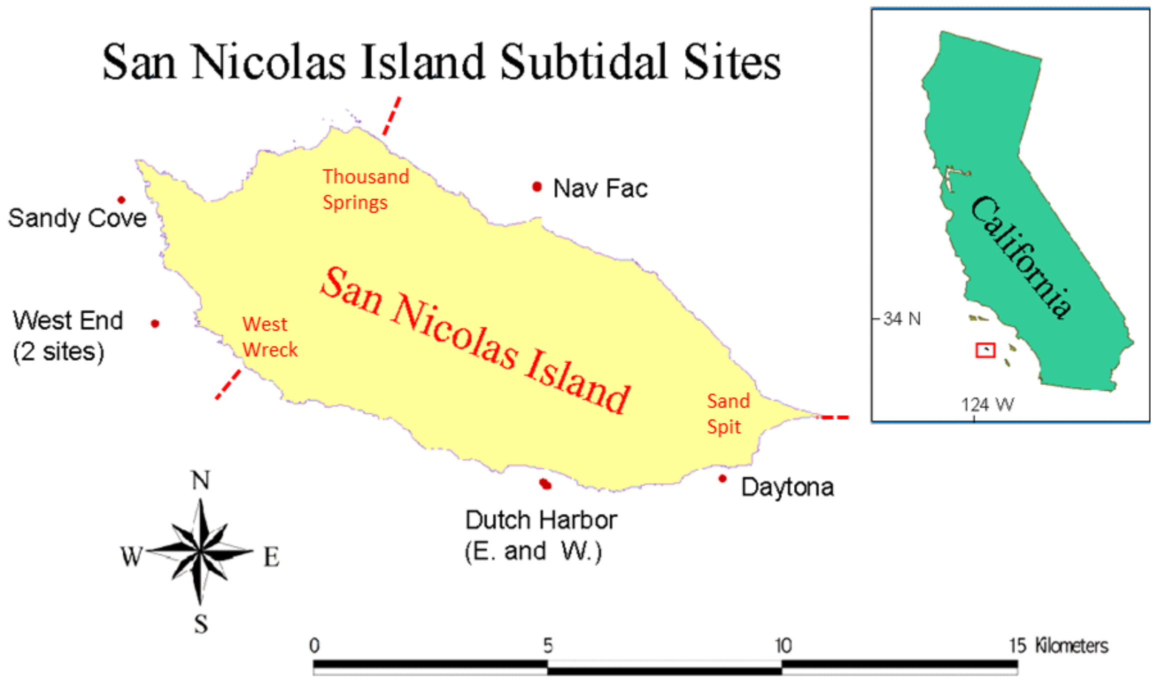
II.A.3. Guidelines for use of data: This dataset is part of an ongoing monitoring program at San Nicolas Island run by the United States Geological Survey Western Ecological Research Center (USGS-WERC).

B. Monitoring Design

1. **Site selection and layout**
2. **Human impacts**
3. **Monitoring method selection**
4. **Choice of species to be monitored**
5. **Monitoring design metadata**

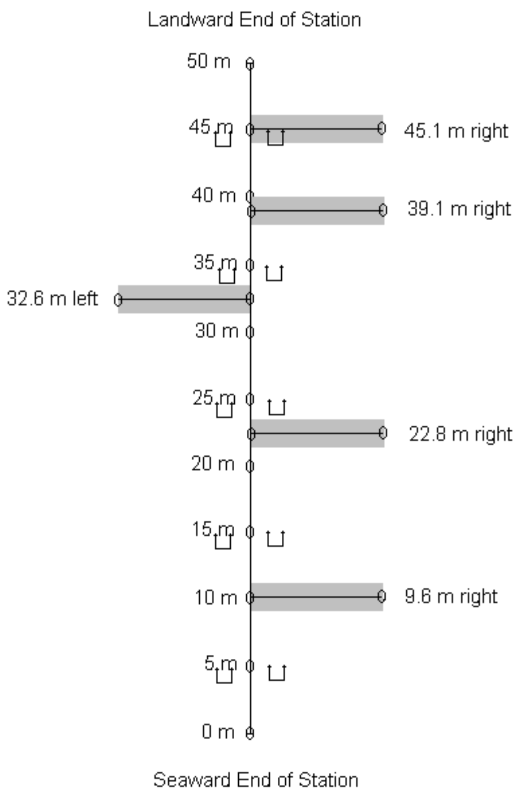
II.B.1. Site Selection and Layout: Seven stations have been chosen for monitoring (six in 1980 and one in 1986). These stations are placed around San Nicolas to provide data from each side of the island and to be representative of the available kelp forested habitat. A map of the stations is given in Figure 1. Three stations are isolated (Sandy Cove, Nav Fac and Daytona), while the other four were placed as two pairs. The pair of stations at West End was chosen to represent an urchin dominated area of reef and a kelp dominated area (although the communities at these stations have changed through time). These two stations are contiguous (the 50 m end of West End Kelp is the zero bolt of West End Urchins). The pair of sampling stations at Dutch Harbor was chosen as experimental (west) and control (east) stations for a sheephead removal experiment run in 1980 through 1982 (Cowen 1983). These two stations are separated by ~140 m. The latitude and longitude of each sampling station are given in Table 1. With a few exceptions, each station has been monitored twice a year (in spring and autumn) since its establishment.

Figure 1: Map of SNI monitoring stations



At each station, monitoring is focused on a permanent 50-meter transect marked by stainless steel eyebolts placed at 5 m intervals. Each transect is placed approximately perpendicular to the coastline between 10 and 15 meters in depth. Associated with each transect are five permanent 10 m by 2 m swaths running perpendicular to it at fixed intervals. The original orientation of swaths (to the left or right of the transect) was chosen at random. Additionally, ten 1 m^2 quadrats are permanently placed one meter to the right and left of the main transect along its length. These quadrats mark locations where biota is sampled using fixed point contact methods. Finally, five 50 m fish transects are associated with each sampling station. Each fish transect starts at one of the permanent eyebolts and is laid out along a specific compass heading. Figure 2 illustrates the layout of quadrats and swaths along a typical transect.

Figure 2. An example of the layout of quadrats and swaths at a typical sampling station.



II.B.2. Human impacts: A number of significant anthropogenic impacts have occurred at the monitoring stations since their establishment. Perhaps the most important was the translocation of southern sea otters (*Enhydra lutris nereis*) from central California to SNI in 1987-1990. During this period, 140 sea otters were released at SNI. Although there was relatively low retention of these translocated animals, a population of ~15 adult animals remained at the island from 1990 to 1998, and their numbers have been increasing consistently since (Hatfield 2003).

Sea otters are not evenly distributed around the island. Sea otter surveys have been done three to five times per year since 1995, and the sampling date with the highest number of sea otters observed is a good measure of their abundance in space and time (Rathbun et al. 2000). When the coastline is divided into three roughly equivalent segments: the west (West Wreck to Thousand Springs, ~ 11.5 km), the north (Thousand Springs to Sand Spit, ~12 km) and the south (Sand Spit to West Wreck, ~ 13 km), it is apparent that independent sea otters (e.g. older juveniles and adults) are consistently abundant in the west and rare in the north (Table 2). This pattern is also observed in sea otter pups, which are common in the west, occasional in the south and effectively absent from the north (Table 3).

Several other human impacts at individual sampling stations are also worth noting. In September 1980, as part of an experimental manipulation, 220 sheephead (*Semicossyphus pulcher*) were removed from Dutch Harbor West. Cowen (1983) estimated that this manipulation eliminated all sheephead at the site. This manipulation was maintained for 2 years, with additional sheephead removed at bimonthly intervals (10-20 removed per visit). In addition to this scientifically motivated removal, substantial recreational and commercial fishing occurs at the island.

Although fine scale spatial data on fishing pressure are not available, several long term datasets document changes in fishing in southern California (Perry et al 2010)

The U.S. Navy's operations on San Nicolas also had significant effects on nearshore kelp forests. Until 2005 when the new pier opened, the navy brought barges in on the beach at Daytona Beach resulting in considerable sand movement, and relatively heavy sediment loads at that site. Since 2005, this practice has stopped.

In addition to human impacts, other factors have affected the continuity of data collection. In particular, the transect at Daytona could not be located in the fall of 1983, probably because of the sand input described above. Swaths 39R and 45R were never relocated and were eventually replaced with 22L and 39L in fall of 1985.

II.B.3. Monitoring method selection: The great diversity of organisms and physical habitats associated with kelp forests requires multiple sampling approaches to effectively monitor species population dynamics. Sampling methods were designed to maximize accuracy and precision while preserving an observer's ability to efficiently sample many target species at once. Counts within fixed areas are made to describe the abundance of fish as well as large invertebrates and algae. Estimates of percent cover are used to measure the abundance of species for which individuals are numerous, small or otherwise difficult to count.

II.B.4. Choice of species to be monitored: The monitoring captures the abundance of most algae, invertebrates and fish larger than a few centimeters, including all primary benthic spaceholders. The species sampled and datasets in which they appear are found in Table 4.

II.B.5. Monitoring design metadata: The following metadata are descriptive of the monitoring methods and context and are available below as comma separated values files.
Table 1: Monitoring stations and their Coordinates
Table 2: Abundance of independent sea otters
Table 3: Abundance of sea otter pups
Table 4: Species sampled

C. Data processing and presentation

1. **Core community structure datasets**
2. **Supplementary datasets**
3. **Additional documentation and data**

II.C.1. Core community structure datasets: The subtidal monitoring data presented here describe the algal, invertebrate and fish components of the kelp forest community at as high a taxonomic resolution as is practical. We present this information in four "core community structure datasets": benthic density (calculated from counts of organisms within fixed 10 m x 2 m swaths), benthic cover (calculated from point contact data in fixed 1 m X 1 m quadrats), midwater fish density (calculated from 50 m x 5 m fish transects), and benthic fish density (calculated from 50 m x 2 m fish transects). Each of these datasets is presented in both summarized form (with means and standard errors for each station) and in raw form (with counts from each sampling replicate reported separately).

II.C.2. Supplementary datasets: In addition to the core data discussed above, supporting data on *Macrosystis pyrifera* populations are also included. The basal diameters of a subset of giant kelp plants are measured and, in some cases, stipes have also been counted. Additionally, some giant kelp plants have been given unique tags, allowing the size of individual plants to be tracked over time. These data are collected biannually with the core community data.

II.C.3. Additional documentation and data: The subtidal data presented here are part of a larger monitoring program that includes intertidal community data collected twice a year and sea otter population surveys done three to five times a year. Users interested in these data should contact:

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100 Shaffer Road, Santa Cruz, CA, 95076
ttinker@usgs.gov

II.D.1.a. Benthic density data

Table 5A: Definition of column headers in the benthic density raw data
Table 5B: Definition of variables in the benthic density raw data
Benthic density raw data: ASCII file in comma separated values format

Table 6A: Definition of column headers in the benthic density summary data
Table 6B: Definition of variables in the benthic density summary data
Benthic density summary data: ASCII file in comma separated values format

II.D.1.a.i. Benthic density summary procedures: Density data for solitary benthic algae and macro-invertebrates are collected by counting the number of individuals in a fixed swath and dividing that count by the area sampled. For each sample date and station, density estimates are reported for each swath in the "raw" dataset and as a mean and standard error across all swaths in the "summary" dataset.

II.D.1.a.ii. Swath count methods: 19 target species (Table 4) are sampled by counting the number of individuals of each that occur within five 10 m by 2 m swaths at each sampling station. Swaths are laid out perpendicular to the main transect at specified intervals (see Figure 2 for an example of swaths placement). On each swath, divers count seven species or categories of brown algae (primarily kelps) and 12 species of macro-invertebrates. Only organisms that can be seen without extensive or destructive searching are counted.

II.D.1.b. Benthic cover data

Table 7A: Definition of column headers in the benthic cover raw data
Table 7B: Definition of variables in the benthic cover raw data
Benthic cover raw data: ASCII file in comma separated values format

Table 8A: Definition of column headers in the benthic cover summary data
Table 8B: Definition of variables in the benthic cover summary data
Benthic cover summary data: ASCII file in comma separated values format

II.D.1.b.i. Benthic cover summary procedures: Percent cover data for the benthic community of algae and sessile invertebrates are collected using a fixed point contact method in which a series of points is superimposed over the bottom, and the species intersecting each point is recorded. The number of times each species is contacted is divided by the total number of points sampled and multiplied by 100 to give the percent of the bottom occupied by that species. Percent cover of each species is calculated separately for each of the 10 1 m^2 quadrats. For each sample date and station, percent cover estimates for each taxon are reported for each quadrat in the "raw" dataset and as a mean and standard error calculated across all quadrats in the "summary" dataset. Note that the raw (quadrat level) estimates of cover are based on 20 points each, so give cover estimates in increments of 5% (one point => 5% cover). The summary (station level) data gives cover estimates in increments of .05% (one point => .05% cover). Thus, while the raw data are very useful for looking at small scale associations between common species, the increased precision given by the summary data make them more appropriate for describing population dynamics, particularly of rare species.

II.D.1.b.ii. Point contact monitoring methods: Benthic percent cover data are collected in $1m^2$ permanent quadrats, with a quadrat placed 1 m to the left or right of the main 50 m transect at 10 fixed locations. Within each quadrat 20 points are distributed in a fixed pattern. The diver imagines a line running vertically through each point up to one meter above the substratum and identifies all organisms that intersect this imaginary line. The diver counts each species only once per point even if multiple individuals of the same species intersect that point. Because of this method of counting multiple layers, total cover of all species can exceed 100% (and usually does), but the cover of any individual species cannot be > 100%. The list of taxa recorded is open and ranges from actual individual species to species groups like "orange encrusting sponge". A few organisms which could not be identified have been recorded as "Unidentified spp." Substrate type is also recorded if exposed.

II.D.1.c. Fish density data

Table 9A: Definition of column headers in the midwater fish density raw data
Table 9B: Definition of variables in the midwater fish density raw data
Midwater fish density raw data: ASCII file in comma separated values format

Table 10A: Definition of column headers in the midwater fish density summary data
Table 10B: Definition of variables in the midwater fish density summary data
Midwater fish density summary data: ASCII file in comma separated values format

Table 11A: Definition of column headers in the benthic fish density raw data
Table 11B: Definition of variables in the benthic fish density raw data
Benthic fish density raw data: ASCII file in comma separated values format
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Table 12A: Definition of column headers in the benthic fish density summary data
Table 12B: Definition of variables in the benthic fish density summary data
Benthic fish density summary data: ASCII file in comma separated values format

II.D.1.c.i. Fish density summary procedures: Fish density data have been collected since autumn 1981 by counting the number of individuals within fixed transects and dividing that count by the area of bottom sampled. At each sampling date, fish are counted in five fish transects per sampling station. A diver passes over each transect twice, counting midwater fish in a 5 m wide transect on the first pass and benthic fish in a 2 m wide transect on the second. These data are presented separately here, because the same individuals could be present in both counts depending on their behavior. Counts are presented as densities per m^2 of horizontal area sampled. For each sample date and sampling station, density estimates are reported for each fish transect separately in the "raw" datasets and as a mean and standard error across all transects in the "summary" datasets. On one occasion (at Daytona Beach in October 1988) a huge school of California anchovy (*Engraulis mordax*) was observed on two transects, but they were too numerous to get an estimate of their abundance. They have been omitted from the data.

II.D.1.c.ii. Fish transect monitoring methods: Five 50 m visual fish transects are sampled at each station on each sampling date. Each of these transects is defined by a beginning point on the main transect and a compass heading, so that the same areas are counted each sampling period (see Table 11 for fish transect placement). On each transect, two counts are made. First the observer swims the entire transect about 2-3 m off the bottom, sampling a 5 m wide transect and counting all fish found between the surface and 2 m above the bottom. Sheephead and all schooling fish (e.g. blacksmith) are counted even if they are within 2 m of the bottom. Fish observed in this count are recorded as midwater fish; the total horizontal area sampled is 250 m^2. After reaching the end of the transect, the observer works backwards more slowly, counting all fish found in a 2 m wide swath within 2 m of the bottom. Midwater fish (such as sheephead) are excluded from this count, even if they are found within 2 m of the bottom. This is slow and careful work, because many of these fish are mixed in with the benthic algae, so despite the smaller area sampled, this second count typically takes longer than the first. Fish observed in the second count are recorded as benthic fish. The total horizontal area sampled is 100 m^2. In each count, an open species list is used, so all fish encountered are sampled. Fish are identified to the highest taxonomic resolution possible in the field, typically to species or genus. In both counts, juveniles are scored separately when observed, and male and female sheephead (*Semicossyphus pulcher*) are recorded separately.

Table 13: Starting point on the main transect and orientation of fish transects

Station	StationName	1	2	3	4	5
1	Nav Fac	0 m E	10 m W	20 m E	30 m W	40 m W
2	West End, Urchin	0 m N	10 m N	20 m N	30 m N	ON
3	West End, Kelp	0 m S	10 m N	20 m S	30 m N	ON
4	West Dutch Harbor	0 m W	10 m W	30 m W	45 m W	ON
5	East Dutch Harbor	0 m E	10 m W	20 m E	30 m W	40 m E
6	Daytona Beach	0 m E	0 m W	10 m E	20 m W	30 m E
7	Sandy Cove	0 m W	10 m W	20 m E	30 m E	ON

Note: "ON" means the fish transect was performed along the main transect, N, E, S and W refer to compass headings of 0, 90, 180 and 270 degrees respectively.

II.D.2. Supplementary datasets

a. Giant kelp size-frequency data

i. Giant kelp size-frequency field methods

II.D.2.a. Giant kelp size-frequency data:

Table 14A: Definition of column headers in the giant kelp size-frequency data
Table 14B: Definition of variables in the giant kelp size-frequency data
Giant kelp size-frequency data: ASCII file in comma separated values format

IV.D.2.a.i. Giant kelp size-frequency methods: Beginning in spring 1981, the basal diameters (holdfast width) of all *Macrocystis pyrifera* plants greater than 1 m tall encountered on swaths have been measured. In some cases the number of stipes on each plant has been counted as well. Stipe counts are typically done on the first two swaths at each sampling station with kelp present, but counts have not been made in all such cases. To obtain information on patterns of recruitment, mortality and lifespan of giant kelp, some individuals were tagged with unique numbers, written on plastic tape and cable-tied loosely around the primary dichotomous branch above the holdfast and followed over time. The number of tagged plants varied through time, sometimes including all plants > 1 m tall, and at other times including only the first 10 plants encountered on each swath. Tagging was discontinued in 2004 to reduce overall sampling effort. Missing holdfast sizes, frond counts or tag numbers are noted with "NA" in the dataset.

Class III. Data set status and accessibility

E. Latest data update

F. **Latest metadata update**
G. **Data verification**
H. **Copyright or proprietary restrictions**

III.A. Latest data update: The dataset may be periodically updated. All updates to the data have been logged in Table 15A. Please check for the latest update before using the dataset.

III.B. Latest metadata update: The metadata may also be updated periodically. All updates have been logged in Table 15B. Please check for the latest update before using the dataset.

III.C. Data verification: Field data sheets are proofed for accuracy after every day in the field as well as during data entry.

III.D. Copyright or proprietary restrictions: None

Class IV. Data set structural descriptors

C. **Data files**
D. **Metadata tables**

IV.A. Data Files:
Benthic density raw data
Benthic density summary data
Benthic cover raw data
Benthic cover summary data
Midwater fish density raw data
Midwater fish density summary data
Benthic fish density raw data
Benthic fish density summary data
Giant kelp size-frequency data

To download a .zip file containing all data files in .csv format click here.
(1881 kb, md5: 3D18C26152E76DB060D4706FDE8789A5)

IV.B. Metadata Files:
- **Table 1:** **Monitoring Stations and Their Coordinates**
- **Table 2:** **Abundance of independent sea otters**
- **Table 3:** **Abundance of sea otter pups**
- **Table 4:** **Species sampled**
- **Table 5A:** **Definition of column headers in the benthic density raw data**
- **Table 5B:** **Definition of variables in the benthic density raw data**
- **Table 6A:** **Definition of column headers in the benthic density summary data**
- **Table 6B:** **Definition of variables in the benthic density summary data**
- **Table 7A:** **Definition of column headers in the benthic cover raw data**

To download a .zip file containing all metadata files in .csv format click here.
(23 kb, md5: 98DD1FFD1AD66712D355D663B06C8053)

Class V. Supplemental descriptors

V.A. Location of completed data forms: USGS-WERC, Santa Cruz Field Station, Long Marine Lab 100 Shaffer Road, Santa Cruz, CA, 95076.

V.B. Data entry verification procedures: See III.C.

V.C. Publications using the data set:

Cowen, R. 1983. The effects of sheephead (*Semicossyphus pulcher*) predation on red sea urchin (*Strongylocentrotus franciscanus*) populations: an experimental analysis. Oecologia 58:249-255.

Cowen, R. K., and J. L. Bodkin. 1993. Annual and spatial variation of the kelp forest fish assemblage at San Nicolas Island, California. Proceedings of the third California Islands symposium. pp 463–474.

Cowen, R. K. 1986. Site-specific differences in the feeding ecology of the California sheephead *Semicossyphus pulcher* (Labridae). Environmental Biology of Fishes 16:193-203.

Harrold, C., and D. C. Reed. 1985. Food availability, sea urchin grazing, and kelp forest community structure. Ecology 66:1160–1169.

Hatfield, B. B. 2005. The translocation of sea otters to San Nicolas Island: An update. Proceedings of the Sixth California Islands Symposium, pp. 473-475.

Newsome, S. D., G. B. Bentall, M. T. Tinker, O. T. Oftedal, K. Ralls, J. A Estes, and M. L. Fogel. 2010. Variation in delta13C and delta15N diet-vibrissae trophic discrimination factors in a wild population of California sea otters. Ecological applications 20:1744-52.

Perry, W. M., K. B. Gustafson, G. S. Sanders, and J. Y. Takekawa. 2010. Pacific Coast Fisheries GIS Resource Database. U.S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, CA and Bureau of Ocean Energy Management, Regulation and Enforcement, Camarillo, CA. BOEMRE study profile #2010-023. [CD-ROM]

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Acknowledgements

Funding for fieldwork and data collection was provided by the US Geological Survey, US Fish and Wildlife Service and University of California Santa Cruz. Logistical support for fieldwork and access to the waters around San Nicolas Island were provided by the US Navy and facilitated by Grace Smith, John Ugoretz and Ron Dow of the Naval Air Warfare Center Weapons Division Pt. Mugu Sea Range Sustainability Office. We are grateful to the dozens of volunteers and agency divers that contributed to field work over the years, in particular Linda Brown, Ken Collins, Keith Miles and Amy Story. During the preparation of this data paper A.R. was supported with funds from the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC under Cooperative Agreement Number M11AC00012. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government. This product (article, paper, etc.) has been peer reviewed and approved for publication consistent with USGS Fundamental Science Practices (http://pubs.usgs.gov/circ/1367/).

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