Marine Resource Assessment

ROV-Based Deep Water Quantitative Survey of the
North Central Coast Marine Protected Areas

Marine Applied Research and Exploration

Pacific States Marine Fisheries Commission

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INTRODUCTION

The state of California is currently implementing a statewide network of Marine Protected Areas (MPAs) that are intended to protect marine ecosystems. As new regional MPA networks are implemented, the California Department of Fish and Game (Department) is required to conduct an evaluation to assess the effectiveness they provide in restoring and maintaining the health of marine ecosystems. Under the Marine Life Protection Act, monitoring is required to ensure that MPA networks meet the stated goals, facilitate adaptive management, and improve the understanding of marine ecosystems. In 2007, the central coast study region was the first of five statewide study regions to complete the Marine Life Protection Act planning and implementation process with the creation of 29 MPAs. In May 2010 the north central coast study region became the second region, with the creation of thirty MPAs, extending from Alder Creek, near Point Arena in Mendocino County, south to Pigeon Point in San Mateo County.

The National Parks Service (NPS) at Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA) received funding to promote collaborative MPA assessments that will aid in future MPA design and consideration, while providing insight to NPS and other agencies implementing MPAs in the future. The goal of this program is to produce a baseline of finfish density and habitats both inside and outside of newly implemented MPAs in the north central region. Funding provided by NPS to Pacific States Marine Fisheries Commission (PSMFC) supports the Department's ROV based MPA monitoring program in the region and sampling efforts in areas adjacent to PORE and GOGA.

Program overview

The Department has used a remotely operated vehicle (ROV) as a non-invasive observation technique for collecting biological information in the deep subtidal (20-100 m). The ROV program was initiated in 1997 when the ROV was purchased in partnership with PSMFC to complete a deep-water species inventory of Punta Gorda Ecological Reserve. The initial focus of this program was the development of quantitative sampling techniques for collecting video and associated sensor data within nearshore rocky habitats. Since that time, numerous partners, including Marine Applied Research and Exploration (MARE), have collaborated on research efforts to further develop the efficiency and value of this technology (Veisze and Karpov 2002; Karpov et al. 2006; Karpov et al. 2010). From these partnerships, a ROV sampling program was established in areas throughout the state.

In 2003, the Department and its partners implemented a Marine Protected Area (MPA) baseline ROV assessment at the northern Channel Islands. The goal was to monitor and track changes in finfish and invertebrate abundances, both inside and outside of newly formed MPAs. Initial exploratory surveys were conducted to evaluate potential study areas for monitoring. Based on results from exploratory surveys conducted from 2003 through 2004, six MPAs and four fished reference areas were selected for annual monitoring. In 2007, the Department expanded sampling to include MPAs in the central coast study region. Exploratory surveys of potential study areas within the

central coast study region resulted in the selection of four MPAs and four fished reference areas for monitoring. To date, over 7,000 $100m^2$ fish density transects have been generated from the 627 km of total ROV survey lines completed within these two regions alone.

The Department's study design requires initial baseline data collection within each MPA region, with re-sampling occurring at intervals thereafter. Within each study area, annual sampling levels are designed to produce a minimum of seventy-five $100m^2$ transects over rocky habitat. Transect size and survey design have been developed to complement the shallow water SCUBA protocols used by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) that target shallow, nearshore, rocky habitats. When feasible, ROV study sites were selected near shallow water SCUBA sites.

Within the different study regions, rocky substrates have been identified as the priority habitat for deep water assessments. In an effort to meet this monitoring priority, the Department has focused survey efforts on finfish and invertebrate species associated with rocky habitat both inside and outside MPA boundaries. Since the majority of rocky habitat within California's waters is patchy, it has been extremely difficult to find comparable areas with similar substrate and habitat compositions. In order to achieve the goal of finding comparable areas of rocky habitat inside and outside of MPAs, potential study areas are selected using multibeam and/or sidescan sonar maps. Each study area is chosen based on available rocky habitat, coastal exposure, geomorphology, and depth range. Following initial study area selection, exploratory ROV surveys are conducted to aid in the planning of baseline surveys.

Using funding provided by NPS in 2009, the Department and PSMFC conducted exploratory surveys of north central coast MPAs in areas adjacent to PORE and GOGA. The results from these surveys were used for evaluating the sampling levels needed for quantitative surveys to be conducted in the following year for selected fish and invertebrate species. Due to significant changes in California's 2010 state budget, the Department was unable to maintain its ROV program, and did not return to sample the region in 2010. In an effort to ensure that the Departments baseline data collection occurred in North Central Coast MPAs, NPS funding is being used by MARE and PSMFC to collect and post-process ROV survey data following the Department's protocols.

Report Purpose

The purpose of this report is to present summarized post-processing results of data collected during baseline surveys conducted in 2011 of select MPAs within the north central coast study region, and adjacent outside areas. Results are presented without detailed analysis and focus on summarized baseline data for use in the Department's review of statewide MPA networks.

METHODS

ROV Equipment

The ROV used in this study was a Deep Ocean Engineering Vector M4, named ROV Beagle, owned by The Nature Conservancy and operated by Marine Applied Research and Exploration. The ROV was equipped with a three-axis autopilot including a rate gyro-damped compass card. Together, these allowed the pilot to maintain a constant heading (± 1 degree) and constant depth (± 0.3 m) with minimal corrections. In addition, a forward speed control was used to help the pilot maintain a consistent forward velocity. A pair of Tritech® 500 kHz ranging sonars, which measure distance across a range of 0.1–10 m using a 6° conical transducer, were added to replace paired lasers as the primary method for measuring transect width. Readings from these sonars were averaged five times per second and recorded at a one-second interval with all other sensor data. Measurements of transect width using a ranging sonar are accurate to ± 0.1 m (Karpov et al. 2006).

An ORE Offshore Trackpoint III® ultra short baseline acoustic positioning system with ORE Offshore Motion Reference Unit (MRU) pitch and roll sensor was used to reference the ROV position relative to the ship's Wide Area Augmentation System Global Positioning System (WAAS GPS). The ship's heading was determined using a KVH magnetic compass. The Trackpoint III® positioning system calculated the XY position of the ROV relative to the ship at approximately two-second intervals. The ship-relative position was corrected to real world position and recorded in meters as X and Y using the World Geodetic System (WGS)1984 Universal Transverse Mercator (UTM) coordinate system using HYPACK® 6.2 hydrographic survey and navigation software. Measurements of ROV heading, depth, water temperature, camera tilt and sonar distance both forward and downward to the substrate, were averaged over a one-second period and recorded along with the position data.

The ROV was equipped with two color cameras, one facing forward and set approximately 30^{o} below the horizon and the other pointing downwards. The two-camera system provided a continuous, slightly overlapping view. Video for both cameras was captured on SONY® DSR 45 digital video tape recorders and Pioneer DVR510 digital video disc recorders. In addition to capturing biological and habitat observations, the forward video was overlaid with an on screen display of text characters representing real time sensor data (time, depth, temperature, range, forward camera angle and heading).

GPS time was used to provide a basis for relating position, field data and video observations (Veisze and Karpov 2002). A Horita® GPS3 and WG-50 were used to generate on screen displays of GPS time, as well as output Society of Motion Picture and Television Engineers (SMPTE) linear time-code (LTC) for capture on SONY® DSR audio tracks at an interval of $1/30^{th}$ of a second. This method was improved by customizing HYPACK® navigational software to link all data collected in the field to the GPS time. ROV tracked position and sensor data were recorded directly by HYPACK® as a time-linked text file. A redundant one-second time code file of sensor data was

also collected in the field using a custom built on-screen display and operating system software with time code extracted from the system's internal clock which was synced to GPS time.

All data collected by the ROV, along with subsequent observations extracted during post-processing of the video, was linked in a Microsoft Access® database using GPS time. Data management software was developed to expand all data records to one second of Greenwich Mean Time (GMT) time code. During video post-processing, a Horita® Time Code Wedge (model number TCW50) was used in conjunction with a computer to record the audio time code in a Microsoft Access® database.

ROV Sampling Operations

ROV operations were conducted off the FV Donna Kathleen, a 19 m fishing vessel owned and operated by Tim Maricich. Surveys were conducted between the hours of 0800 and 1700 PST to avoid the low light conditions of dawn and dusk that might affect finfish abundance measurements and underwater visibility.

The ROV was flown off the vessel's starboard side using a "live boat" technique that employed a 227 kg (600 lb) clump weight. Using this method, all but 45 m of the ROV umbilical was secured from current-induced drag by coupling it with the clump weight cable and suspending the clump weight at least 10 m off the seafloor. The 45 m tether allowed the ROV pilot sufficient maneuverability to maintain a constant speed (0.5 to 0.75 m/sec) and a straight course down the planned survey line. In addition, the ROV pilot and ship's helm used real-time video displays of the location of the ship and the ROV, relative to the planned survey line, to navigate along the 500 m line. The ship's captain used the displays to follow and maintain the position of the ship within 35 m of the ROV. Three small (10 cm long) rigid foam floats were affixed to the 45 m tether to provide umbilical flotation and prevent snagging in high relief areas.

At each site, the ROV was flown along pre-planned survey lines. The ROV pilot maintained forward direction within ± 10 m of the planned line. The ranging sonars were fixed below and parallel to the camera between two forward-facing red lasers spaced 110 mm apart. The ROV pilot used the sonar readings to sustain a consistent transect width by maintaining the distance from the camera to the substrate (at the screen horizontal mid-point) between 1.5 and 3 m.

Site and Survey Line Selection

The boundaries of the eight sites sampled in 2011 were selected based on habitat interpretations from multibeam and/or sidescan sonar maps (Figure 1). Areas determined to be predominantly rocky bottom and that showed potential as candidate study areas for MPA monitoring (both MPA and fished reference areas) were targeted for baseline survey. Study sites were selected as 500 m wide rectangles with variable lengths covering the target depth range of 20 m to 70 m.

Prior to at-sea operations, planned survey lines within each site were selected and placed across the width of the site parallel to the prevailing depth contour and

bathymetry. The locations of the survey lines were chosen by selecting the desired number of planned lines and then evenly distributing them across the site. Survey lines were numbered according to the distance along the site boundary running from shallow to deep. The number of survey lines planned at each site was determined based on the estimated total rocky habitat, from multibeam mapping data, and the survey goal of collecting at least 3 km of hard substrate per study site, which is typically sufficient for generating seventy-five 100 m^2 fish density transects. In the case that rocky habitat was underestimated within the site, alternate survey lines were placed between the primary lines as needed.

Post-Processing

Acoustic tracking systems generate numerous erroneous positional fixes due to acoustic noise and other errors caused by vessel movement. For this reason positional data was post-processed to remove outliers. Positional information, in the form of XY metric coordinates, was filtered for outliers and smoothed using a 21-point running mean (Karpov et al. 2006). Planar length of positions tracked was calculated for each second and combined with width to calculate area surveyed per second. Gaps in the positional data that occurred due to deviations from quantitative protocols, such as pulls (ROV pulled back by tension on the 40 m tether), stops (ROV stops to let the ship catch up) or loss of target altitude caused by traveling over backsides of high relief structures (visual loss of 4 m target distance for more than 6 seconds which typically occurs on the downward slope of high relief habitat) were removed from the data to be used to generate quantitative transects along each survey line. The remaining usable portions of each survey line was then divided into two different transect types; fish density transects and invertebrate density transects. Fish density transects used the entire camera field of view at the mid-screen and invertebrate transects used only the field of view at the bottom of the viewing monitor, which was calculated using paired lasers as 45**%** of the mid screen width.

Substrate and Habitat

A protocol to characterize substrate observed in video along survey lines was developed to be compatible to a hierarchical system classification developed by Green et al. (1999). The video record was reviewed and substrate types were classified independently as rock, boulder, cobble, or sand. Rock was defined as any igneous, metamorphic or sedimentary substrate; boulder as broken or rounded rock material that is between 0.25 and 3.0 m in diameter and clearly detached from the base substrate; cobble as broken or rounded rock material that is between 6 and 25 cm in diameter and clearly detached; and sand as any granular material with a diameter less than 6 cm (may include mud, organic debris such as shell or bone, gravel or pebble).

During review of the video record, a transparency film overlay with guidelines approximating a 1.5 m wide swath was placed over a video monitor screen. Each of the substrate types are identified by the processor independent of each other and were recorded as discrete segments with a beginning and ending time code, thus the segments of substrate types may overlap each other along the survey line creating segments of mixed substrate combinations (e.g. rock/sand, sand/cobble). A substrate

segment was considered continuous until a break of 2 m or greater occurred along the survey line or the substrate dropped below 20% of the total combined substrates for a distance of at least 3 m. After the review process, the substrates were combined to create three independent habitat types: hard (rock and/or boulder), mixed (rock and/or boulder with either cobble and/or sand) or soft (cobble and/or sand).

Finfish Abundance

Fish density transects were calculated using a two-step approach. First, the usable portions of each survey line were divided into 25 m^2 segments (subunits). Component subunits were typically 8 to 10 m in length with a width averaging approximately 3 m. Each subunit's total percent hard and/or mixed habitat was then calculated and those with percentages below 50% hard or mixed were removed. Next, the remaining subunits were concatenated into 100 m^2 transects (four sequential useable 25 m^2 subunits) for use in density calculations. A spacer subunit was discarded between each to minimize bias of contiguous transects (spatial autocorrelation). Using this method generates hard substrate transects without the loss of rock/sand interface habitat which may be important to some species.

Finfish video review and enumeration classified finfish to the lowest taxonomic level possible. Finfish that were not able to be classified to the species level were grouped into a complex of species, or recorded as unidentified. All finfish species and groupings were selected after a preliminary review of video prior to the formal enumeration processing. Only finfish greater than or equal to 11 cm were enumerated. Olive rockfish (*S. serranoides*) and yellowtail rockfish (*S. flavidus*) are difficult to distinguish when viewed in video and were grouped together into the olive/yellowtail rockfish complex. The Sebastomus rockfish complex may include rosy rockfish (*S. rosaceus*), starry rockfish (*S. constellatus*), and greenspotted rockfish (*S. chlorostictus*).

A screen overlay representing a diminishing perspective was used during fish review to approximate the transect width across the viewing screen, calculated by the ranging sonar, at mid-screen (Karpov et al. 2006). The overlay served as a guide for determining if a fish was in or out of the ROV transect. Finfish enumeration was limited to a maximum distance of 4 m. Using the sonar range value depicted on the screen as a gauge, the processor determined if a fish was within 4 m as it entered the viewing area. Fish that entered the viewing area were only counted if more than half the fish crossed the overlay guidelines.

In order to accurately correlate the location of the fish with habitat, time code entry was made when the fish crossed the mid-screen line. For finfish that were within 4 m, but swam away before they crossed the mid-screen line, time code entry was made when the location where the finfish had been observed reached the mid-screen point. All data entries were recorded in a Microsoft Access® database linked with the time code.

Macro invertebrate Abundance

Invertebrate transects were calculated by dividing the usable portions of each survey line into 30 m^2 transects. Each transect was typically 18 to 24 m in length with a

transect width averaging approximately 1.5 m. The total percent hard and/or mixed habitat was then calculated. No transects were removed based on habitat criteria.

Invertebrate video review and enumeration identified macro invertebrates to the lowest taxonomic classification level possible, or grouped them into a complex of species. All invertebrate species and groupings were based on review of video prior to enumeration. Only macro invertebrates with body forms and colors that are uniformly identifiable on video were selected to be enumerated (Gotshall 2005). Due to the difficulty in distinguishing individuals, species that form large colonial mats or cover large areas were not enumerated.

A screen overlay was also used during invertebrate review and enumeration to approximate the transect width, calculated by the ranging sonar, at the bottom of the screen. The diminishing perspective overlay lines served as a guide for determining if an invertebrate was in or out of the ROV transect. The overlay used for invertebrate enumeration was the same as the overlay used in habitat classification, allowing for direct correlation of habitat to each invertebrate observation. In order to accurately correlate the location of the invertebrate with the habitat, time code entry was made when the invertebrate crossed the bottom of the screen line. All data entries were recorded in a Microsoft Access® database linked with the time code. Invertebrates that entered the viewing area were only counted if more than half the animal crossed the overlay guidelines at the bottom of the screen.

Spatial Data Maps

The eight sites sampled were depicted with final completed survey lines, substrate types, finfish, and macro invertebrates using ArcView® 9.1 software. Site maps produced for this report show the locations along the ROV survey line of selected finfish, invertebrates, substrate, bathymetry, and topography. Map products include associated bathymetry and multibeam and/or sidescan sonar imagery with shaded relief. The background multibeam sonar bathymetry imagery was collected by California State University Monterey Bay Seafloor Mapping Lab.

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RESULTS

Survey Totals

Baseline ROV surveys were conducted both inside and outside of Bodega Bay SMR and SMCA, Farallon Islands SMR and SMCA, and Point Arena SMR and SMCA during seven survey days from 12 July through 8 August, 2011. A period of high winds at the end of the sampling period resulted in the Point Arena reference site, PA-2, not being fully sampled as planned. A total of 33.4 km of planned survey lines were completed and post-processed across the seven sites (Table 1; Appendix 1). From this, 26.2 km was determined to be hard and/or mixed habitat, which accounted for 78.4% of the total usable data from all sites combined. The amount of hard and mixed habitat sampled by site averaged 3.7 km, with a range of 5.3 to 0.3 km surveyed at FI-3 and PA-2 respectively. The number of survey lines completed at each site ranged from two at PA-2 to thirteen at FI-3, with an average of 9.1 survey lines per site.

Table 1. Total distance of hard and/or mixed habitat from completed survey lines, total number of 100 m^2 fish transects and total number of 30 m^2 invertebrate transects generated from video collected at the seven sites sampled in 2011.

Study Area	Site	No. of lines	Total km	Hard and/or mixed Habitat		No. of transects 100 m^2	No. of transects 30 m^2
				Km	Area (ha)		
Bodega Bay							
	BB-1	11	5.7	4.4	1.34	102	264
	BB-2	10	5.2	4.6	1.50	104	230
	BB-3	10	5.1	4.5	1.49	110	243
Farallon Islands							
	FI-1	8	4.3	3.7	1.48	89	213
	FI-3	13	6.8	5.3	2.01	139	348
Point Arena							
	PA-1	10	5.3	3.4	1.19	78	235
	PA-2	2	1.0	0.3	0.09	6	43
	Totals	64	33.4	26.2	9.10	628	1,576

The number of transects, both fish and invertebrate, compiled from usable survey lines varied by site and was dependent on the number of survey lines completed at each site. A total of six hundred and twenty eight 100 m^2 fish transects and fifteen hundred and seventy six 30 m^2 invertebrate transects were generated from the 64 lines sampled (Table 1). An average of 9.0 fish transects were generated per survey line with a range

from 3.0 to 11.1 at PA-2 and FI-3 respectively. The average number of invertebrate transects generated per survey line was 24.2, with a range of 21.5 to 26.8 at PA-2 and FI-3 respectively.

Site Descriptions

Substrate and habitat composition for all study sites and survey lines processed are presented in Tables 2 and Appendix 2. Visual representations of substrate and habitat data for each sampled survey line are shown in Figures 2–8. Habitat percentages are presented as the relative proportion of the survey line that contained the specific habitat type. Percent by component substrates represent the ratio of the survey line that has a given substrate compared to the total line and are not relative percentages.

Table 2. Percentages of substrates and habitats for all survey lines completed and post processed at each of the eleven sites sampled in 2011.

Study area	Site	Percentage by substrate				Percentage by habitat		
		Rock	Boulder	Cobble	Sand	Hard	Mixed	Soft
Bodega Bay								
	BB-1	76	6	4	48	50	26	24
	BB-2	87	20	16	43	53	35	12
	BB-3	88	23	15	38	57	31	12
Farallon Islands								
	FI-1	85	11	3	28	71	14	14
	FI-3	78	9	7	63	36	42	22
Point Arena								
	PA-1	62	1	4	60	39	24	37
	PA-2	27	3	1	87	13	14	73
	Average	72	10	7	52	46	27	28

Rock and sand substrate coverage for all sites combined averaged 72% and 52%, respectively, and are not mutually exclusive. Lines may have sections in which rock and sand are observed concurrently. There were differences in the percentages of rock and sand among sites; PA-2 had the least rock (27%) and the most sand (87%), while BB-3 had the most rock (88%) and FI-1 had the least amount of sand (28%). Boulder and cobble were the least observed substrates, with an average of 10% and 7%, respectively. Outliers were at BB-2 and BB-3 where boulder substrate covered at least 20% and cobble covered at least 15% of the surveyed line. The percent composition of mixed habitat averaged 27% for all sites combined and ranged from 14% at FI-1 and PA-2 to 42% at FI-3. Hard and soft habitat averaged 46% and 28% respectively at all sites combined.

Finfish Biological Data

A complete list and total counts of all finfish species and groupings identified from video collected at all sites combined in 2011 are shown in Table 3. Descriptive statistics from the 100 m^2 transects for twelve selected finfish species and groupings are provided in Table 4 and Appendix 3. The locations of the twelve selected finfish species on the surveyed lines of are displayed in Figures 9-15.

Table 3. Common and scientific names of quantified finfish from 2011 ROV survey (list sorted by count).

Common Name	Scientific Name	Total Count
Blue rockfish	*Sebastes mystinus*	420
Yellowtail/Olive complex	*Sebastes flavidus/serranoides*	371
Kelp greenling	*Hexagrammos decagrammus*	303
Lingcod	*Ophiodon elongatus*	155
Canary rockfish	*Sebastes pinniger*	155
Unidentified rockfish	*Sebastes*	126
Sebastomus complex	*Sebastomus*	97
Canary/Vermillion complex	*Sebastes pinniger/miniatus*	48
Vermilion rockfish	*Sebastes miniatus*	44
Copper rockfish	*Sebastes caurinus*	22
Unidentified Surfperch	Embiotocidae	18
China rockfish	*Sebastes nebulosus*	15
Quillback rockfish	*Sebastes maliger*	12
Gopher rockfish	*Sebastes carnatus*	11
Spotted ratfish	*Hydrolagus colliei*	10
Black rockfish	*Sebastes melanops*	3
Wolf eel	*Anarrhichthys ocellatus*	2
Yelloweye rockfish	*Sebastes ruberrimus*	2
Big skate	*Raja binoculata*	1
Starry skate	*Raja stellulata*	1
Black-and-yellow rockfish	*Sebastes chrysomelas*	1
	Total	**1,817**

Table 4. Descriptive statistics for 12 select finfish species from transects ($100m^2$) at each site sampled during quantitative ROV surveys conducted in 2011. A full species list is provided in Appendix 3.
Mean - mean density; SD - standard deviation; %FO - percent frequency of occurrence

Site	BB-1 (n=102)			BB-2 (n=104)			BB-3 (n=110)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Blue rockfish	0.01	0.1	1	0.11	0.59	5	0.21	0.79	9
Canary rockfish	0.04	0.24	3	0.18	0.52	13	0.28	0.98	13
China rockfish	0	0	0	0.03	0.17	3	0.01	0.1	1
Copper rockfish	0.02	0.14	2	0.03	0.17	3	0	0	0
Gopher rockfish	0	0	0	0.02	0.14	2	0.05	0.21	5
Kelp greenling	0.58	0.91	37	0.44	0.81	33	0.3	0.57	25
Lingcod	0.25	0.43	25	0.14	0.4	13	0.15	0.4	13
Quillback rockfish	0.02	0.14	2	0.02	0.14	2	0	0	0
Sebastomus complex	0.01	0.1	1	0.1	0.33	9	0.16	0.52	13
Vermilion rockfish	0.04	0.2	4	0.06	0.27	5	0.06	0.25	6
Yelloweye rockfish	0	0	0	0	0	0	0.01	0.1	1
Yellowtail/Olive complex	0.09	0.35	7	0.48	2.53	8	0.73	2.28	16
Average	0.09	0.22	7	0.13	0.51	8	0.16	0.52	9

Table 4. Continued.

Site	FI-1 (n=89)			FI-3 (n=139)			PA-1 (n=78)			PA-2 (n=6)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Blue rockfish	0.94	2.43	28	0.4	1.82	9	0.63	2.8	10	0	0	0
Canary rockfish	0.07	0.33	4	0.06	0.45	4	0.15	0.56	10	0	0	0
China rockfish	0.04	0.21	4	0	0	0	0	0	0	0	0	0
Copper rockfish	0.01	0.11	1	0.01	0.12	1	0.09	0.29	9	0.17	0.41	17
Gopher rockfish	0.02	0.15	2	0.01	0.08	1	0	0	0	0	0	0
Kelp greenling	0.11	0.32	11	0.16	0.47	12	0.78	1.11	45	0.5	0.55	50
Lingcod	0.07	0.29	6	0.14	0.41	12	0.22	0.5	18	0.33	0.52	33
Quillback rockfish	0	0	0	0.01	0.08	1	0.04	0.19	4	0	0	0
Sebastomus complex	0.55	1.07	27	0.04	0.22	3	0	0	0	0.17	0.41	17
Vermilion rockfish	0.03	0.18	3	0.11	0.49	8	0.08	0.35	5	0	0	0
Yelloweye rockfish	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail/Olive complex	0.8	1.58	31	0.14	0.6	6	0.78	3.83	13	0.5	0.84	33
Average	0.22	0.56	10	0.09	0.40	5	0.23	0.80	10	0.14	0.23	13

Of the 1,817 finfish observed from all sites combined, blue rockfish, canary rockfish, kelp greenling, lingcod and yellowtail/olive complex accounted for 77% of the total number of fish enumerated (Table 3). Rockfish species represented 73% of the total finfish species observed with unidentified rockfish accounting for less than 10% of the total rockfish observations. A total of 490 individuals of non-rockfish species were observed, with kelp greenling and lingcod accounting for 94% of the total non-rockfish observations.

For the purposes of this report, twelve finfish species common in the commercial and recreational fisheries, were selected for comparison Table 4 and Figure 16. Overall, kelp greenling and lingcod showed a relatively high frequency of occurrence at all sites compared to other species. Canary rockfish and yellowtail/olive complex also showed a relatively high frequency of occurrence, but not at all sites. Bodega Bay MPA sites had lower overall densities for most rockfish species when compared to the outside reference site. In contrast, kelp greenling appeared to have a higher density inside the Bodega Bay MPAs. Blue rockfish, sebastomus complex and yellowtail/olive complex showed higher densities inside the Farallon Islands MPAs, when compared to the outside reference area.

Invertebrate Biological Data

A complete list and total counts of all macro invertebrate species and groupings identified from video collected at all sites combined in 2011 is shown in Table 5. Descriptive statistics by site are provided in Table 6 and Appendix 4 for invertebrate species and groupings that were quantified from the 30 m^2 transects sampled in 2011. The locations of fifteen selected macro invertebrate species relative to survey lines are displayed in Figures 17-23.

Of the 18,258 macro invertebrates observed from all sites combined, six species (*Asterina miniata, Lophogorgia chilensi, Metridium giganteum, Parastichopus californicus, and Urticina piscivora*) accounted for 84% of the total number of invertebrates enumerated (Table 5). Echinoderm species represented 50% of the total invertebrate species observed with cnidarian species accounting for around 19% of the total observations. Sea cucumbers represented approximately 20% of the total macro invertebrates enumerated.

For the purposes of this report, fifteen macro invertebrate species (listed by common name) with relatively high abundances were selected for comparison Table 6 and Figure 24. Both the California sea cucumber and the red sea star showed a relatively high frequency of occurrence at most sites compared to other species. Densities for California sea cucumbers, fish eating urticina, red sea stars and the white plumed anemone were higher at all sites compared to other species. The red gorgonian was not observed at the Bodega Bay sites, while the northern staghorn bryozoan was only observed that the Farallon Islands MPA site.

Table 5. Common and scientific names of quantified macro invertebrates from 2011 ROV survey (list sorted by count). Common names from Gotshall 2005.

Common Name	Scientific Name	Total Count
White-plumed anemone	*Metridium giganteum*	5,286
California sea cucumber	*Parastichopus californicus*	3,951
Bat star	*Asterina miniata*	1,900
Red sea star	*Mediaster aequalis*	1,791
Fish eating urticina	*Urticina piscivora*	1,324
Red gorgonian	*Lophogorgia chilensis*	1,127
Henricia complex	*Henricia sp.*	562
Orange puffball sponge	*Tethya aurantia*	475
Short spined sea star	*Piaster brevispinus*	291
Sand-rose anemone	*Urticina columbiana*	289
White sea pen	*Stylatula elongata*	284
Northern staghorn bryozoan	*Heteropora pacifica*	217
Sand star	*Luidia foliolata*	175
Rainbow star	*Orthasterias koehleri*	157
Leather star	*Dermasterias imbricata*	137
Red sea urchin	*Strongylocentrotus franciscanus*	51
Aggregated nipple sponge	*Polymastia pacifica*	45
Cancer complex	*Cancer sp.*	38
Sunflower star	*Pycnopodia helianthoides*	36
Stimpson's sun star	*Solaster stimpsoni*	30
Boot sponge	*Rhabdocalyptus dawsoni*	19
Orange sea pen	*Ptilosarcus gurneyi*	14
Common basket star	*Gorgonocephalus eucnemis*	13
California hydrocoral	*Stylaster californicus*	13
Purple sea urchin	*Strongylocentrotus purpuratus*	10
Gray puffball sponge	*Craniella arb*	6
Sea whip	*Halipteris californica*	6
Giant spined star	*Pisaster giganteus*	4
Orange sea cucumber	*Cucumaria miniata*	3
Stalked tunicate	*Styela montereyensis*	2
Feather star	*Florometra serratissima*	1
Southern staghorn bryozoan	*Diaperoecia californica*	1
	Total	**18,258**

Table 6. Descriptive statistics for 15 select invertebrate species from transects ($30m^2$) at each site sampled during quantitative ROV surveys conducted in 2011. A full species list is provided in Appendix 4.
Mean - mean density; SD - standard deviation; %FO - percent frequency of occurrence

Site	BB-1 (n=254)			BB-2 (n=223)			BB-3 (n=233)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Bat star	0.15	0.44	13	0.07	0.32	6	0.07	0.29	6
CA sea cucumber	1.19	1.73	47	2.05	2.3	70	2.75	2.51	82
Fish eating urticina	0.51	0.94	31	1.04	1.45	52	1.04	1.64	46
Henricia complex	0.56	1.04	32	0.44	0.77	30	0.86	1.32	44
Leather star	0.13	0.37	12	0.08	0.3	7	0.03	0.16	3
Northern staghorn bryozoan	0	0	0	0	0	0	0	0	0
Orange puffball sponge	0.06	0.41	3	0.01	0.09	1	0.02	0.13	2
Rainbow star	0.12	0.37	11	0.13	0.37	11	0.29	0.62	22
Red gorgonian	0	0	0	0	0	0	0	0	0
Red sea star	0.39	0.87	24	2.08	2.15	75	2.52	2.44	77
Sand star	0.09	0.33	8	0.1	0.35	9	0.01	0.11	1
Sand-rose anemone	0.1	0.41	7	0.22	0.69	15	0.17	0.62	11
Short spined sea star	0.2	0.5	17	0.16	0.46	13	0.27	0.62	21
White sea pen	0.7	2.55	15	0	0.07	0	0.04	0.44	1
White-plumed anemone	1.97	5.17	33	6.71	12.83	62	3.29	9.71	40
Average	0.41	1.01	17	0.87	1.48	23	0.76	1.37	24

Table 6. Continued.

Site	FI-1 (n=206)			FI-3 (n=336)			PA-1 (n=227)			PA-2 (n=41)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Bat star	2.64	4.27	63	5.01	5.09	87	0.06	0.28	5	0	0	0
CA sea cucumber	2.85	3.64	64	3.88	3.42	85	5.14	4.31	80	2.78	5.59	32
Fish eating urticina	1.09	2.1	42	1.03	2.1	36	0.76	1.05	45	0.12	0.33	12
Henricia complex	0.2	0.56	15	0.17	0.57	11	0.32	1.07	15	0	0	0
Leather star	0.08	0.27	8	0.02	0.17	2	0.27	0.67	19	0.07	0.26	7
Northern staghorn bryozoan	0	0	0	0.55	4.22	3	0	0	0	0	0	0
Orange puffball sponge	0.06	0.39	4	0.44	1.74	16	1.6	2.94	40	0.02	0.16	2
Rainbow star	0.07	0.36	5	0.07	0.3	6	0	0.07	0	0	0	0
Red gorgonian	0.91	2.42	21	0.44	1.47	13	3.26	6.45	37	1.34	3.31	20
Red sea star	2.04	2.56	59	0.94	1.36	45	0.91	1.44	44	0.34	0.82	17
Sand star	0.04	0.2	4	0.13	0.4	11	0.34	0.88	18	0.49	1.23	20
Sand-rose anemone	0.09	0.63	4	0.2	1.13	7	0.31	0.71	20	0.05	0.31	2
Short spined sea star	0.11	0.37	9	0.04	0.2	3	0.42	0.82	27	0	0	0
White sea pen	0	0	0	0	0	0	0.62	1.84	15	0.49	1.25	17
White-plumed anemone	0.79	3.55	14	0.26	1.14	11	3.96	9.17	34	1.71	7.85	22
Average	0.73	1.42	21	0.88	1.55	22	1.20	2.11	27	0.49	1.41	10

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DISCUSSION

Survey Totals

The goal of collecting video over a minimum of 3 km of hard substrate was met at all but one site. Strong winds at the end of the scheduled boat time prevented the complete sampling of the Point Arena reference site (PA-2), where only 0.3 km of hard bottom was surveyed. Weather conditions were not an issue at all other sites and sampling was conducted as planned.

The number of transects generated from rocky habitats surveyed also exceeds the planned goal of generating at least seventy-five 100 m^2 fish density transects from each site (excluding PA-2). Transect totals exceeded planned goals by 40%, and ranged between 13% at PA-1 and 77% at FI-3. This increase in the number of transects generated at each site was attributed to an underestimate of the available rocky bottom habitats from the multibeam mapping during cruise planning. Future sampling levels should be adjusted to reduce oversampling and survey/post-processing costs.

Site Description

The amount of rocky habitat sampled at each site, excluding PA-2, exceed sampling goals by almost 44% (13% at PA-1 to 77% at FI-3). Rocky substrate was found on an average of 72% of all lines surveyed and was most notably different at the PA-2 site, where soft substrates were more common. Given that only two lines were sampled at PA-2, it is likely that the calculated percent hard substrate was underestimated for the entire site. Further sampling at PA-2 will be needed to accurately describe the habitat characteristics of this site.

Finfish Biological Data

Rockfish species represented the majority of the species identified from the video, with non-rockfish species being comprised primarily of two species, lingcod and kelp greenling. These two non-rockfish species also had a relatively high percent frequency of occurrence at most sites, when compared to rockfish species with similar densities such as blue rockfish and the yellowtail/olive complex. Lingcod and kelp greenling also showed a fairly consistent density to percent frequency of occurrence ratio, indicating a more even distribution across the site. As expected, schooling species such as blue rockfish and yellowtail/olive complex showed an inconsistent ratio of density to percent frequency of occurrence.

Finfish observations from the north central coast had some similarities and differences, when compared anecdotally to other MPA regions sampled by the Department (CDFG unpublished). Blue rockfish and the yellowtail/olive complex were the most commonly observed rockfish species, which is consistent with observations from other MPA regions. Canary rockfish observations were the next highest observed rockfish species/complex, which is inconsistent with past observations in other MPA regions sampled by the Department. Kelp greenling was also more commonly observed in the

north central coast, but only at the mainland sites. These differences, while only anecdotal, support a species composition shift within the north central coast, when compared to data collected in the central coast and northern Channel Islands.

Invertebrate Biological Data

Invertebrate transects and observations were generated as a starting point for future analysis and methods development. The methods developed during post-processing were intended to provide an accurate estimate of density, while matching the species observation to the exact habitat it was observed on. Density data presented within this report only provides an overall estimate of abundance within the entire site and does not take into account the habitat variability within each transect. In addition, species were identified to the closest taxa possible, but due to camera resolution, lighting and water visibility, accurate identification to species was not always possible. For example, the red gorgonian was identified as the species *Lophogorgia chilensis,* but may include other gorgonian species that have a red coloration. To address these issues, further refinement of sampling protocols and a more detailed habitat analysis will be undertaken with the Department following this report.

MPA Monitoring Totals

Data collected within the North Central Coast MPA study region in 2011 will be added to the Department's statewide MPA monitoring database. Currently the Department has collected almost 8,000 fish density transects within newly formed MPA regions (Table 7). Data collected over the eight years of ROV surveys represents a substantial MPA monitoring effort that provides a snapshot of baseline conditions in rocky habitats.

Table 7. The California Department of Fish and Game's ROV based MPA monitoring totals for km surveyed and transects generated by region and year.

Study Area	Year	Total km	No. of transects 100 m^2
Northern Channel Islands			
	2003	18	95
	2004	75	485
	2005	117	1,014
	2006	85	1,120
	2007	71	933
	2008	77	981
	2009	81	737
Central Coast Region			
	2007	26	486
	2008	53	971
	2009	24	308
North Central Coast Region			
	2009	18	220
	2011	33	628
	Totals	**678**	**7,978**

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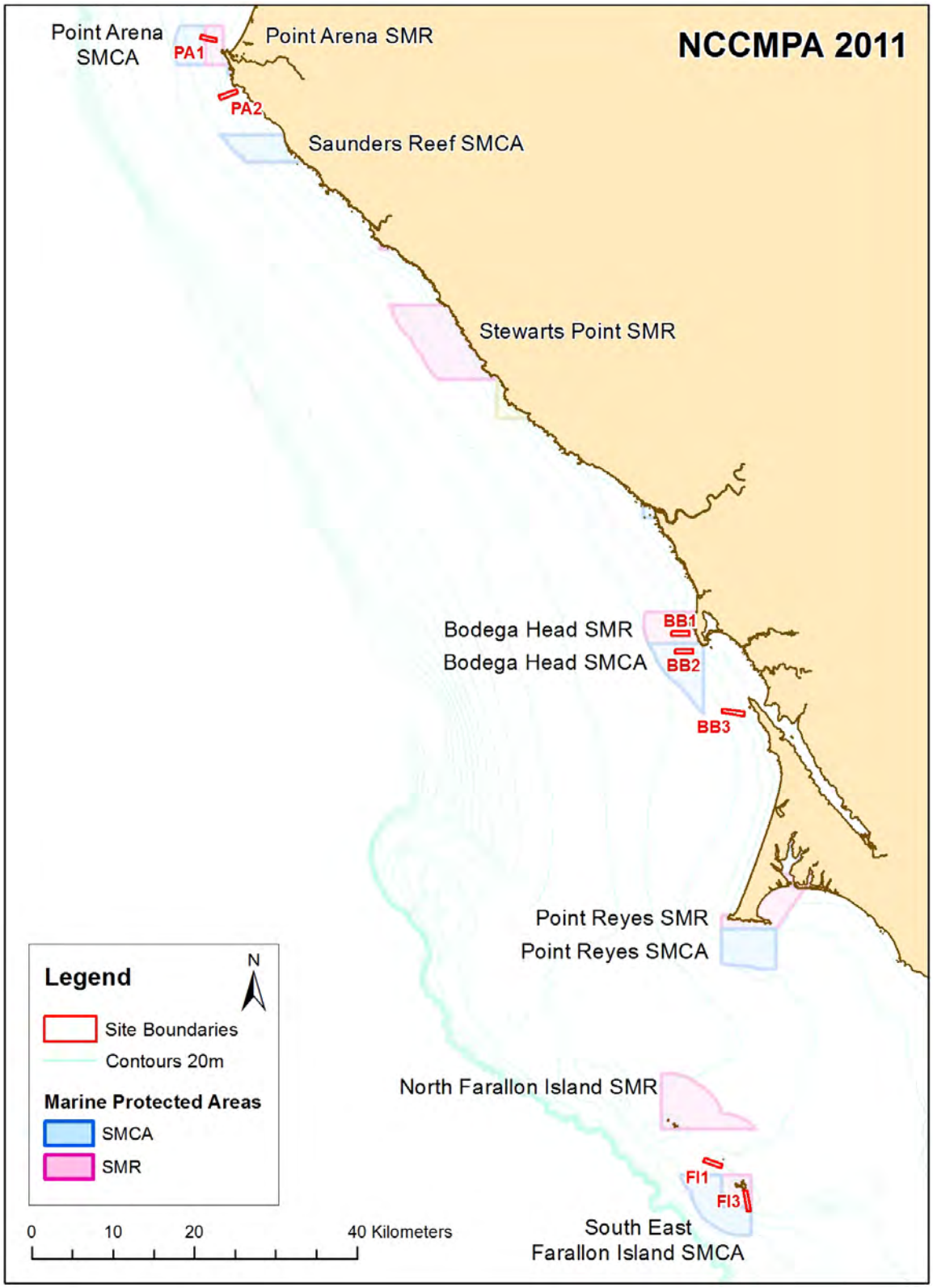

Figure 1. Location codes for sites surveyed in 2011 relative to the State Marine Conservation Area and State Marine Reserves.

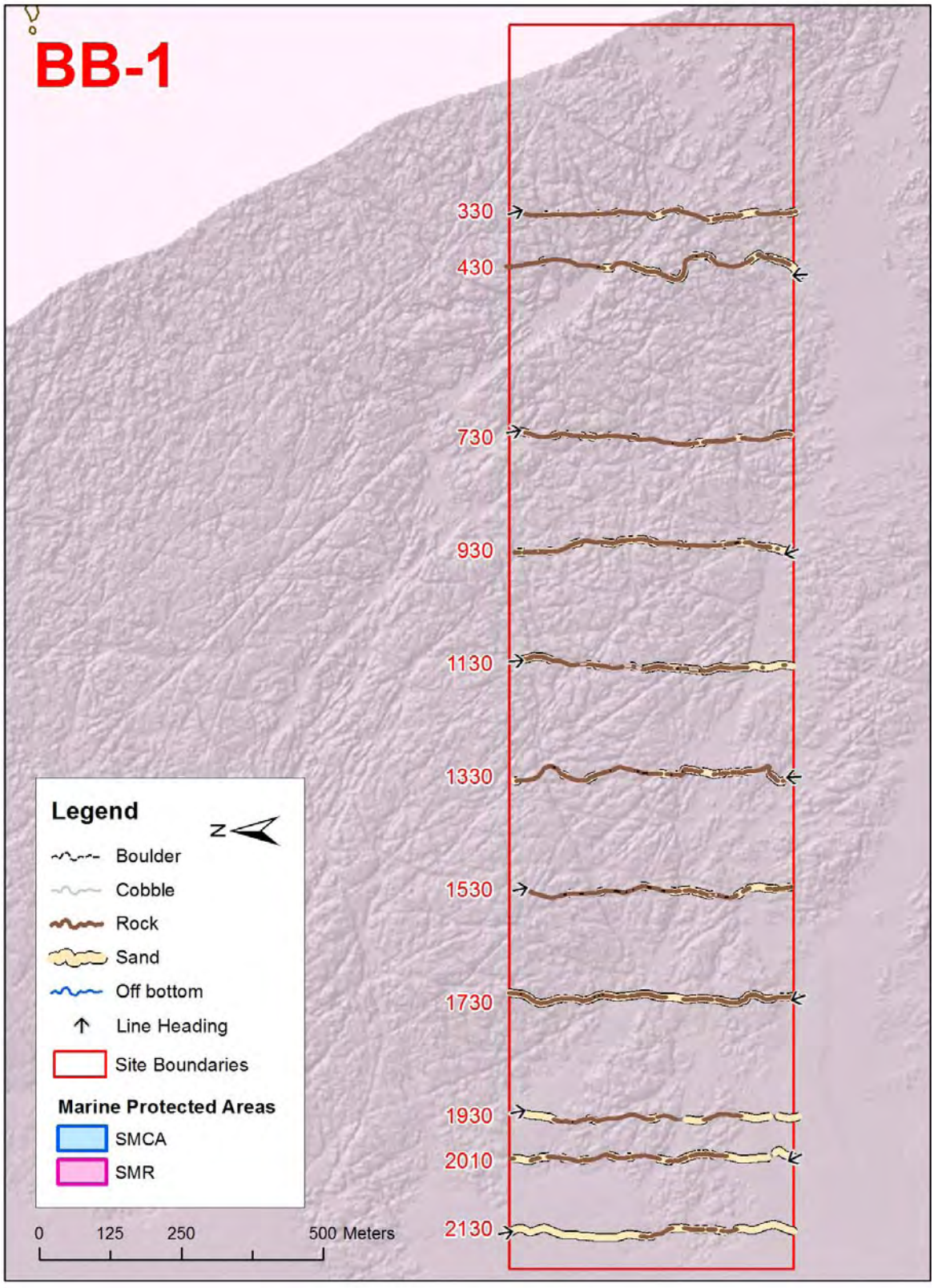

Figure 2. The Bodega Bay State Marine Reserve site (BB-1) boundary, survey lines and substrate estimates from ROV video collected in 2011.

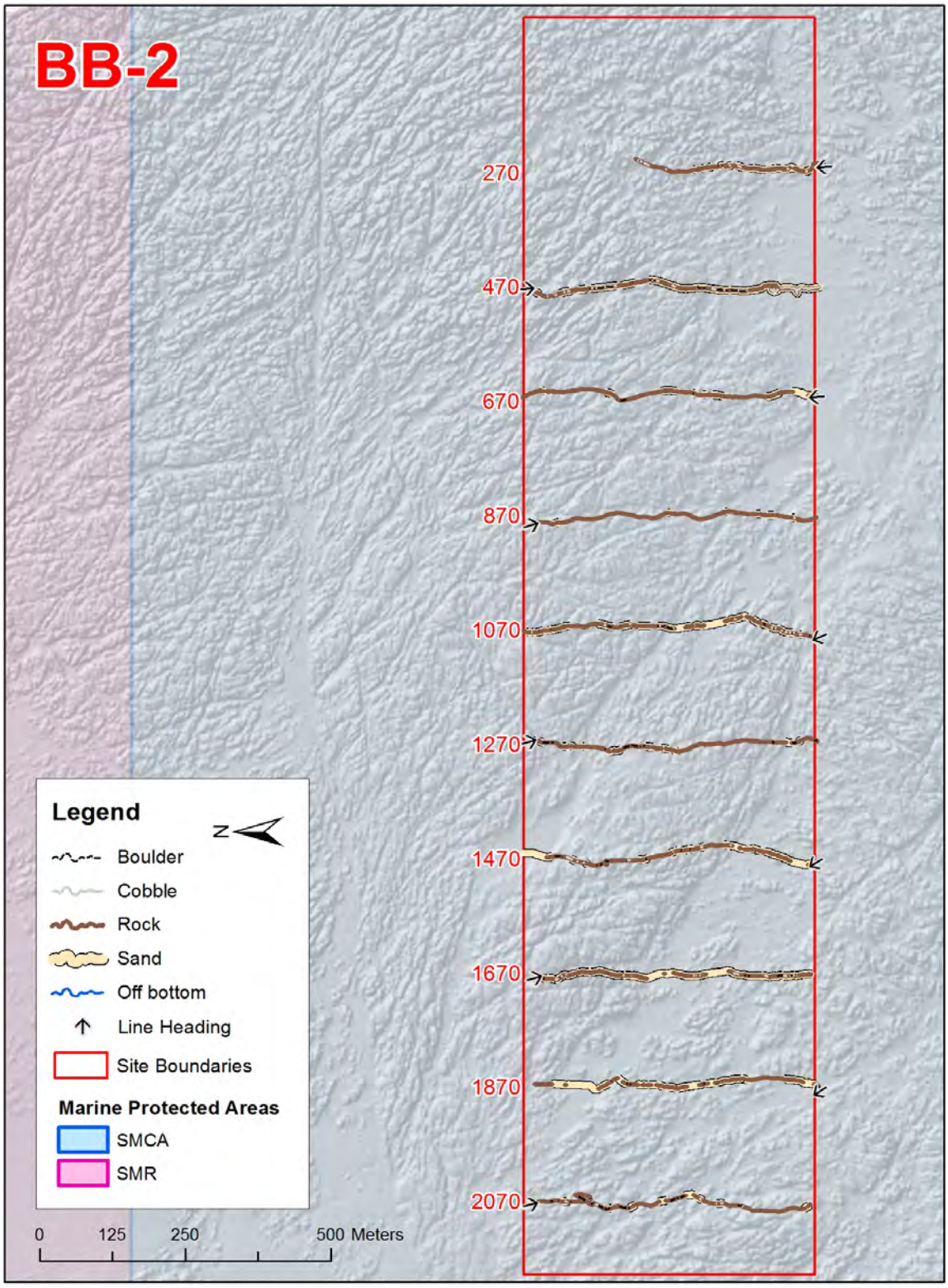

Figure 3. The Bodega Bay State Marine Conservation Area site (BB-2) boundary, survey lines and substrate estimates from ROV video collected in 2011.

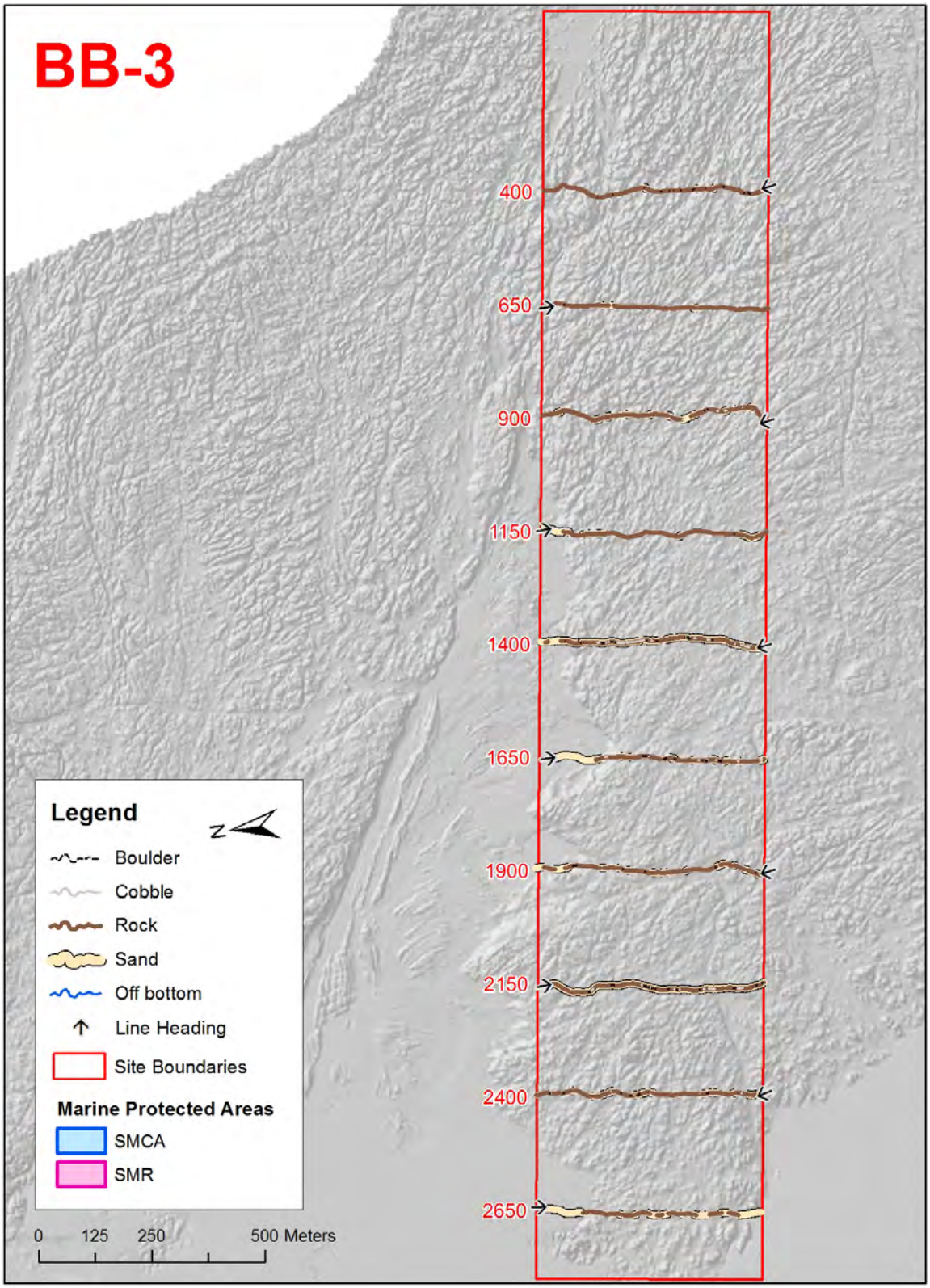

Figure 4. The Bodega Bay reference area site (BB-3) boundary, survey lines and substrate estimates from ROV video collected in 2011.

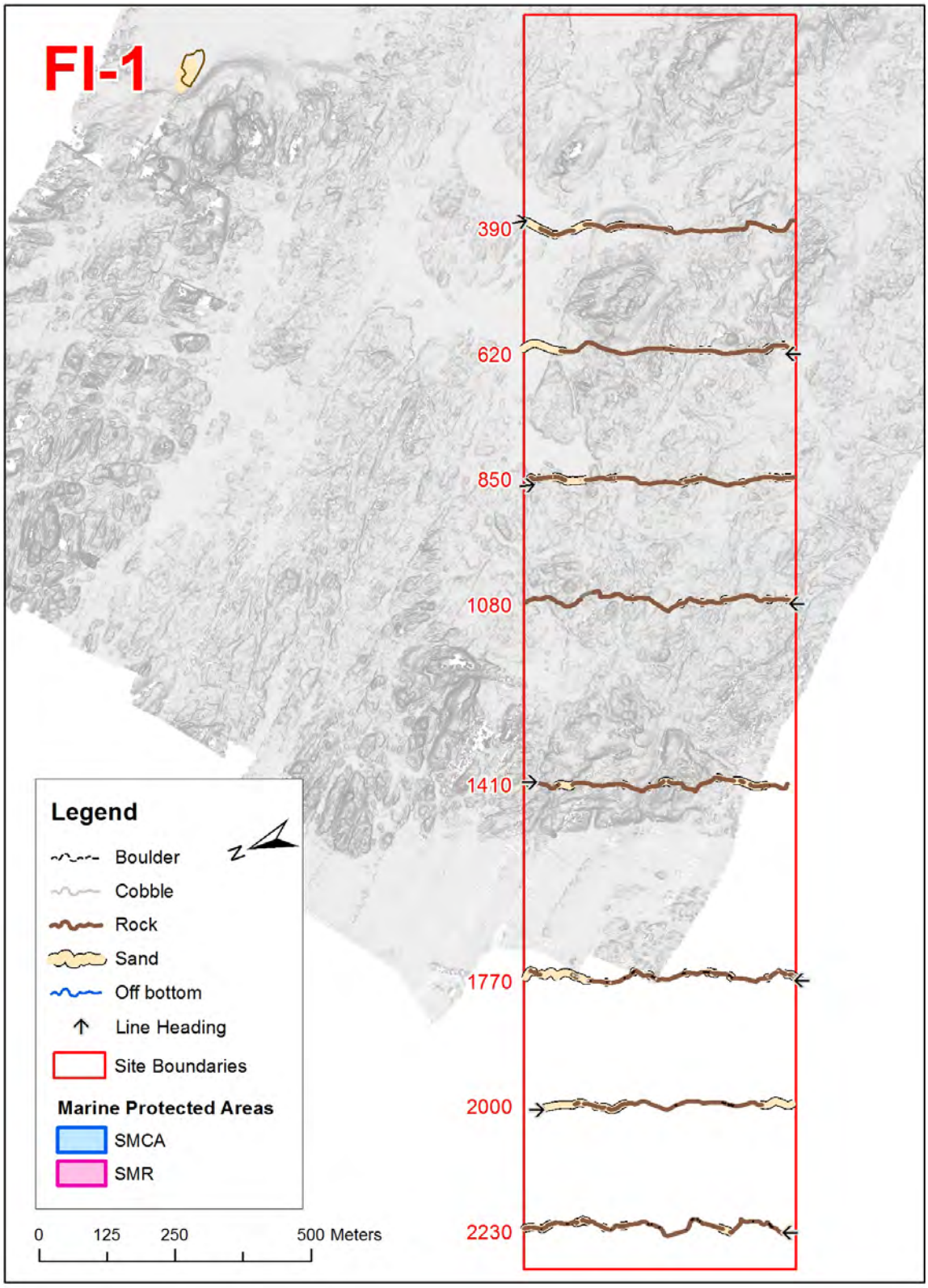

Figure 5. The Farallon Islands reference area site (FI-1) boundary, survey lines and substrate estimates from ROV video collected in 2011.

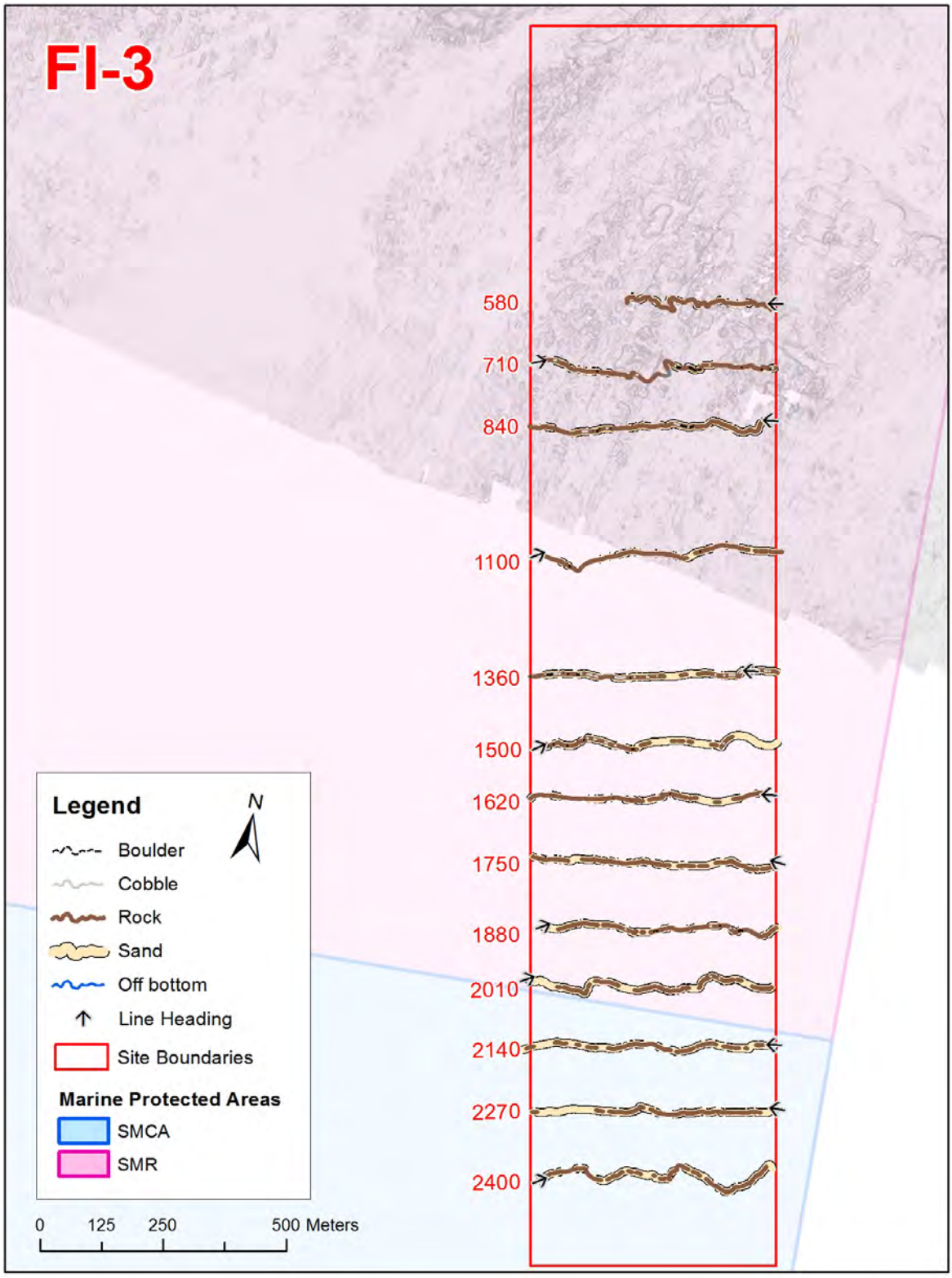

Figure 6. The Farallon Islands State Marine Reserve and State Conservation area site (FI-3) boundary, survey lines and substrate estimates from ROV video collected in 2011.

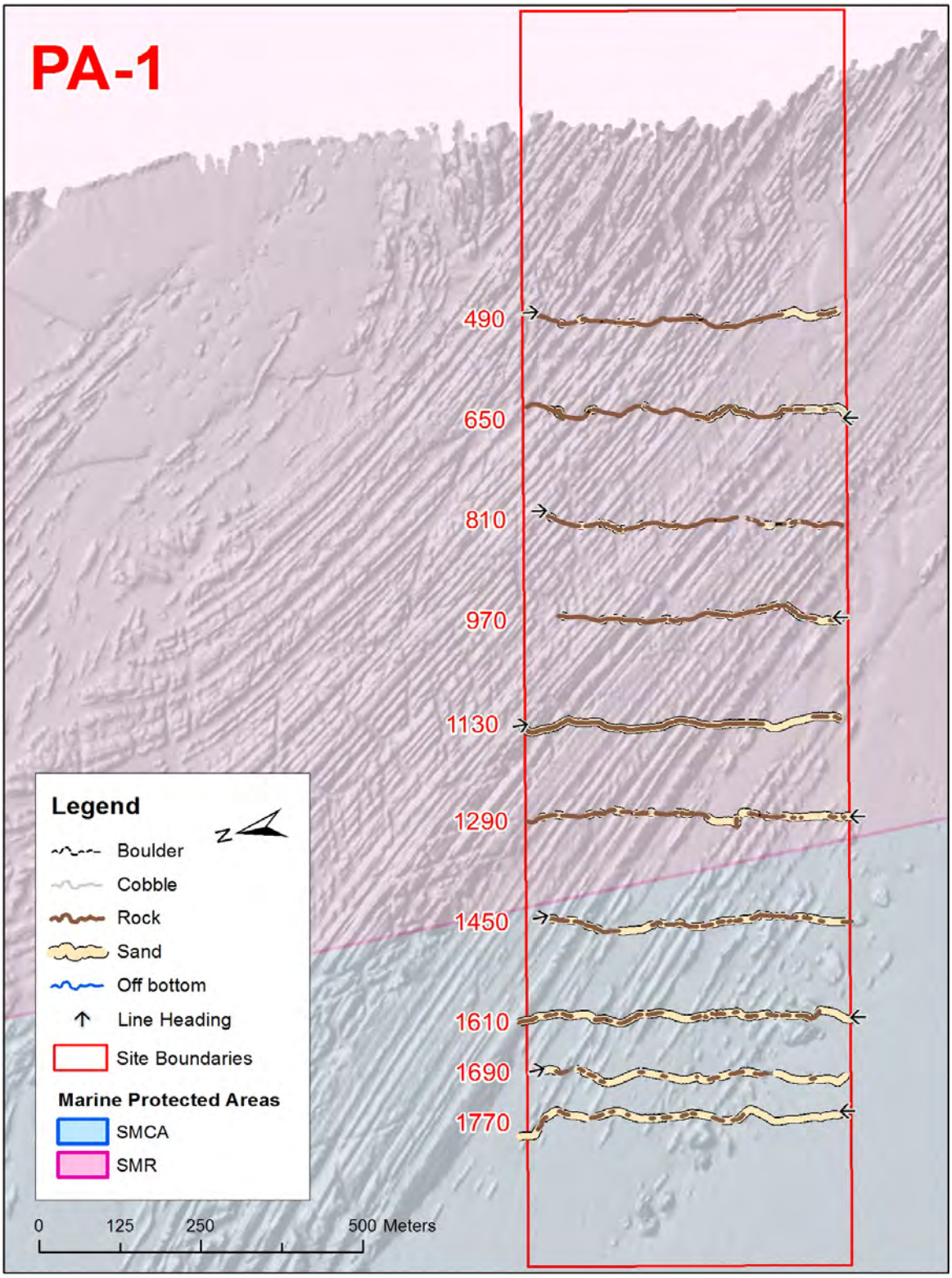

Figure 7. The Point Arena State Marine Reserve and State Conservation area site (PA-1) boundary, survey lines and substrate estimates from ROV video collected in 2011.

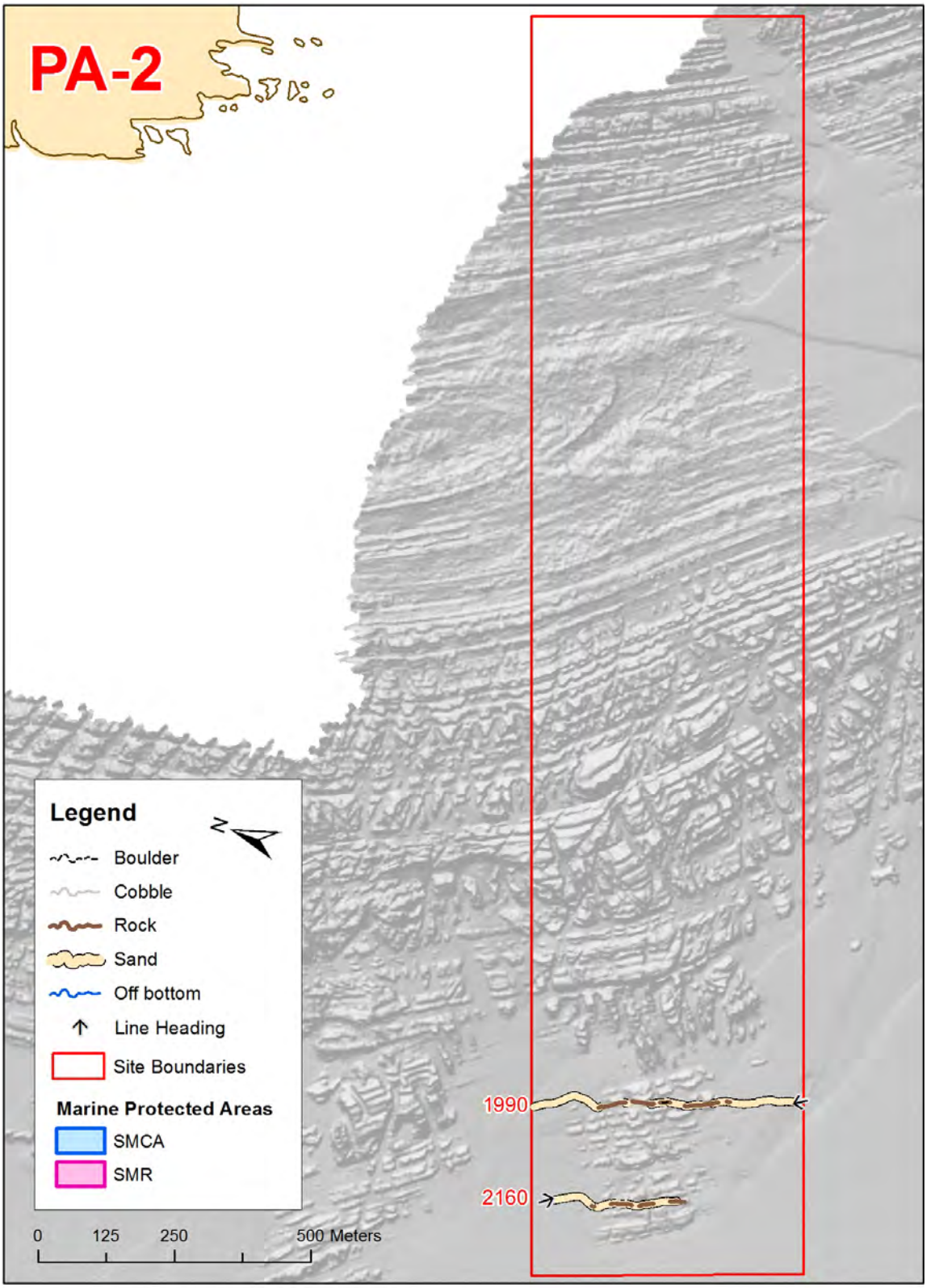

Figure 8. The Point Arena reference area site (PA-2) boundary, survey lines and substrate estimates from ROV video collected in 2011.

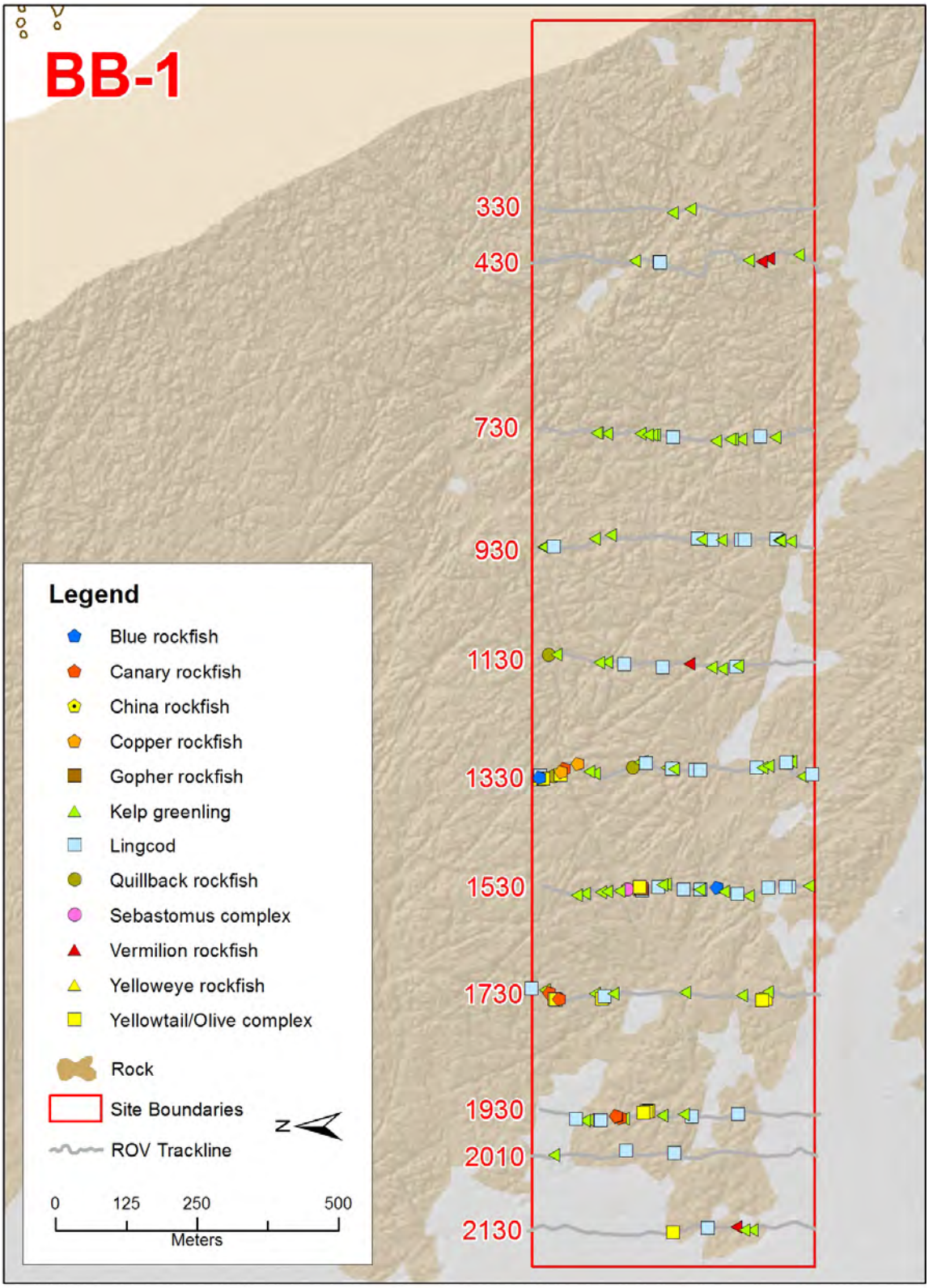

Figure 9. The Bodega Bay site (BB-1) boundary with ROV survey lines showing select finfish species identified from ROV video.

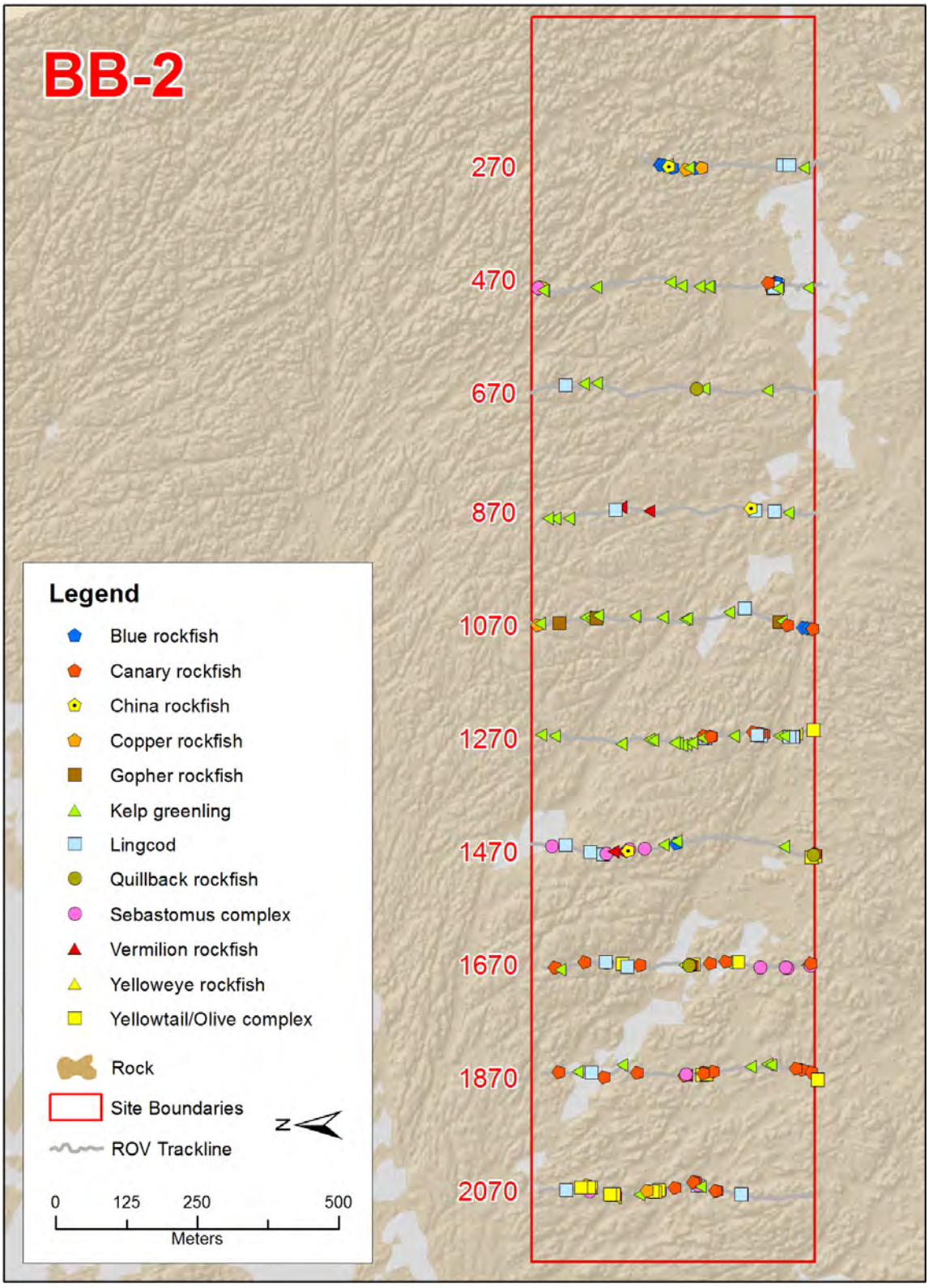

Figure 10. The Bodega Bay site (BB-2) boundary with ROV survey lines showing select finfish species identified from ROV video.

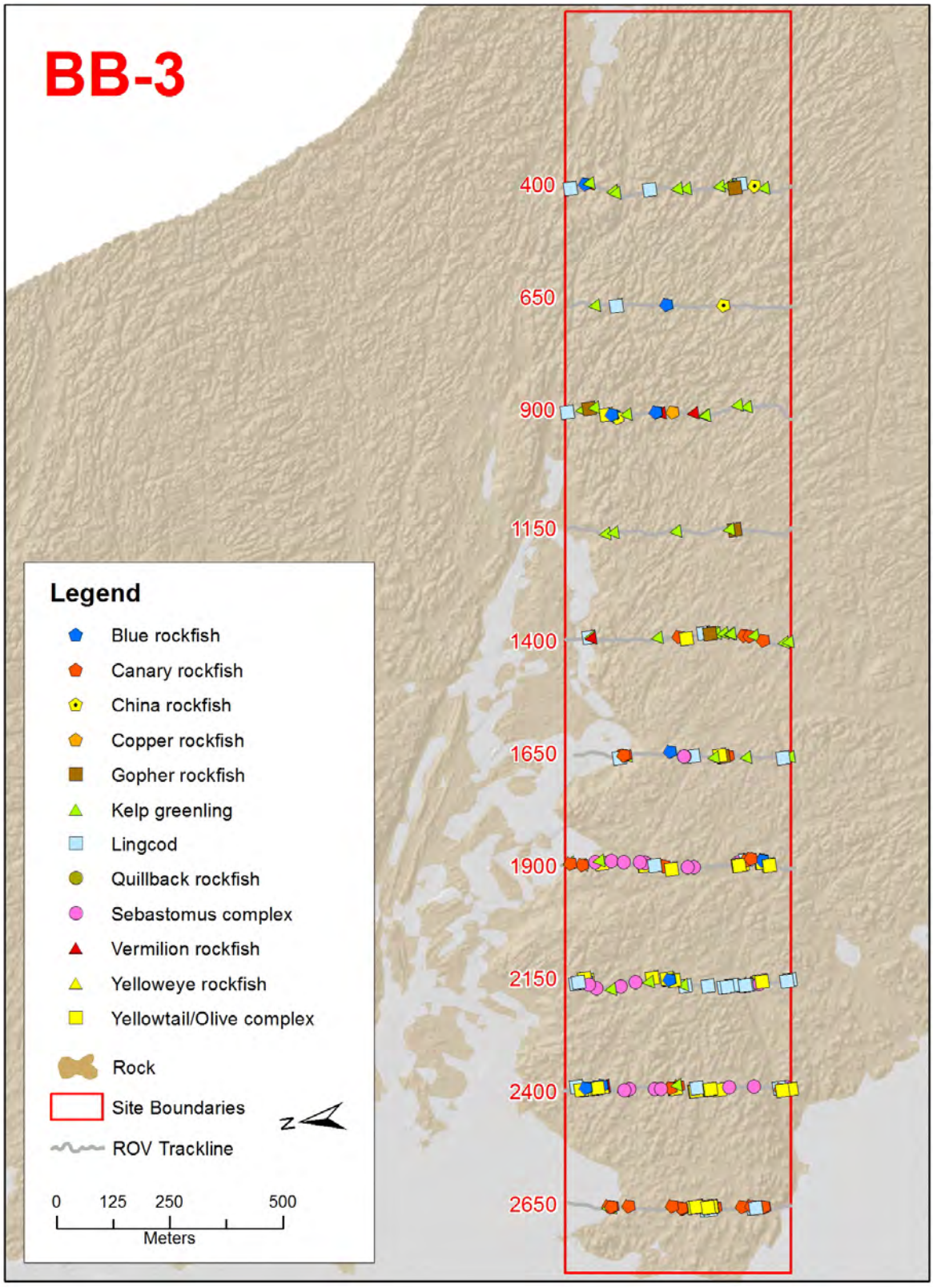

Figure 11. The Bodega Bay site (BB-3) boundary with ROV survey lines showing select finfish species identified from ROV video.

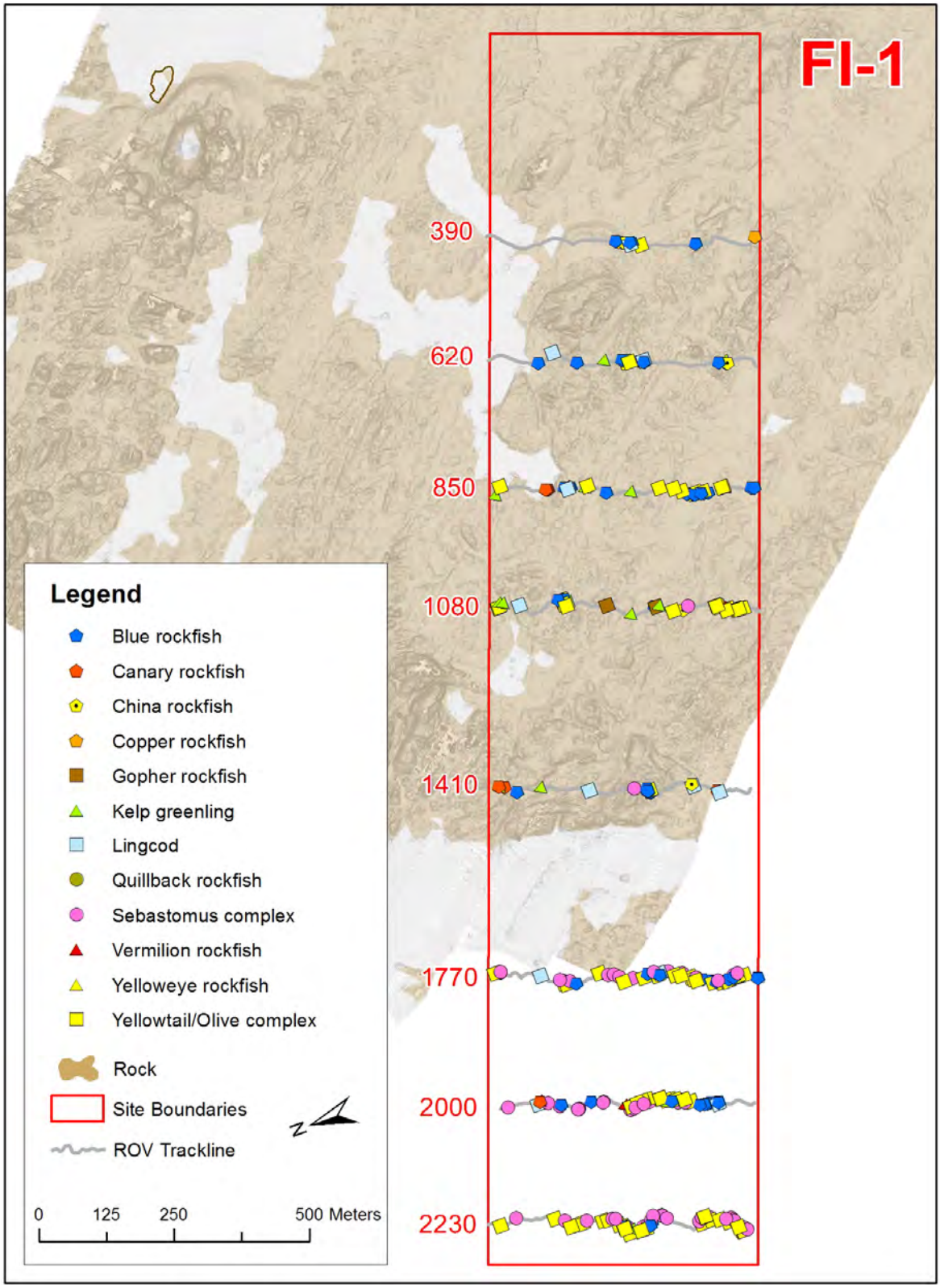

Figure 12. The Farallon Islands site (FI-1) boundary with ROV survey lines showing select finfish species identified from ROV video.

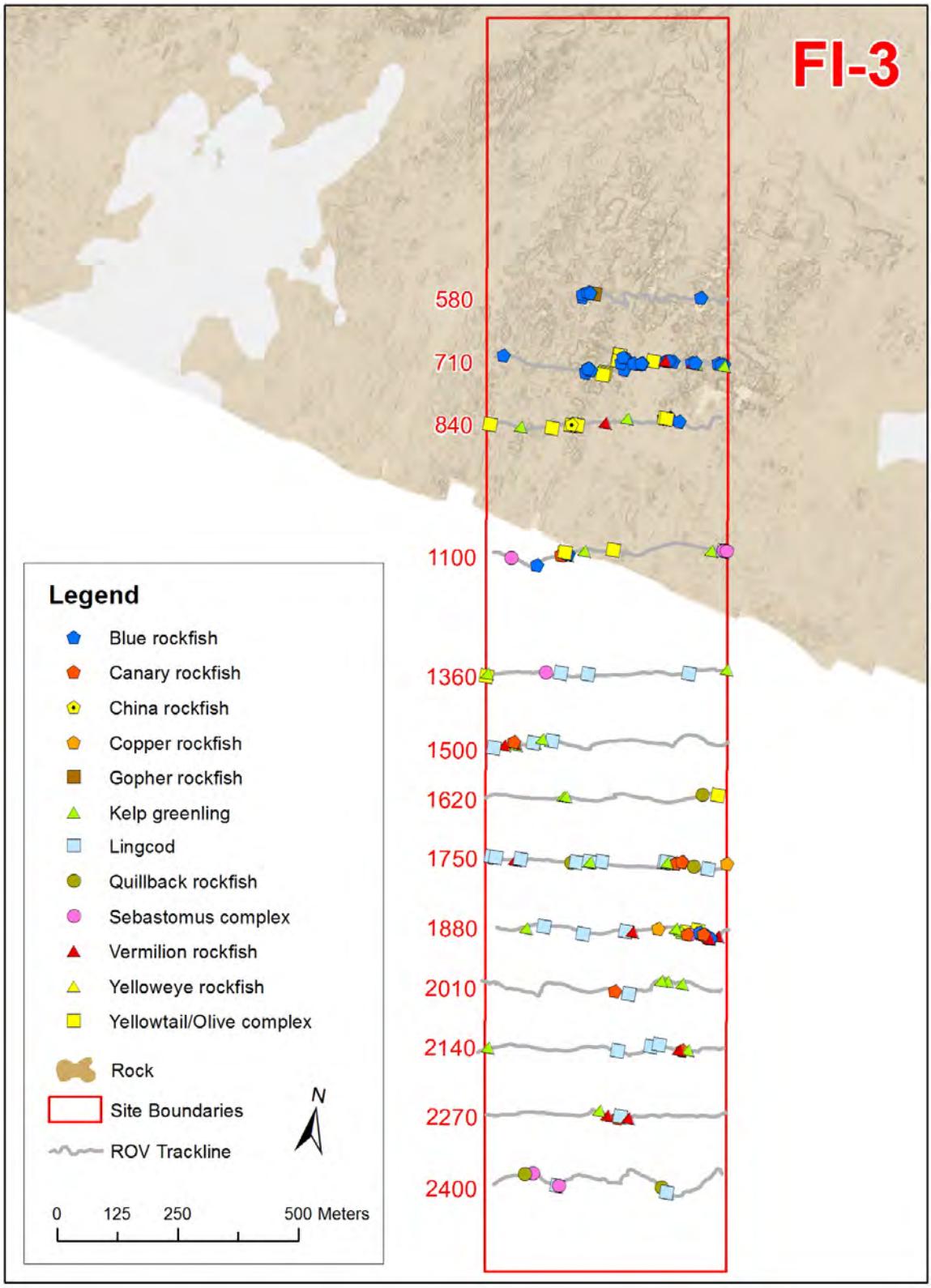

Figure 13. The Farallon Islands site (FI-3) boundary with ROV survey lines showing select finfish species identified from ROV video.

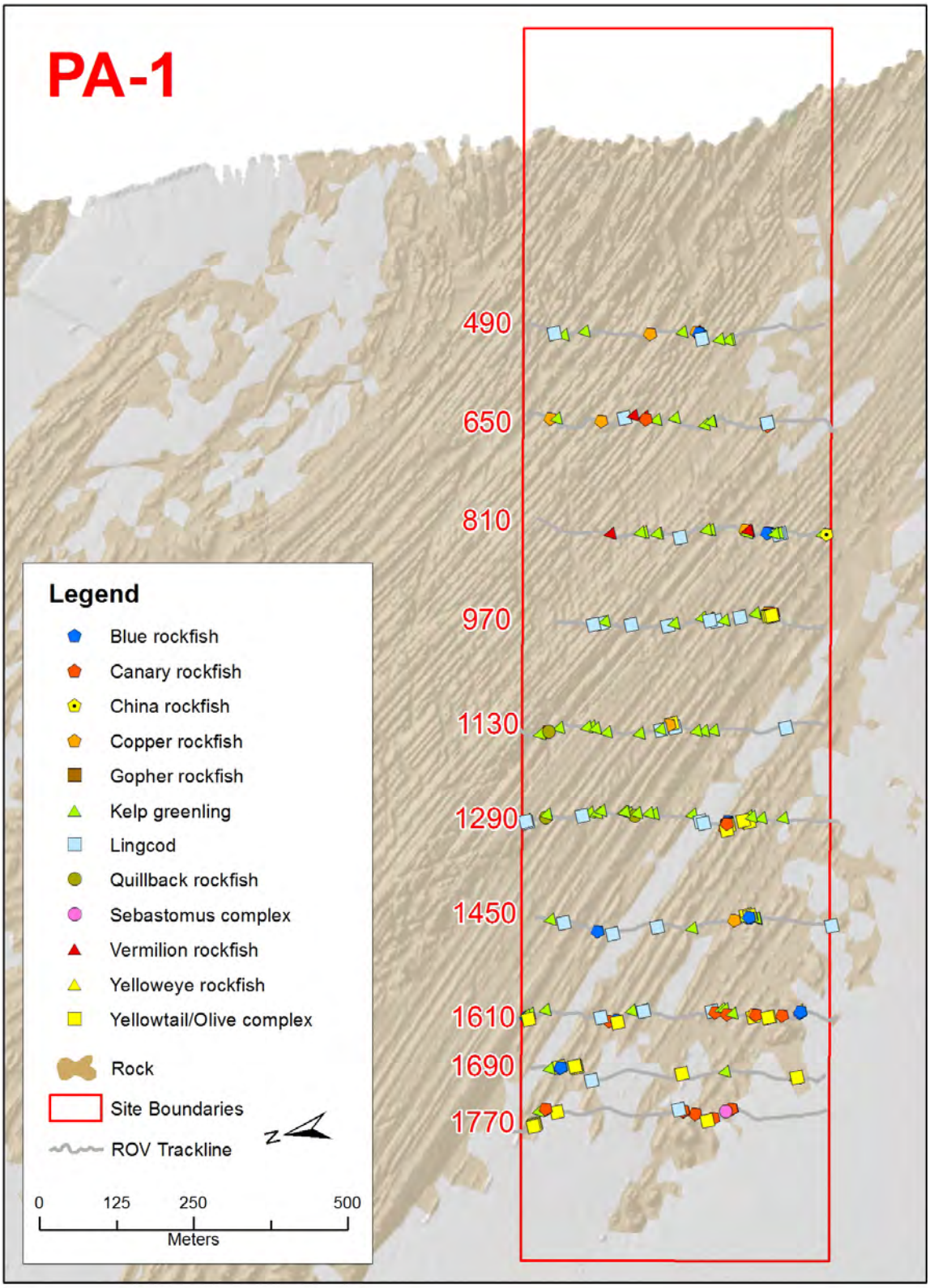

Figure 14. The Point Arena site (PA-1) boundary with ROV survey lines showing select finfish species identified from ROV video.

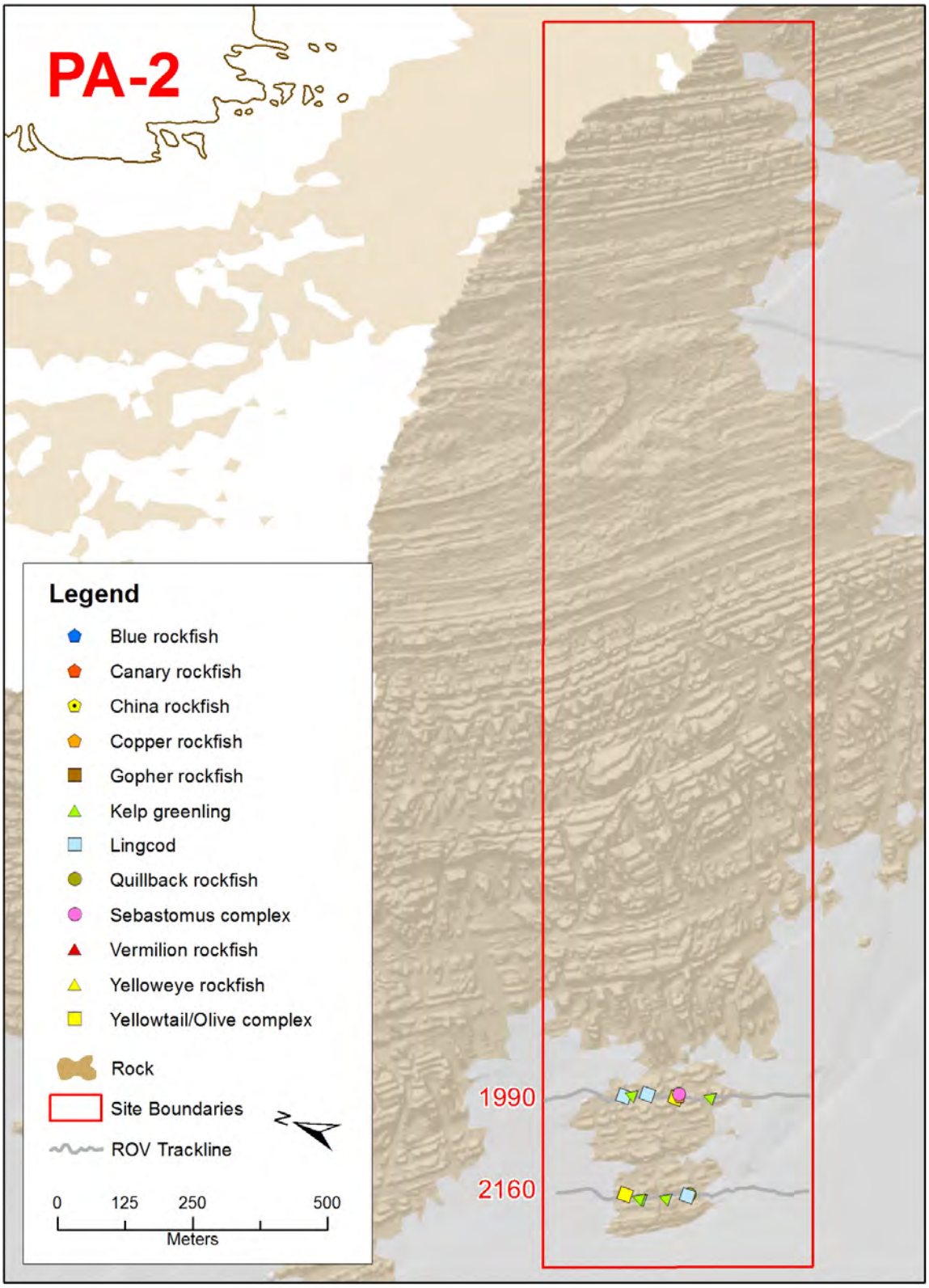

Figure 15. The Point Arena site (PA-2) boundary with ROV survey lines showing select finfish species identified from ROV video.

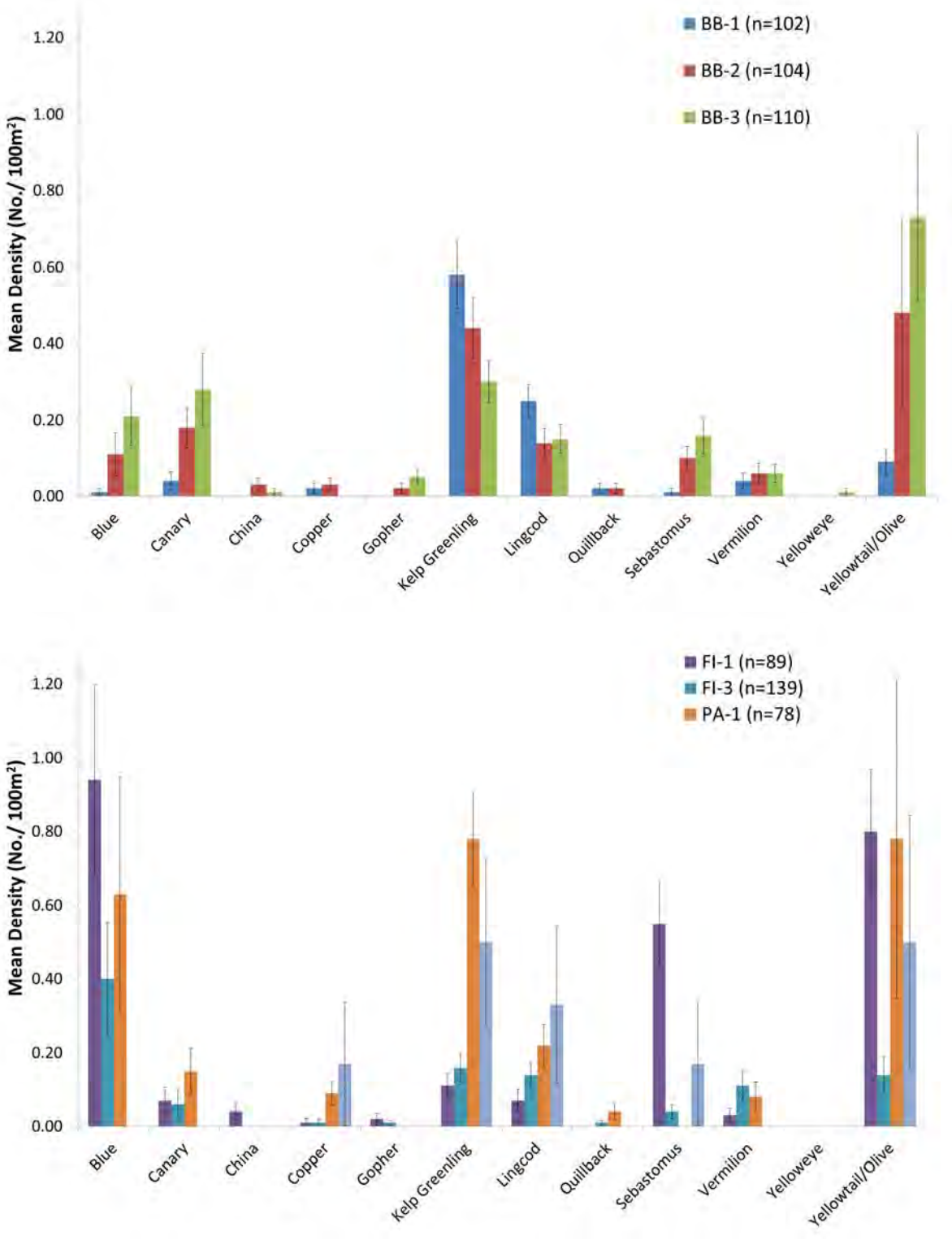

Figure 16. Mean density and standard error for select finfish species at all sites surveyed in 2011.

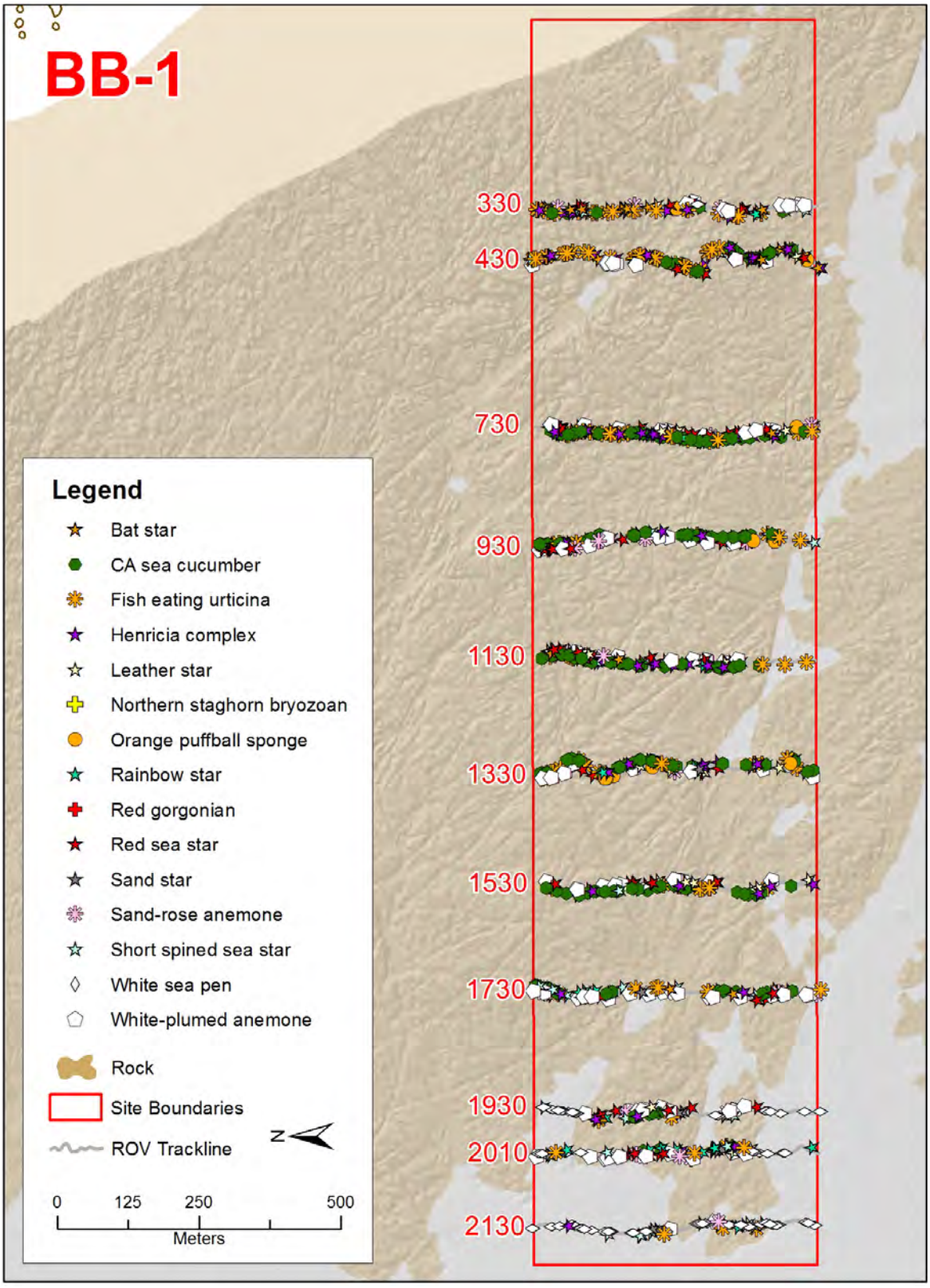

Figure 17. The Bodega Bay site (BB-1) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

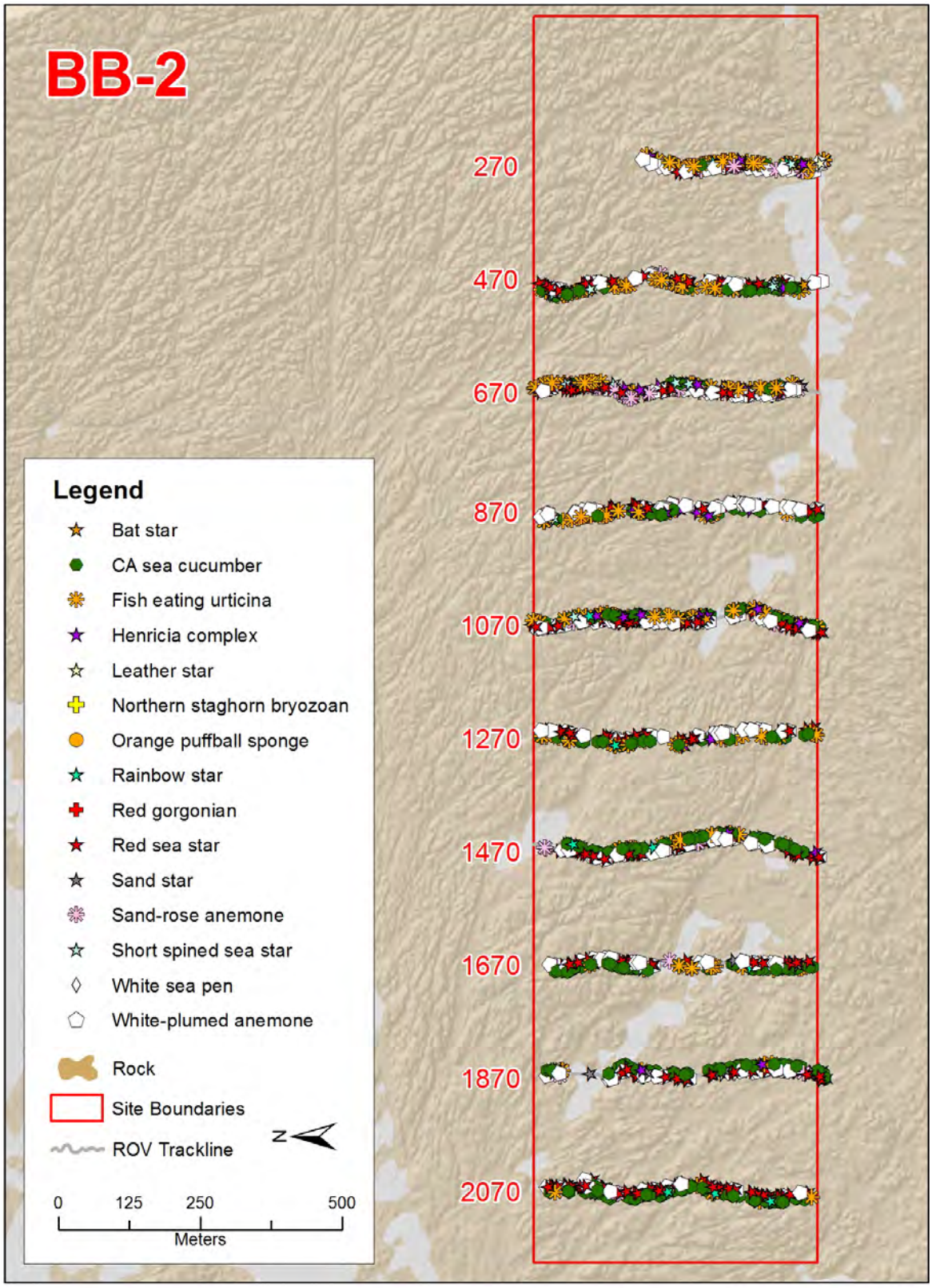

Figure 18. The Bodega Bay site (BB-2) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

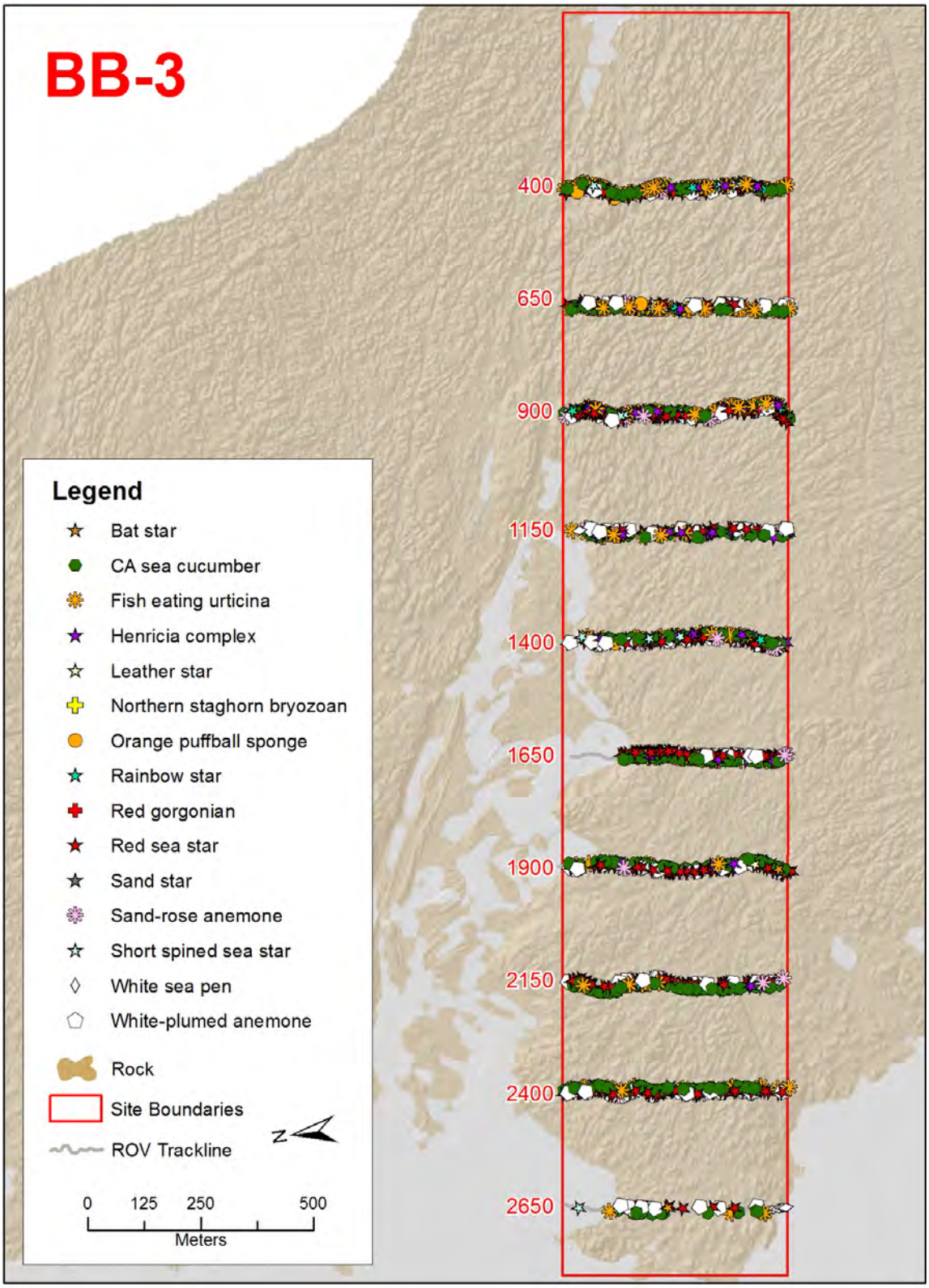

Figure 19. The Bodega Bay site (BB-3) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

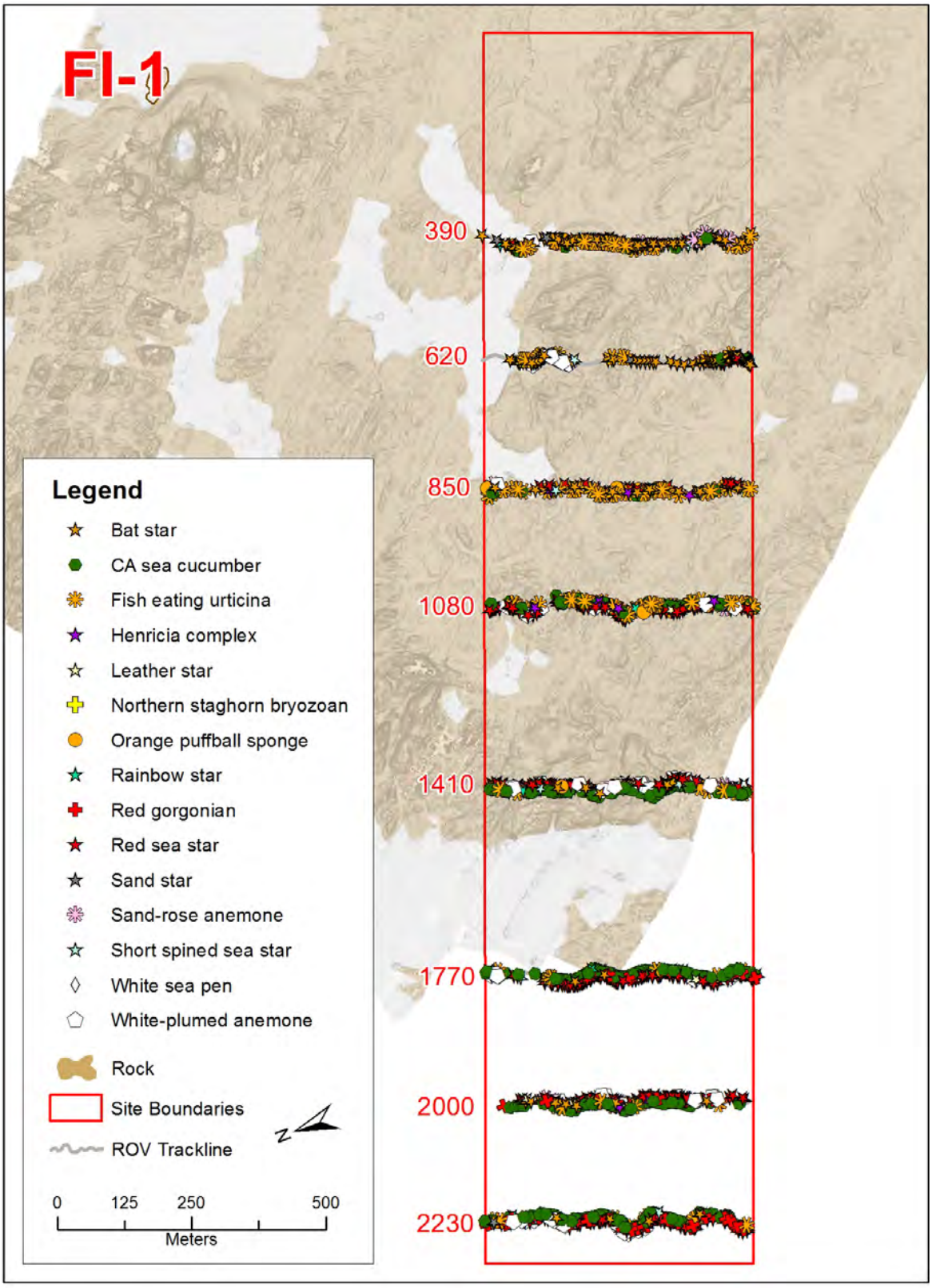

Figure 20. The Farallon Islands site (FI-1) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

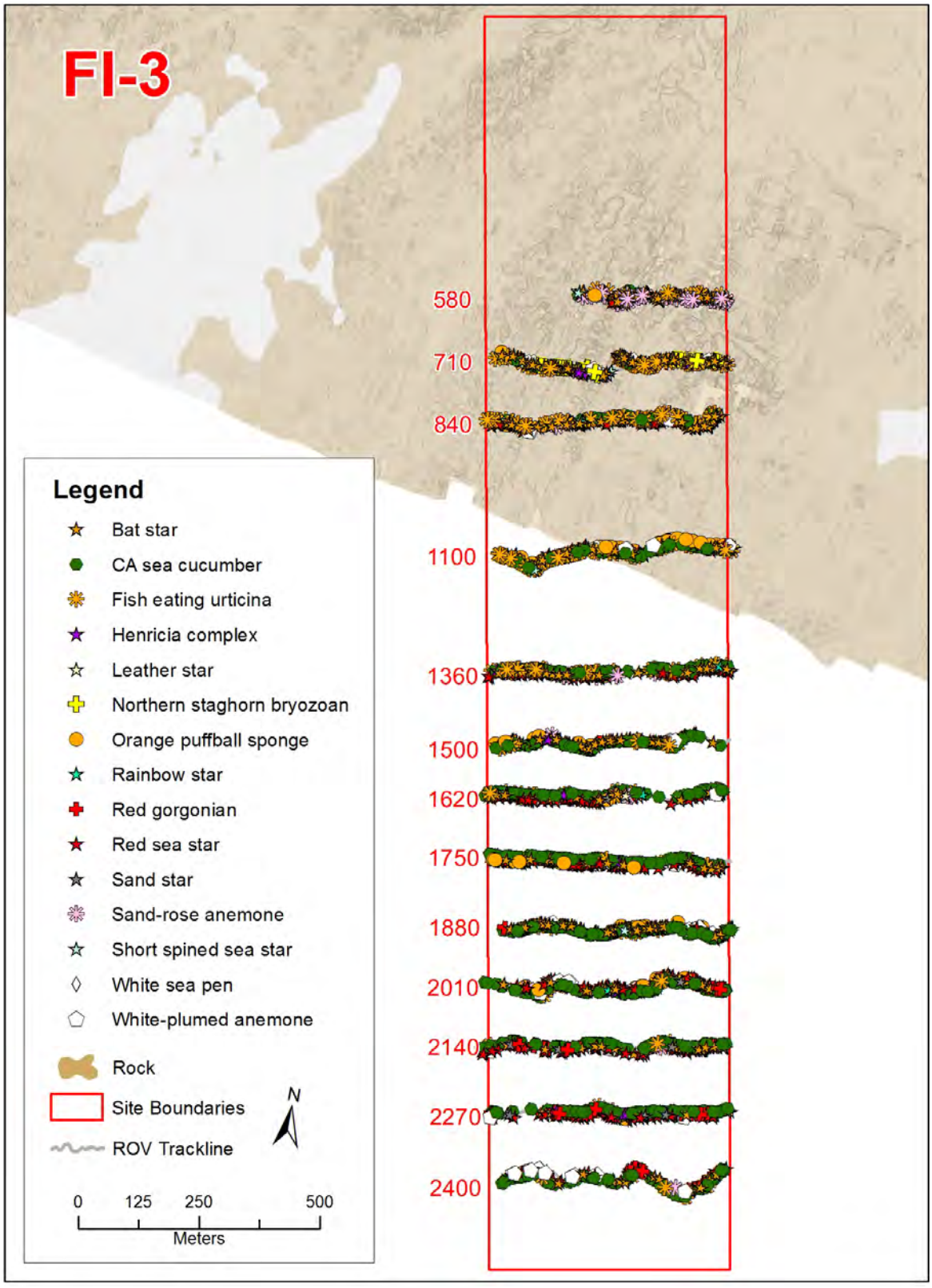

Figure 21. The Farallon Islands site (FI-3) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

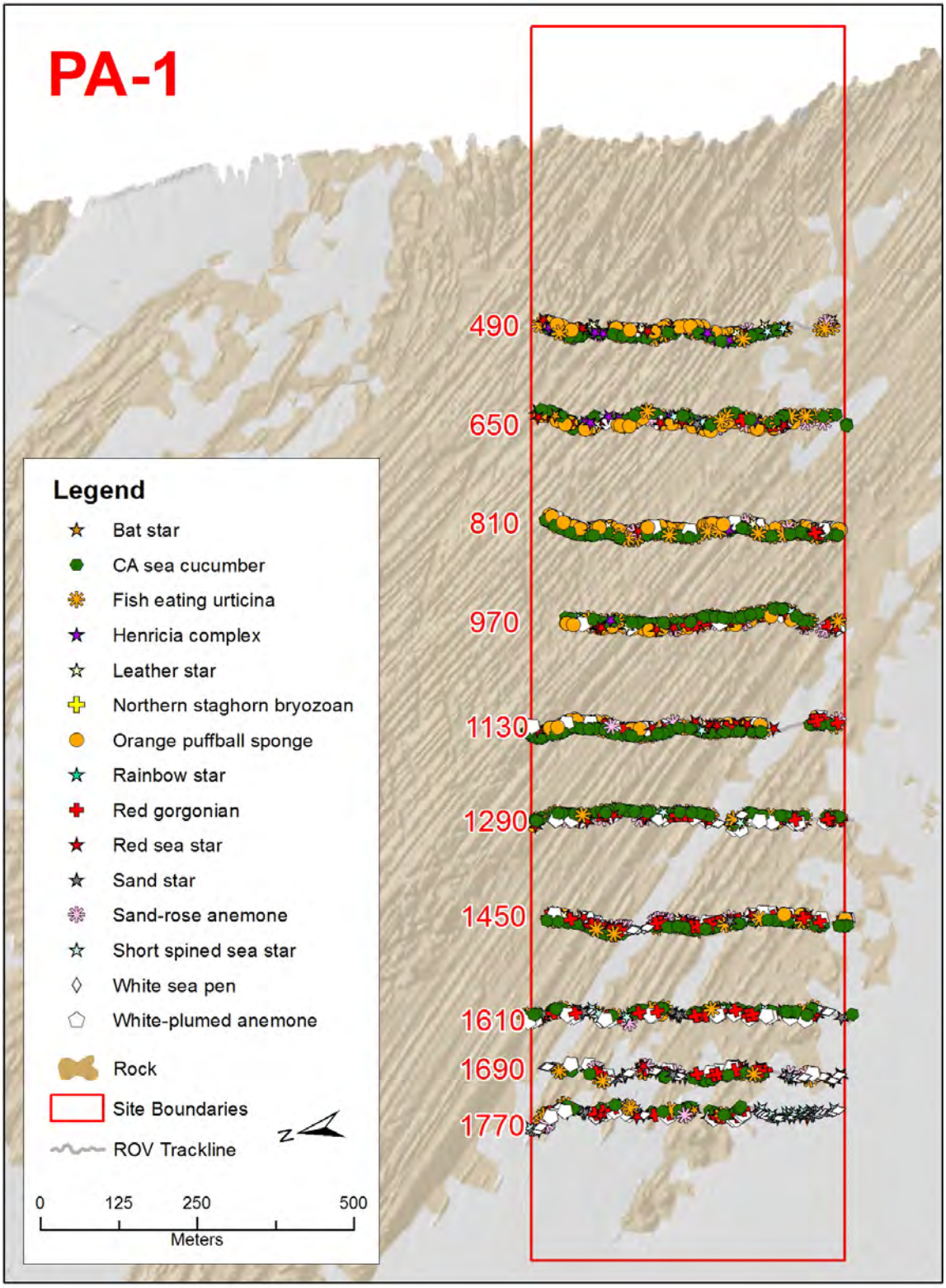

Figure 22. The Point Arena site (PA-1) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

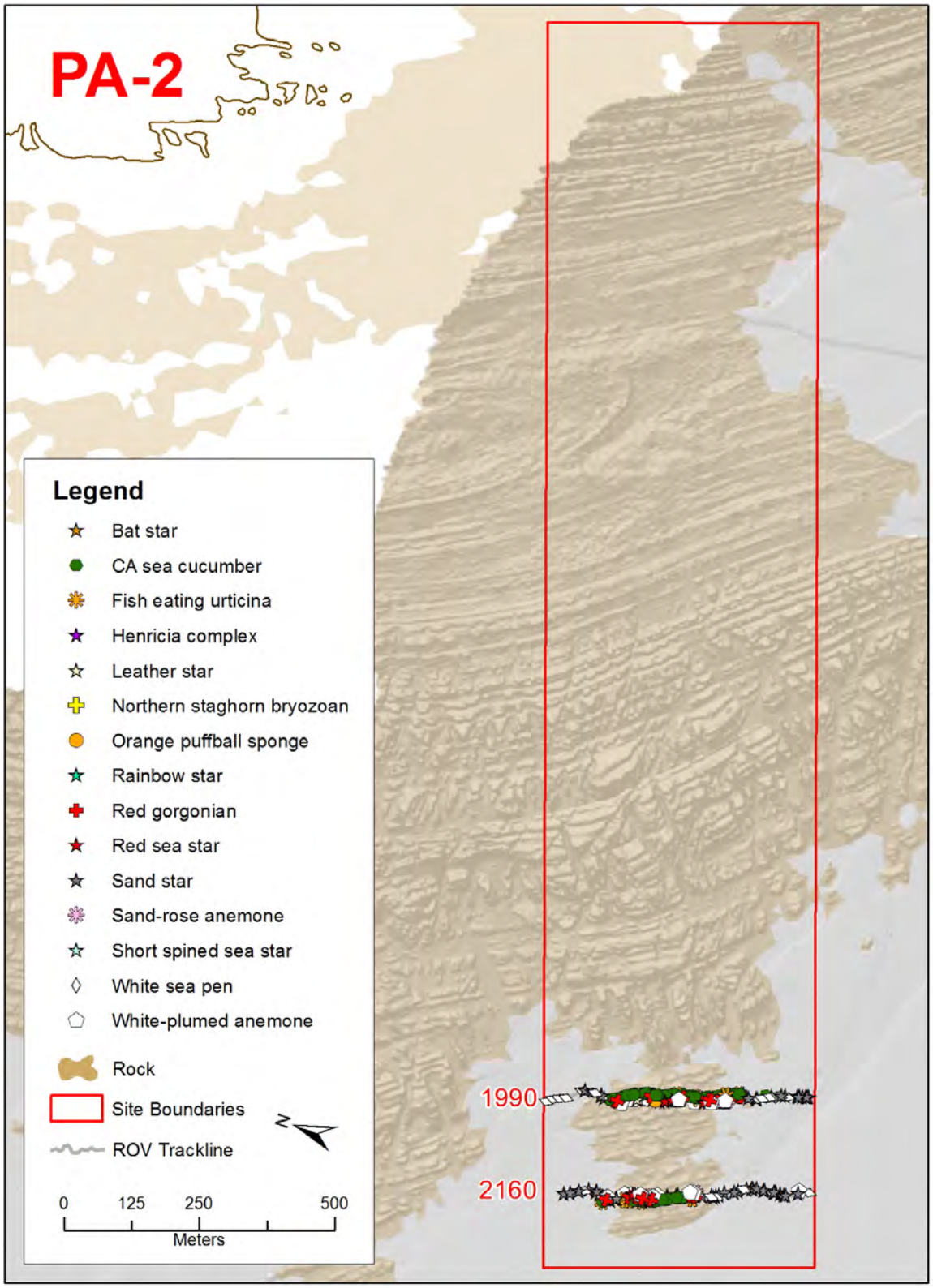

Figure 23. The Point Arena site (PA-2) boundary with ROV survey lines showing select invertebrate species identified from ROV video.

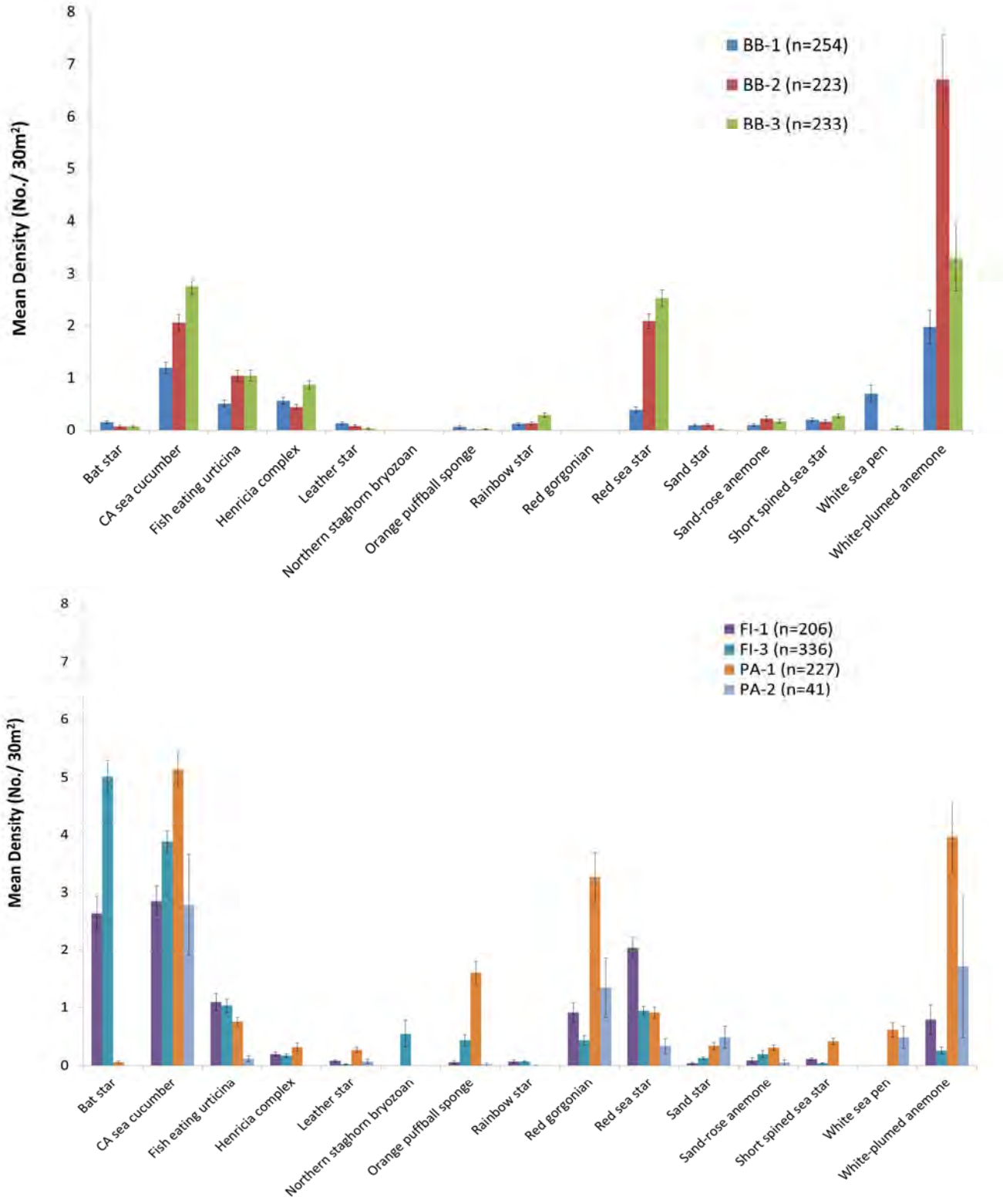

Figure 24. Mean density and standard error for select macro invertebrate species at all sites surveyed in 2011.

Appendix 1. ROV dive data for Bodega Bay study sites surveyed in 2011.

Dive	Date	Line number	Beginning time (GMT)	Ending time (GMT)	Begin X	Begin Y	End X	End Y	Avg velocity (m/s)	Avg width: fish (m)	Avg width: invert (m)	Min depth (m)	Max depth (m)	Avg depth (m)
BB-1														
202	7/30/2011	330	18:47:03	19:03:30	492822.8	4240643.5	492824.0	4240151.0	1.0	3.5	1.6	23.3	32.0	26.9
		430	18:22:47	18:42:54	492711.0	4240144.0	492726.8	4240660.6	1.0	3.1	1.4	24.7	34.4	29.2
		730	17:52:19	18:09:11	492433.8	4240647.3	492429.5	4240158.1	1.0	3.1	1.4	32.2	39.5	35.7
		930	17:28:22	17:44:52	492221.5	4240158.3	492221.4	4240645.9	1.0	3.2	1.5	36.3	42.3	38.9
		1130	17:02:32	17:19:08	492028.3	4240643.6	492020.0	4240156.3	1.0	2.9	1.3	39.9	45.4	42.8
		1330	16:33:18	16:50:54	491822.8	4240155.4	491816.0	4240645.9	1.0	2.5	1.1	42.7	48.8	46.0
		1530	16:04:58	16:20:57	491624.5	4240635.1	491629.4	4240158.0	1.0	2.7	1.2	44.4	52.2	49.7
		1730	15:41:02	15:57:58	491432.5	4240146.2	491442.1	4240656.2	1.0	2.8	1.3	51.0	55.3	53.3
		1930	15:17:03	15:32:58	491231.1	4240639.8	491223.2	4240145.8	1.1	3.0	1.4	55.3	58.5	57.0
		2010	14:58:36	15:12:49	491148.8	4240152.0	491148.9	4240654.0	1.2	3.3	1.5	57.4	59.3	58.3
		2130	14:37:25	14:52:13	491016.6	4240661.4	491019.9	4240154.3	1.2	3.2	1.5	59.4	61.2	60.2
BB-2														
203	7/30/2011	270	23:48:51	23:59:49	493291.1	4237923.8	493306.4	4238246.7	1.0	3.0	1.4	25.5	34.0	30.5
		470	23:21:49	23:41:39	493078.4	4238433.6	493082.0	4237928.8	0.9	3.4	1.6	25.8	36.5	32.8
		670	22:59:23	23:11:53	492889.0	4237936.4	492889.2	4238441.2	1.4	4.3	2.0	29.3	38.7	34.0
		870	22:37:20	22:51:46	492664.7	4238425.6	492679.1	4237936.9	1.1	3.7	1.7	34.5	40.6	37.4
		1070	22:12:43	22:29:02	492469.7	4237931.3	492483.0	4238443.5	1.1	3.0	1.4	38.2	43.2	40.8
		1270	21:48:03	22:04:46	492286.1	4238430.3	492287.3	4237934.3	1.0	3.2	1.5	42.4	47.8	45.1
		1470	21:20:44	21:40:09	492074.0	4237937.1	492092.2	4238439.8	0.9	3.0	1.4	44.5	51.2	47.9
		1670	20:49:45	21:08:21	491873.1	4238420.3	491879.9	4237946.0	0.9	2.6	1.2	48.4	54.2	51.9
		1870	20:22:42	20:40:30	491674.4	4237931.3	491686.8	4238421.4	1.0	2.6	1.2	53.6	56.6	55.6
		2070	19:48:32	20:13:04	491475.7	4238427.6	491476.7	4237947.6	0.8	2.8	1.3	56.4	59.6	57.7
BB-3														
204	7/31/2011	400	18:27:27	18:45:17	499484.2	4230301.3	499543.8	4230795.8	1.0	3.0	1.4	24.2	31.9	27.6
		650	18:00:45	18:15:00	499287.1	4230822.9	499220.5	4230338.0	1.1	4.3	2.0	26.7	32.0	29.4
		900	17:34:40	17:52:17	498971.0	4230375.0	499052.6	4230866.4	1.1	3.1	1.4	31.7	35.6	33.9
		1150	17:13:13	17:27:38	498801.9	4230897.8	498733.6	4230407.7	1.2	3.5	1.6	36.1	41.7	38.9
		1400	16:44:52	17:02:10	498480.1	4230447.9	498557.7	4230936.5	1.0	2.7	1.2	38.0	44.2	41.4
		1650	16:17:11	16:32:42	498300.6	4230954.7	498233.7	4230480.5	1.0	3.0	1.4	41.9	46.5	44.4
		1900	15:51:11	16:06:48	497984.5	4230506.6	498064.3	4231016.4	1.1	3.2	1.5	43.3	50.8	47.0
		2150	15:18:33	15:35:41	497802.3	4231031.3	497745.2	4230549.4	1.0	3.1	1.4	45.2	53.7	49.1
		2400	14:49:43	15:06:11	497500.5	4230580.3	497566.6	4231082.0	1.0	3.3	1.5	49.2	58.1	52.3
		2650	14:19:32	14:36:08	497320.1	4231107.6	497243.8	4230622.8	1.0	3.3	1.5	54.3	61.4	57.4

Appendix 1. ROV dive data for Farallon Islands study sites surveyed in 2011.

Dive	Date	Line number	Beginning time (GMT)	Ending time (GMT)	Begin X	Begin Y	End X	End Y	Avg velocity (m/s)	Avg width: fish (m)	Avg width: invert (m)	Min depth (m)	Max depth (m)	Avg depth (m)
FI-1														
164	7/13/2011	1080	17:46:23	18:05:37	495980.3	4174924.5	496155.2	4175389.9	1.0	3.5	1.6	29.9	40.0	35.7
		1410	17:10:50	17:30:03	495841.4	4175498.4	495675.6	4175053.8	0.9	3.6	1.7	38.8	52.9	46.0
		1770	16:32:25	16:55:02	495329.0	4175155.1	495508.9	4175628.1	0.9	3.6	1.6	51.6	58.2	54.8
		2000	16:02:52	16:20:42	495272.9	4175692.7	495122.4	4175248.1	0.9	4.5	2.1	52.1	58.8	56.2
		2230	15:26:58	15:49:59	494902.0	4175334.9	495078.0	4175789.4	0.9	4.4	2.0	53.5	58.8	56.2
177	7/18/2011	390	20:11:03	20:27:07	496812.1	4175159.2	496641.2	4174684.1	1.1	4.0	1.9	19.3	33.6	27.8
		620	19:47:02	20:01:15	496412.6	4174772.5	496593.1	4175234.6	1.2	3.9	1.8	25.5	35.0	29.6
		850	19:21:31	19:37:26	496354.2	4175312.9	496198.8	4174846.9	1.1	4.2	1.9	31.0	37.5	34.6
FI-3														
163	7/12/2011	580	23:45:03	23:59:47	500353.6	4171262.1	500056.9	4171214.9	1.0	4.2	1.9	15.3	24.4	19.9
		710	23:17:46	23:39:09	499900.9	4171061.0	500378.7	4171130.6	1.0	3.9	1.8	19.5	31.1	25.3
		840	22:53:24	23:11:17	500384.3	4171019.1	499904.5	4170924.4	1.0	3.7	1.7	26.9	32.9	30.7
		1100	22:27:22	22:42:58	499966.5	4170661.9	500455.5	4170752.6	1.1	3.4	1.6	35.7	41.5	39.2
		1360	22:00:46	22:15:23	500433.2	4170494.8	499994.8	4170408.7	1.0	3.3	1.5	40.7	46.1	44.8
		1500	21:34:39	21:52:14	500036.9	4170265.1	500513.7	4170357.3	1.0	3.5	1.6	42.8	48.3	46.9
		1620	21:09:38	21:28:29	500515.2	4170246.0	500037.6	4170156.2	0.9	4.2	1.9	46.4	49.4	48.1
		1880	20:41:28	20:58:33	500107.1	4169895.9	500581.2	4169973.6	1.0	4.0	1.9	49.4	53.5	51.5
		2140	20:21:02	20:31:22	500426.5	4169685.0	500111.1	4169634.6	1.0	4.2	1.9	53.3	56.2	54.6
		2400	19:43:48	20:03:49	500191.2	4169369.3	500653.9	4169472.3	0.9	4.1	1.9	56.1	60.3	58.0
165	7/13/2011	1750	21:47:13	22:03:18	500555.8	4170108.0	500062.7	4170036.6	1.1	3.6	1.7	47.7	51.2	49.6
		2010	21:15:55	21:35:50	500094.4	4169781.8	500587.9	4169848.0	0.9	3.3	1.5	51.6	54.5	53.1
		2270	20:47:41	21:03:06	500640.7	4169599.0	500151.5	4169509.4	1.1	3.3	1.5	54.7	58.0	56.2

Appendix 1. ROV dive data for Point Arena study sites surveyed in 2011.

Dive	Date	Line number	Beginning time (GMT)	Ending time (GMT)	Begin X	Begin Y	End X	End Y	Avg velocity (m/s)	Avg width: fish (m)	Avg width: invert (m)	Min depth (m)	Max depth (m)	Avg depth (m)
PA-1														
206	8/7/2011	490	19:28:31	19:46:10	434508.9	4313798.8	434406.4	4313336.3	0.9	3.4	1.6	27.9	35.8	32.5
		650	18:58:12	19:20:37	434234.8	4313354.3	434363.8	4313838.4	0.9	3.1	1.4	31.9	38.2	35.9
		810	18:29:14	18:44:56	434197.6	4313855.0	434070.8	4313404.9	1.0	3.7	1.7	35.3	42.3	39.0
		970	18:00:39	18:15:32	433927.9	4313440.4	434028.4	4313864.2	1.0	3.4	1.6	37.6	47.4	42.3
		1130	17:37:09	17:53:20	433870.7	4313959.3	433771.6	4313476.7	1.0	3.3	1.5	38.7	50.5	45.9
		1290	17:07:28	17:29:59	433613.3	4313485.2	433720.5	4313983.4	1.0	4.1	1.9	44.1	52.9	49.6
		1450	16:43:12	16:59:46	433565.2	4313997.2	433453.5	4313531.2	1.0	3.5	1.6	50.3	56.5	54.5
		1610	16:16:41	16:34:48	433301.1	4313555.6	433409.6	4314068.1	1.1	3.5	1.6	51.8	59.8	57.5
		1690	15:56:15	16:11:38	433328.5	4314057.2	433215.5	4313595.3	1.1	3.5	1.6	54.5	61.6	60.0
		1770	15:37:14	15:50:16	433159.8	4313605.6	433232.9	4314107.8	1.4	3.8	1.8	59.8	62.5	61.3
PA-2														
207	8/8/2011	1990	15:15:39	15:29:47	435692.4	4306283.8	435520.9	4306741.9	1.2	3.0	1.4	56.6	61.9	60.6
		2160	14:53:09	15:08:13	435367.6	4306662.6	435525.5	4306227.9	1.2	2.8	1.3	62.5	64.9	63.8

Appendix 2. ROV substrate and habitat summary data for Bodega Bay study sites surveyed in 2011.

Site	Line Number	Length (m)	Percentage of substrate on each line					Percentage of habitat on each line			
			Rock	Boulder	Cobble	Sand	Backsides	Hard	Mixed	Soft	Off Transect
BB-1	330	506.8	85	0	0	27	5	73	13	14	1
	430	588.6	89	2	1	35	5	65	25	11	0
	730	500.6	87	1	0	23	1	75	12	11	2
	930	501.4	86	6	5	39	0	60	26	14	0
	1130	500.2	79	8	27	62	0	23	57	21	0
	1330	548.9	88	11	0	33	0	66	21	12	0
	1530	495.0	82	27	6	33	1	62	20	16	1
	1730	533.0	90	5	3	86	1	14	76	10	0
	1930	511.1	53	3	0	42	0	50	3	38	9
	2010	521.2	60	0	0	57	2	40	20	36	4
	2130	527.0	24	0	0	83	0	17	7	76	0
BB-2	270	345.0	89	9	20	30	4	58	32	7	4
	470	575.2	96	50	59	78	3	18	80	2	0
	670	522.1	92	3	0	24	10	75	17	7	1
	870	506.9	99	19	10	7	3	83	16	1	0
	1070	533.2	86	21	25	59	1	36	50	14	0
	1270	516.3	94	20	0	18	0	82	12	6	0
	1470	545.0	79	14	11	41	1	53	26	21	0
	1670	492.0	80	10	24	92	0	7	74	19	0
	1870	523.9	65	17	0	62	0	37	28	34	0
	2070	596.2	94	27	15	12	1	78	16	6	0
BB-3	400	522.3	99	13	0	3	4	96	3	0	1
	650	498.1	94	4	0	3	17	92	2	1	5
	900	532.1	94	11	14	19	0	74	20	6	0
	1150	514.4	87	11	0	23	3	76	10	12	1
	1400	506.6	90	53	50	90	1	1	89	10	0
	1650	489.2	74	30	23	38	0	46	29	25	0
	1900	533.7	84	17	0	29	0	71	14	16	0
	2150	506.5	97	66	45	99	0	1	97	2	0
	2400	523.5	94	20	17	22	3	68	27	5	0
	2650	505.3	52	3	0	49	3	45	7	42	6

Appendix 2. ROV substrate and habitat summary data for Farallon Islands study sites surveyed in 2011.

Site	Line Number	Length (m)	Percentage of substrate on each line					Percentage of habitat on each line			
			Rock	Boulder	Cobble	Sand	Backsides	Hard	Mixed	Soft	Off Transect
FI-1	390	543.9	87	5	0	27	6	72	15	12	1
	620	523.5	85	0	0	24	10	76	9	15	0
	850	516.9	89	0	6	32	14	67	22	10	1
	1080	556.3	95	7	0	6	12	89	6	0	5
	1410	519.6	87	2	0	25	13	75	13	13	0
	1770	565.4	75	23	18	38	4	57	19	24	0
	2000	496.7	71	24	0	41	14	58	13	28	1
	2230	564.6	94	16	0	19	17	80	15	5	1
FI-3	580	420.4	99	0	0	15	21	85	14	1	0
	710	571.5	90	23	15	25	19	64	26	2	8
	840	524.4	98	28	20	63	3	37	62	1	0
	1100	524.8	91	17	0	34	0	66	25	9	0
	1360	517.6	88	20	35	77	0	20	67	12	0
	1500	523.6	55	8	9	83	3	16	40	45	0
	1620	508.3	79	3	0	46	11	54	25	21	0
	1750	518.5	81	0	0	65	0	35	46	19	0
	1880	508.3	83	12	6	52	10	43	40	17	0
	2010	561.5	65	1	2	93	0	7	59	35	0
	2140	530.8	60	0	0	80	6	20	39	40	0
	2270	511.9	56	0	0	85	0	15	41	44	0
	2400	571.9	72	0	0	69	13	31	41	28	0

Appendix 2. ROV substrate and habitat summary data for Point Arena study sites surveyed in 2011.

Site	Line Number	Length (m)	Percentage of substrate on each line					Percentage of habitat on each line			
			Rock	Boulder	Cobble	Sand	Backsides	Hard	Mixed	Soft	Off Transect
PA-1	490	498.5	83	3	0	29	11	70	14	15	2
	650	599.5	83	1	15	37	6	62	21	17	0
	810	491.3	80	3	14	17	7	71	9	19	1
	970	457.7	86	1	0	37	5	63	24	13	0
	1130	518.0	80	1	0	97	4	3	77	20	0
	1290	574.8	59	1	8	48	11	46	12	37	4
	1450	497.1	58	1	0	60	7	39	19	41	1
	1610	560.6	47	1	0	89	10	8	40	50	3
	1690	508.5	23	0	0	74	12	18	5	69	8
	1770	551.8	25	0	0	87	11	12	13	74	1
PA-2	1990	511.0	35	3	0	77	3	21	14	63	2
	2160	486.1	18	2	3	93	0	4	14	79	3

Appendix 3. Finfish abundances and sample size of 100 m^2 transects for all sites surveyed in 2011.

Site	BB-1 (n=102)			BB-2 (n=104)			BB-3 (n=110)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Big skate	0	0	0	0	0	0	0	0	0
Black rockfish	0	0	0	0.01	0.1	1	0	0	0
Black-and-yellow rockfish	0	0	0	0	0	0	0	0	0
Blue rockfish	0.01	0.1	1	0.11	0.59	5	0.21	0.79	9
Canary rockfish	0.04	0.24	3	0.18	0.52	13	0.28	0.98	13
Canary/Vermillion complex	0.02	0.14	2	0.11	0.48	7	0.11	0.39	8
China rockfish	0	0	0	0.03	0.17	3	0.01	0.1	1
Copper rockfish	0.02	0.14	2	0.03	0.17	3	0	0	0
Gopher rockfish	0	0	0	0.02	0.14	2	0.05	0.21	5
Kelp greenling	0.58	0.91	37	0.44	0.81	33	0.3	0.57	25
Lingcod	0.25	0.43	25	0.14	0.4	13	0.15	0.4	13
Quillback rockfish	0.02	0.14	2	0.02	0.14	2	0	0	0
Sebastomus complex	0.01	0.1	1	0.1	0.33	9	0.16	0.52	13
spotted ratfish	0.02	0.14	2	0	0	0	0.01	0.1	1
Starry skate	0	0	0	0	0	0	0	0	0
UI rockfish	0.24	0.73	15	0.19	0.48	15	0.15	0.45	13
UI Surfperch	0	0	0	0.01	0.1	1	0.15	1.43	2
Vermilion rockfish	0.04	0.2	4	0.06	0.27	5	0.06	0.25	6
Wolf eel	0	0	0	0	0	0	0	0	0
Yelloweye rockfish	0	0	0	0	0	0	0.01	0.1	1
Yellowtail/Olive complex	0.09	0.35	7	0.48	2.53	8	0.73	2.28	16
Average	0.06	0.17	5	0.09	0.34	6	0.11	0.41	6

Appendix 3. Continued.

Site	FI-1 (n=89)			FI-3 (n=139)			PA-1 (n=78)			PA-2 (n=6)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Big skate	0	0	0	0	0	0	0.01	0.11	1	0	0	0
Black rockfish	0	0	0	0	0	0	0	0	0	0	0	0
Black-and-yellow rockfish	0.01	0.11	1	0	0	0	0	0	0	0	0	0
Blue rockfish	0.94	2.43	28	0.4	1.82	9	0.63	2.8	10	0	0	0
Canary rockfish	0.07	0.33	4	0.06	0.45	4	0.15	0.56	10	0	0	0
Canary/Vermillion complex	0.02	0.15	2	0.09	0.47	4	0.03	0.16	3	0	0	0
China rockfish	0.04	0.21	4	0	0	0	0	0	0	0	0	0
Copper rockfish	0.01	0.11	1	0.01	0.12	1	0.09	0.29	9	0.17	0.41	17
Gopher rockfish	0.02	0.15	2	0.01	0.08	1	0	0	0	0	0	0
Kelp greenling	0.11	0.32	11	0.16	0.47	12	0.78	1.11	45	0.5	0.55	50
Lingcod	0.07	0.29	6	0.14	0.41	12	0.22	0.5	18	0.33	0.52	33
Quillback rockfish	0	0	0	0.01	0.08	1	0.04	0.19	4	0	0	0
Sebastomus complex	0.55	1.07	27	0.04	0.22	3	0	0	0	0.17	0.41	17
spotted ratfish	0.01	0.11	1	0.01	0.12	1	0.03	0.16	3	0	0	0
Starry skate	0	0	0	0	0	0	0	0	0	0	0	0
UI rockfish	0.15	0.41	12	0.12	0.34	11	0.08	0.42	4	0.33	0.82	17
UI Surfperch	0	0	0	0	0	0	0.01	0.11	1	0	0	0
Vermilion rockfish	0.03	0.18	3	0.11	0.49	8	0.08	0.35	5	0	0	0
Wolf eel	0.02	0.15	2	0	0	0	0	0	0	0	0	0
Yelloweye rockfish	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail/Olive complex	0.8	1.58	31	0.14	0.6	6	0.78	3.83	13	0.5	0.84	33
Average	0.14	0.36	6	0.06	0.27	3	0.14	0.50	6	0.10	0.17	8

Appendix 4. Macro invertebrate abundances and sample size of 30 m^2 transects for Bodega Bay study sites surveyed in 2011.

Site	BB-1 (n=254)			BB-2 (n=223)			BB-3 (n=233)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Aggregated nipple sponge	0	0.06	0	0.01	0.09	1	0	0	0
Bat star	0.15	0.44	13	0.07	0.32	6	0.07	0.29	6
Boot sponge	0	0	0	0	0.07	0	0	0	0
California hydrocoral	0	0	0	0	0	0	0	0	0
California sea cucumber	1.19	1.73	47	2.05	2.3	70	2.75	2.51	82
Cancer complex	0.02	0.14	2	0	0	0	0	0	0
Common basket star	0	0	0	0	0	0	0	0	0
Feather star	0	0	0	0	0	0	0	0	0
Fish eating urticina	0.51	0.94	31	1.04	1.45	52	1.04	1.64	46
Giant spined star	0	0.06	0	0	0	0	0.01	0.09	1
Gorgonian complex	0	0	0	0	0	0	0	0	0
Gray puffball sponge	0	0	0	0	0	0	0	0	0
Henricia complex	0.56	1.04	32	0.44	0.77	30	0.86	1.32	44
Leather star	0.13	0.37	12	0.08	0.3	7	0.03	0.16	3
Northern staghorn bryozoan	0	0	0	0	0	0	0	0	0
Orange puffball sponge	0.06	0.41	3	0.01	0.09	1	0.02	0.13	2
Orange sea cucumber	0	0.06	0	0	0	0	0	0.07	0
Orange sea pen	0	0	0	0	0.07	0	0	0	0
Purple sea urchin	0	0	0	0	0	0	0	0	0
Rainbow star	0.12	0.37	11	0.13	0.37	11	0.29	0.62	22

Appendix 4. Bodega Bay continued.

Site	BB-1 (n=254)			BB-2 (n=223)			BB-3 (n=233)		
Taxon	Mean	SD	%FO	Mean	SD	%FO	Mean	SD	%FO
Red gorgonian	0	0	0	0	0	0	0	0	0
Red sea star	0.39	0.87	24	2.08	2.15	75	2.52	2.44	77
Red sea urchin	0	0	0	0	0	0	0.02	0.17	2
Sand star	0.09	0.33	8	0.1	0.35	9	0.01	0.11	1
Sand-rose anemone	0.1	0.41	7	0.22	0.69	15	0.17	0.62	11
Sea whip	0.17	0.74	7	0	0	0	0	0	0
Short spined sea star	0.2	0.5	17	0.16	0.46	13	0.27	0.62	21
Southern staghorn bryozoan	0	0	0	0	0	0	0	0	0
Stalked tunicate	0	0	0	0	0	0	0	0	0
Stimpson's sun star	0.04	0.19	4	0.03	0.16	3	0.04	0.22	4
Sunflower star	0.04	0.21	4	0.01	0.12	1	0.04	0.19	4
White sea pen	0.7	2.55	15	0	0.07	0	0.04	0.44	1
White-plumed anemone	1.97	5.17	33	6.71	12.83	62	3.29	9.71	40
Average	0.20	0.50	8	0.40	0.69	11	0.35	0.65	11

Appendix 4. Macro invertebrate abundances and sample size of 30 m^2 transects for Farallon Islands study sites surveyed in 2011.

Site	FI-1 (n=206)			FI-3 (n=336)		
Taxon	Mean	SD	%FO	Mean	SD	%FO
Aggregated nipple sponge	0.16	0.66	8	0.01	0.08	1
Bat star	2.64	4.27	63	5.01	5.09	87
Boot sponge	0.08	0.32	6	0	0	0
California hydrocoral	0.06	0.64	1	0	0	0
California sea cucumber	2.85	3.64	64	3.88	3.42	85
Cancer complex	0	0.07	0	0.18	0.87	6
Common basket star	0	0	0	0	0	0
Feather star	0	0	0	0	0	0
Fish eating urticina	1.09	2.1	42	1.03	2.1	36
Giant spined star	0	0	0	0	0.05	0
Gorgonian complex	0	0	0	0	0	0
Gray puffball sponge	0.01	0.12	1	0.01	0.09	1
Henricia complex	0.2	0.56	15	0.17	0.57	11
Leather star	0.08	0.27	8	0.02	0.17	2
Northern staghorn bryozoan	0	0	0	0.55	4.22	3
Orange puffball sponge	0.06	0.39	4	0.44	1.74	16
Orange sea cucumber	0	0	0	0	0	0
Orange sea pen	0	0	0	0.01	0.14	1
Purple sea urchin	0	0	0	0.01	0.08	1
Rainbow star	0.07	0.36	5	0.07	0.3	6

Appendix 4. Farallon Islands continued.

Site	FI-1 (n=206)			FI-3 (n=336)		
Taxon	Mean	SD	%FO	Mean	SD	%FO
Red gorgonian	0.91	2.42	21	0.44	1.47	13
Red sea star	2.04	2.56	59	0.94	1.36	45
Red sea urchin	0.02	0.18	2	0.1	0.57	4
Sand star	0.04	0.2	4	0.13	0.4	11
Sand-rose anemone	0.09	0.63	4	0.2	1.13	7
Sea whip	0	0	0	0	0	0
Short spined sea star	0.11	0.37	9	0.04	0.2	3
Southern staghorn bryozoan	0	0	0	0	0.05	0
Stalked tunicate	0	0	0	0	0	0
Stimpson's sun star	0.01	0.1	1	0.01	0.09	1
Sunflower star	0.04	0.22	3	0.02	0.16	2
White sea pen	0	0	0	0	0	0
White-plumed anemone	0.79	3.55	14	0.26	1.14	11
Average	0.34	0.72	10	0.41	0.77	11

Appendix 4. Macro invertebrate abundances and sample size of 30 m^2 transects for Point Area study sites surveyed in 2011.

Site	PA-1 (n=227)			PA-2 (n=41)		
Taxon	Mean	SD	%FO	Mean	SD	%FO
Aggregated nipple sponge	0.04	0.22	4	0	0	0
Bat star	0.06	0.28	5	0	0	0
Boot sponge	0	0	0	0	0	0
California hydrocoral	0	0	0	0	0	0
California sea cucumber	5.14	4.31	80	2.78	5.59	32
Cancer complex	0	0	0	0	0	0
Common basket star	0.04	0.22	4	0.07	0.35	5
Feather star	0	0	0	0.02	0.16	2
Fish eating urticina	0.76	1.05	45	0.12	0.33	12
Giant spined star	0	0	0	0	0	0
Gorgonian complex	0	0	0	0	0	0
Gray puffball sponge	0	0	0	0	0	0
Henricia complex	0.32	1.07	15	0	0	0
Leather star	0.27	0.67	19	0.07	0.26	7
Northern staghorn bryozoan	0	0	0	0	0	0
Orange puffball sponge	1.6	2.94	40	0.02	0.16	2
Orange sea cucumber	0	0.07	0	0	0	0
Orange sea pen	0.03	0.17	3	0	0	0
Purple sea urchin	0	0	0	0	0	0
Rainbow star	0	0.07	0	0	0	0

Appendix 4. Point Arena continued.

Site	PA-1 (n=227)			PA-2 (n=41)		
Taxon	Mean	SD	%FO	Mean	SD	%FO
Red gorgonian	3.26	6.45	37	1.34	3.31	20
Red sea star	0.91	1.44	44	0.34	0.82	17
Red sea urchin	0	0	0	0	0	0
Sand star	0.34	0.88	18	0.49	1.23	20
Sand-rose anemone	0.31	0.71	20	0.05	0.31	2
Sea whip	0	0	0	0	0	0
Short spined sea star	0.42	0.82	27	0	0	0
Southern staghorn bryozoan	0	0	0	0	0	0
Stalked tunicate	0	0.07	0	0	0	0
Stimpson's sun star	0.01	0.11	1	0	0	0
Sunflower star	0	0	0	0	0	0
White sea pen	0.62	1.84	15	0.49	1.25	17
White-plumed anemone	3.96	9.17	34	1.71	7.85	22
Average	0.55	0.99	12	0.23	0.66	5