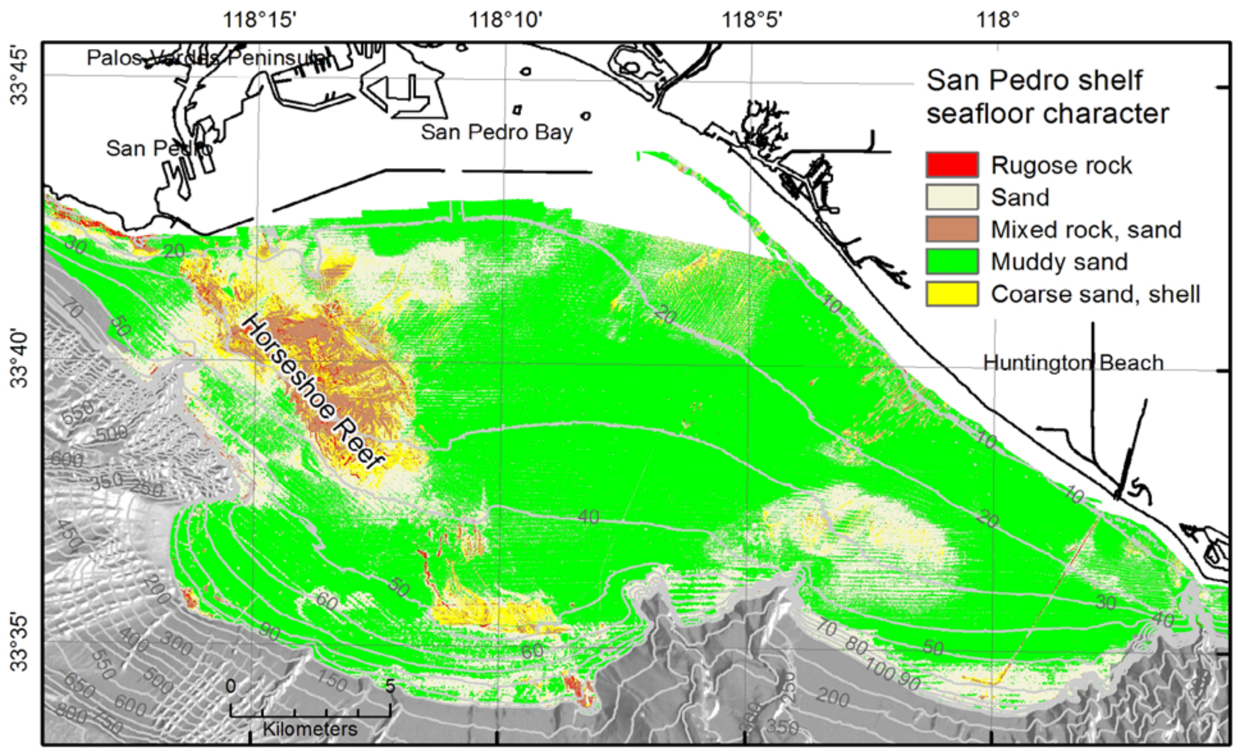
Prepared in cooperation with the Sanitation Districts of Los Angeles County and the Orange County Sanitation District

Seafloor Geology and Benthic Habitats, San Pedro Shelf, Southern California

By Florence L. Wong, Peter Dartnell, Brian D. Edwards, and Eleyne L. Phillips



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Seafloor character map of the San Pedro Shelf, southern California.

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

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Abstract

Seafloor samples, videography, still photography, and real-time descriptions of geologic and biologic constituents at or near the seafloor of the San Pedro Shelf, southern California, advance the study of natural and man-made processes on this coastal area off the metropolitan Los Angeles area. Multibeam echo-sounder data collected by the U.S. Geological Survey in 1998 and 1999 guided sampling and camera work in 2004 resulting in a new seafloor character map that shows possible benthic habitats in much higher resolution (4- and 16-m pixels) than previously available. The seafloor is characterized by primarily muddy sand and sand with outcrops of Miocene and Pliocene bedrock along the Palos Verdes Fault Zone. Observed benthic populations indicate low abiotic complexity, low biotic complexity, and low biotic coverage. The data are provided for use in geographic information systems (GIS).

Introduction

Between 1998 and 2004, the U.S. Geological Survey (USGS) headed an interdisciplinary study to map seafloor composition and habitat on the San Pedro Shelf, a part of the continental shelf off southern California (fig. 1). Multibeam-sonar data collected on the shelf in 1998 and 1999 provide a detailed base map from which to (1) understand and quantify controls on the San Pedro Shelf multibeam-backscatter intensity, which is a measure of sound energy reflected from the seafloor that contains clues about seafloor character; (2) classify and map surface-sediment types (for example, rock, sand, or mud) at 4- and 16-m/pixel resolution; and (3) use the type data to quantitatively map the complexity of marine communities and benthic habitats of the San Pedro Shelf.

The study is a cooperative effort between USGS scientists and personnel from the Sanitation Districts of Los Angeles County and the Orange County Sanitation District. The USGS provided expertise in geology and marine mapping, and the sanitation districts provided funding, biological expertise, and ship time.

Offshore of the populous Los Angeles metropolitan area, the San Pedro Shelf is affected by recreational and commercial fisheries and is impacted by numerous human activities, such as sanitation outfalls, shipping, anchor dragging, sand mining for beach replenishment, and waste disposal. This tectonically active area is also cut by numerous faults, whose earthquake potential could pose both shaking and tsunami hazards to onshore communities (fig. 2).

The San Pedro Shelf is one of the broadest mainland continental shelf segments between Monterey, California, and the United States-Mexico border. Approximately 75 to 80 percent of the San Pedro Shelf segment is composed of low-relief, sediment-covered seafloor, and the remaining 20 to 25 percent is composed of rock outcrop interspersed with boulders and cobbles. The study area, which covers approximately 400 km^2, is shallower than 100 m water depth. San Pedro Sea Valley, San Gabriel

Canyon, and Newport Canyon cut into the slope off San Pedro Shelf at the west, south, and southeast, respectively (fig. 1).

Two sedimented portions of the shelf are divided by a southeastward-trending outcrop of Miocene and Pliocene bedrock bounded by faults of the Palos Verdes Fault Zone and are expressed on the seafloor as Horseshoe Reef (fig. 2; Moore, 1954; Fischer and Rudat, 1987; Fisher and others, 2004, Wolf and Gutmacher, 2004). Surface sediment consists of silty sand, sandy silt, and sand that is classified as relict, detrital, or mixed (Moore, 1954; Bandy and others, 1964; Gorsline and Grant, 1972; Karl and others, 1980). Seasonal and tidal currents have generated complex bedforms on the seafloor (Karl and others, 1980; Drake and others, 1985).

This publication provides the seafloor video, still photographs, real-time observations, and sediment texture data from the 2004 surveys and the resulting refined seafloor character map that may be used to identify and map the distribution of benthic organisms (appendix A). With the character map and benthic organisms, seafloor geology and benthic faunal relations can be integrated to develop species-specific suitability maps and more general habitat maps designed to support California Fish and Game Marine Protected Area (MPA) work and demersal-fisheries management. Final products from this project can also be used to study shelf-sediment processes, offshore hazards, marine resources, and anthropogenic impacts on the seafloor.

Methods

The San Pedro Shelf was mapped for bathymetry and backscatter data during 1998 and 1999 using two different multibeam echo-sounding systems (MBES). In 1998, the outer mainland shelf and slope were mapped using a Kongsberg EM300 MBES (30 kHz) (U.S. Geological Survey, A-3-98-SC; Gardner and Mayer, 1998) and processed to 16-m resolution. In 1999, the inner mainland shelf from the Palos Verdes Peninsula south to Dana Point was mapped using a Kongsberg EM3000D MBES (300 kHz) more suited to shallower water depths (U.S. Geological Survey, C-1-99-SC; Gardner and others, 1999; Dartnell and others, 2004) and processed to 4-m resolution. The resulting bathymetric and acoustic backscatter maps were combined with historical textural data from USGS sediment database usSEABED (Reid and others, 2006) and hardground observations for a preliminary character map to guide sampling and photography in 2004 (fig. 3; Edwards and others, 2003).

In October 2004, along 190 line-km of trackline, 156 hr of seafloor video (78 hr from each of two cameras running simultaneously) and over 13,000 photographs were collected over the entire shelf (U.S. Geological Survey, O-1-04-SC; fig. 3). A 2 x 1 m camera sled was towed about 2 m off bottom at a speed of 1–1.5 kt. The sled consisted of one forward-looking video camera and one downward-looking video camera, each equipped with paired lasers for scale (green dots are spaced 15 cm apart and red dots are spaced 24 cm apart), one 6-megapixel still camera, and flood lights. Both videos were streamed to the ship in real time for observation on video monitors and recorded on MiniDV tapes. Navigational information including Greenwich Mean Time (GMT) and geographic coordinates were superimposed on the video and recorded onto the second audio channel of the MiniDV tapes. The still camera was manually triggered about once every minute at an optimal focal height and the image and the related navigational information were stored with the camera image file.

During the camera sled operations, real-time observations were recorded every minute using three programmable keypads (Anderson and others, 2008) and USGS GNAV software (Gerry Hatcher, written commun., 2004). Identifications were based on a key code consisting of 120 codes from 13 categories, including seafloor composition, abiotic complexity, biotic complexity, biologic modifiers of the seafloor, and number of benthic fauna and demersal fish (table 1); Phillips and others, 2007). From these 120 key codes, as many as 29 geologic and biologic attributes were entered during each 20- to 30-

second observation window. Each observation consisted of six mandatory attributes and as many secondary attributes as could be observed and noted. The string of attributes were recorded to a comma-delimited file with time stamps and geographic coordinates at the beginning and end of the observation. During the survey, these attributes were immediately incorporated into a geographic information system (GIS) for comparison with the multibeam bathymetry and backscatter and the preliminary seafloor character map.

During a 10-day survey in December 2004, 182 sediment samples were collected using a grab sampler designed by MEC Analytical Systems, Inc. (U.S. Geological Survey, E-2-04-SC). Sample locations over the shelf (figs 3, 4) were selected to ascertain differences in the acoustic backscatter and ground-truth findings from the preliminary seafloor character map. Sediment texture (grain size) analyses of the samples at the USGS sediment laboratory in Menlo Park, California, provided percentages of gravel, sand, and mud (appendix B).

All of the data sets mentioned above were used to refine and finalize the preliminary San Pedro Shelf character map. The bathymetry and backscatter data were used as basemap information and analyzed using the Knowledge Engineer Module (decision-tree classification process) within ERDAS Imagine 9.0 (ERDAS, 2010). The following procedure, which is slightly modified from Dartnell and Gardner (2004a,b), was applied the same way to the inner shelf (1999 study) and outer shelf (1998 study) data. The decision-tree classification process used three co-registered raster images, the original backscatter-intensity image, and two derivative raster images calculated from the original bathymetry data—seafloor slope and a 3x3-cell-filtered bathymetry-variance. Because the three images are co-registered, rules can be established that relate pixel values within or between images that will ultimately classify a new seafloor-character map.

Seafloor slope was calculated using standard GIS techniques. Bathymetry variance was calculated as the variability of bathymetry within a set of raster cells. An area with a large range of bathymetric relief, such as a rocky outcrop, would have a large bathymetry variance. A smooth area would have low bathymetry variance. The variance image was calculated by generating two intermediate images: a maximum image and a minimum image. The maximum image was calculated by running a filter (3x3 cells) that returned the maximum value within a kernel to the center cell. The minimum image was calculated by running a filter that returned the minimum value within a kernel to the center cell. The variance image was then created from the difference between the maximum and minimum images.

The decision-tree classification is a rules-based approach that uses a hierarchy of conditions to parse the input data into a set of classes. The framework was developed from empirically determined textural rules, variables, and hypotheses. A hypothesis is an output class, such as muddy sand, a variable is a raster image of derived values (that is, backscatter intensity), and a rule is a conditional statement about the variable's pixel (data) values that describes the hypothesis. The rules are based on information gathered from the ground-truth information including the seafloor video, photography, real-time observations, and textural data.

The seafloor character map consists of 5 output classes: (1) rugose rock, (2) mixed rock and sand, (3) coarser sand with shell material, (4) sand, and (5) muddy sand. Multiple iterations were run in the decision tree classifying process to try and match the output classes with the ground-truth information. The texture component (sand, muddy sand) was defined by the grain size analysis, and the hard grounds (rugose rock, mixed, coarser sand with shell material) were defined from the seafloor photographs, video, and real-time observations.

Results

The San Pedro Shelf data sets are provided with metadata and downloadable files suitable for public and proprietary geographic information system applications (appendix A). As not all of the data collected are provided with this publication, the user may contact the USGS for additional content (*http://www.usgs.gov/ask/* with "San Pedro Shelf DS 552" in the subject line).

A selection of 245 photographs from the 13,000 collected in 2004 are included in this data set (fig. 5). The selection provides examples of seafloor textures and plant and animal varieties viewed on the San Pedro Shelf. The shapefile of their locations is photopt.shp with primary attributes of latitude, longitude, image identifier as recorded on the image, and a descriptive caption. The coordinates have been corrected for the camera sled layback (distance behind vessel). The photos are viewable from a web page of thumbnails (appendix C) and from the Google Earth file that accompanies the report.

Because of the large file size, only one video clip is provided with this report (fig. 6; appendix D). The clip is from the San Pedro Shelf at Izor's Artificial Reef, which is a man-made feature consisting of stacks of cement columns (possibly old lamp posts). Numerous fish can be seen swimming among the columns; Gorgonia coral, algae, and encrusting corals are attached to the columns. The surrounding seafloor is composed of muddy sand with small burrows and mounds. The geographic locations displayed in the video image are slightly offset from the GIS maps in this report. As with the still photos, the locations displayed on the video have been corrected for the camera sled layback.

For a more continuous view of the seafloor than is provided by single still photos, some video tape segments were sampled as multiple still frames and were mosaicked into continuous video mosaic images (figs. 7, 8). The footprints of the mosaicked segments are provided in vidmosfoot.shp. The mosaicked images are provided as TIFF files.

Real-time observations (5,216 records) made during the camera runs are in shapefile videodes.shp with the 29 attribute fields populated by codes of species or descriptors as listed in table 1 The codes for each observation were concatenated and parsed out to 120 attributes with 0 or 1 values indicating absence or presence, respectively. Presence for each attribute was summed and include in table 1 by decreasing abundance within each category. Figure 9 includes maps of several of the attributes.

Textural data are provided as a point shapefile texture.shp with attributes gravel, sand, silt, clay, and mud (silt + clay) (appendix B). Finer grain size partitions are not available due to a corruption of data files from the grain size calculations. Interpolated maps of gravel, sand, and mud were calculated by the ArcGIS topogrid function (Esri, 2010).

The final interpreted character map is provided as inner shelf and outer shelf data layers in georeferenced Imagine (inner_shelf_character.img, outer_shelf_character.img) and TIFF (inner_shelf_character.tif, inner_shelf_character.tif) formats.

Discussion

Textural or grain size data show a dominance of sand-size sediment on the San Pedro Shelf (appendix B, figs. 10, 11). Samples consisting of as much as 95 percent sand surround a finer grained area shoreward of San Gabriel Canyon off the south end of the shelf. Coarse gravel-size sediment occurs in isolated patches defined by only one or two samples in the northwestern and eastern parts of the study area. Mud (silt plus clay) abundance inversely corresponds to sand abundance and is the dominant grain size in only a few isolated samples. Silty sand (29 percent of samples), slightly gravelly muddy sand (25 percent), slightly gravelly sand (22 percent), and sand (14 percent) are the primary classes of sediment among the uppermost subsamples from each grab sample (fig. 10; Folk, 1954, 1974). These data expand the coverage of sediment texture classes mapped in previous studies (fig. 12; Karl and others, 1980; Gorsline and Grant, 1972).

Seafloor images contain a variety of seafloor textures and benthic and demersal plants and animals. Continuous video provides extent of various habitats or seafloor types (fig. 6). Images mosaicked from many individual video frames provide scale of changes or continuity on the seafloor. For example, a video mosaic from the northwestern part of Horseshoe Reef shows a rubbly center with smoother seafloor at each end of the reef, reflecting the transition from a mixed rock and sand seafloor character to rugose rock and back to a mixed rock (fig. 8).

Descriptions logged in real time by observing video feeds on board help define the seafloor types (fig. 9, table 1). The San Pedro Shelf is characterized by low abiotic complexity, low biotic complexity, and low biotic coverage. Sand and mud are the major observed sediment components. Bedforms commonly consist of degraded, confused, oscillating, or sharp ripples. Among observed burrows, small burrows dominate and some are bioturbated or hummocky. The most frequently observed biologic species were roundfish, white urchin, sand stars, and pennatulids.

The final seafloor character map shows that the San Pedro Shelf is floored by a broad expanse of muddy sand with patches of sand, mixed rock and sand areas, and, rarely, rugose rock (fig. 13). The distribution is 66 percent muddy sand, 25 percent sand, 4 percent mixed rock and sand, 5 percent coarser sand and shell material, and less than 1 percent rugose rock. The category “Muddy sand” here includes both silty sand and muddy sand. Horseshoe Reef and other mixed rock and sand zones trend along the outcrop of Miocene and Pliocene bedrock. The results of dredging operations to deepen the shipping channel south of Long Beach Harbor and the man-made debris offloaded at Izor’s Reef (fig. 6) are identifiable in the seafloor character map (fig. 13).

The classification process analyzes processed bathymetry and backscatter imagery. These data can be classified or binned in many different ways based on the user needs (for example, to map seafloor habitats for identifying possible Marine Protected Areas, to map seafloor geology for sedimentary pathways, or to map hazards). The seafloor character map presented here best fit the ground-truth information (fig. 14) and satisfied the project’s goals for characterization of the seafloor.

The seafloor character map shows a considerable striping pattern mainly within the sand and muddy sand classes. This is caused by an artifact in the backscatter data collection process and occurs near the MBES nadir, a region dominated by noise. The striping misclassifications occurred because of the abnormally high backscatter from the vertical incidence and the near-vertical incidence at the MBES nadir. This high-backscatter zone rapidly decreases with across-track distance from nadir. Some of the pixels in the nadir zone have low bathymetric variance but high backscatter intensity similar to the sand class, but based on the surrounding sediment type these pixels should probably be classified as muddy sand.

As a research topic within this project, the classification process attempted to distinguish the finer grained seafloor (muddy sand) from coarser grained seafloor (sand). An accuracy assessment conducted using the sediment textural data revealed that the sedimented portion of the map is 72 percent accurate, but it does have the considerable striping pattern. However, since this is a digital GIS map, the sand and muddy sand classes can be combined together into a more general sand class and most of the mis-classified strips disappear (fig. 15).

Visualizations of the data in Google Earth and as animated fly-throughs give the seafloor properties other geographic expressions. The Google Earth presentation allows users to examine the layers of raster data (acoustic backscatter, shaded relief, and interpreted seafloor character) and vector data (sample and camera locations and content) in any combination and at any scale navigated by the application (fig. 16; separate .kmz file; Wong and others, 2008). The animated fly-through provides a submariner's view of the seafloor data with stops at special points of interest (fig. 17; separate .mov file).

Data Revisions and Updates

This GIS compilation will be revised and updated as new data become available. Any updated data will be posted on the publication's web page at *http://pubs.usgs.gov/ds/552/*, and changes will be noted in versionHist.txt. The hosting site may change; if there is no forwarding link, go the USGS home page (*http://www.usgs.gov*) and search for keywords "San Pedro Shelf DS 552."

Acknowledgments

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A-3-98-SC (available at *http://walrus.wr.usgs.gov/infobank/a/a398sc/html/a-3-98-sc.meta.html*),
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O-1-04-SC (available at *http://walrus.wr.usgs.gov/infobank/o/o104sc/html/o-1-04-sc.meta.html*).

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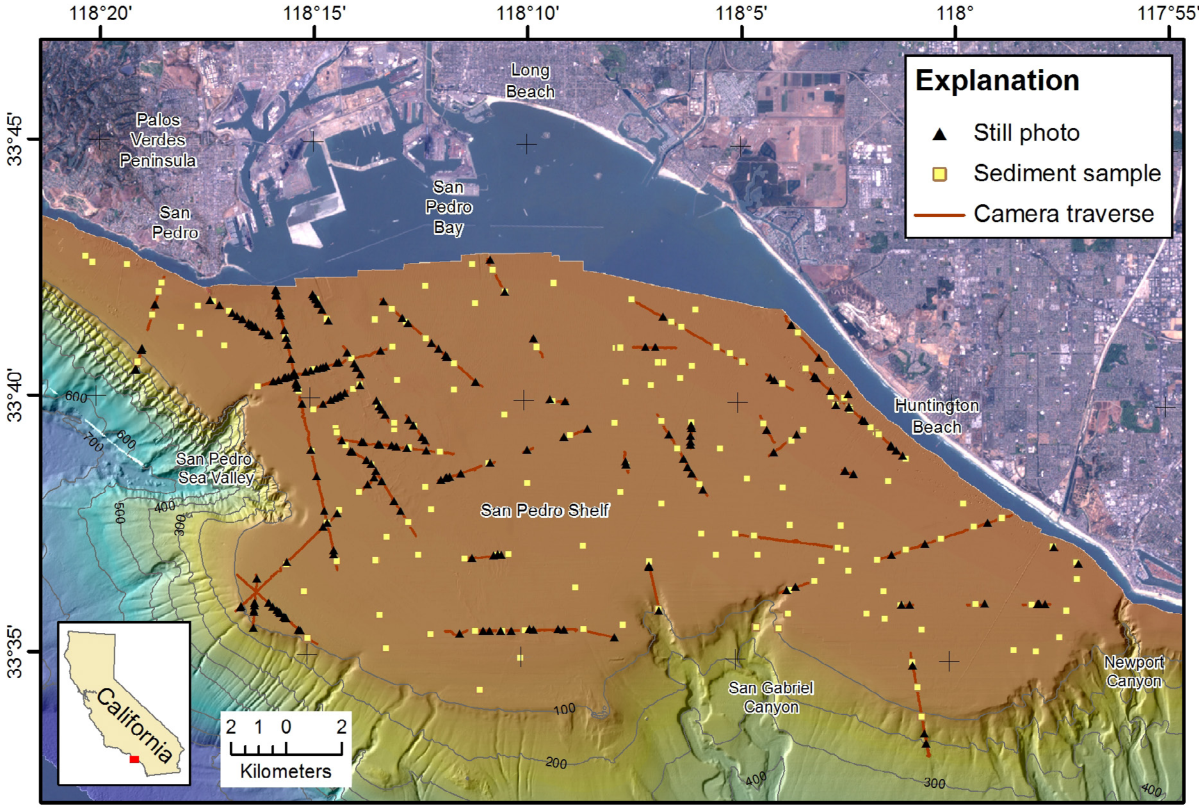
A.



B.

Figure 1. *A*, Location map of video camera traverses, still photographs, and sediment samples for San Pedro Shelf, California, study area (U.S. Geological Survey, O-1-04-SC, E-2-04-SC). Base map consists of color shaded relief (Dartnell and Gardner, 1999) and Landsat image. Bathymetric contour interval 100 m. *B*, Orange County Sanitation District personnel George Robertson (left) and Mike McCarthy recover box sampler onboard the research vessel *Early Bird I* (Edwards and others, 2005).

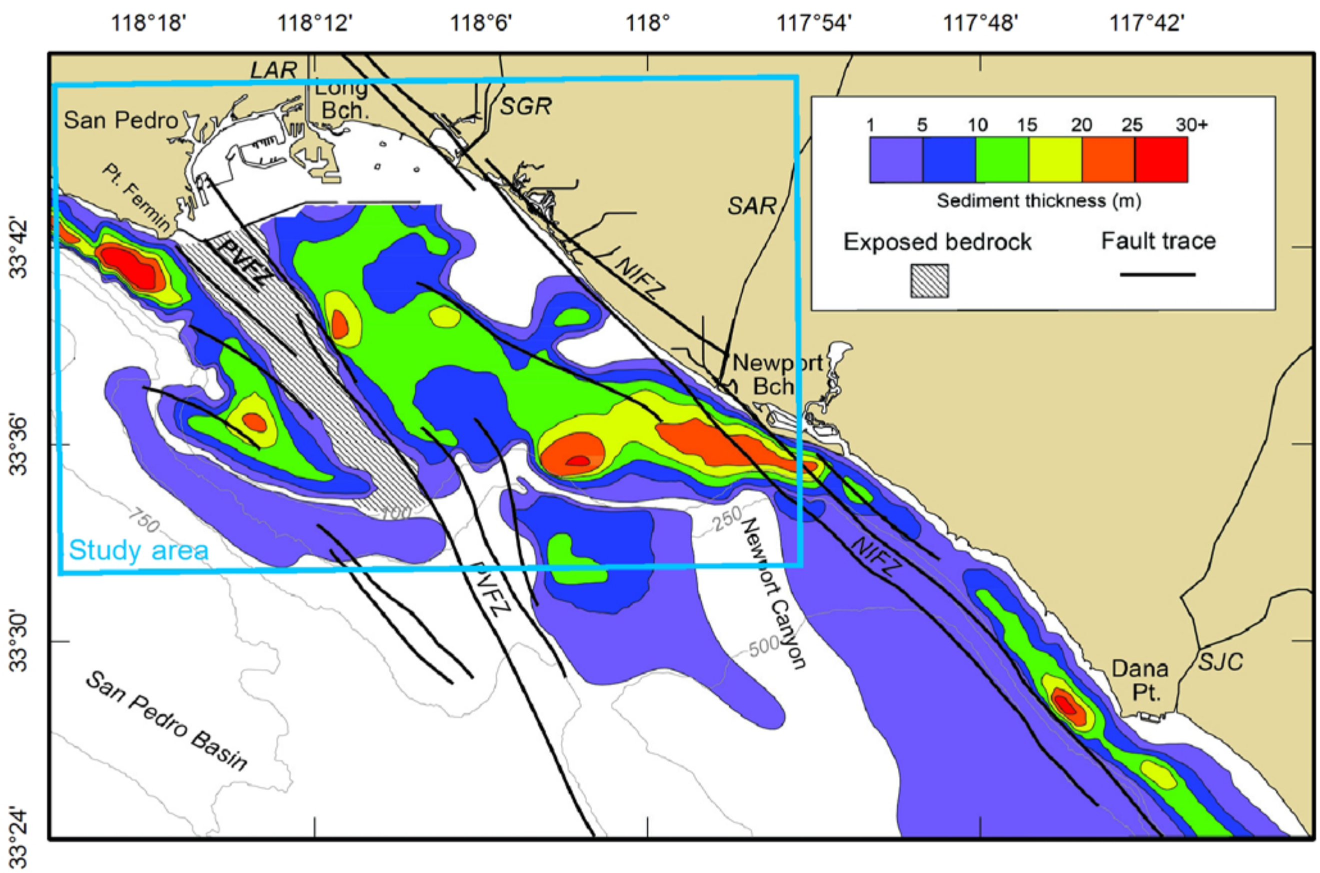
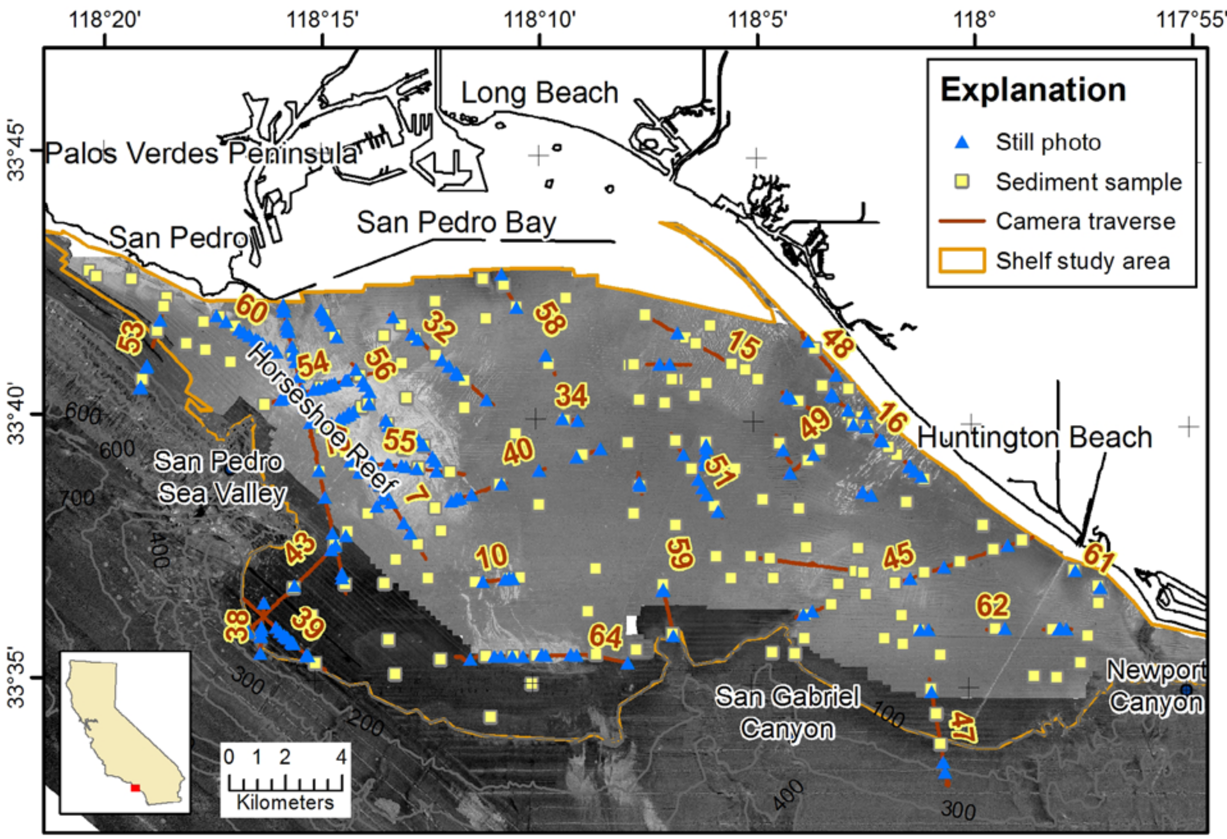
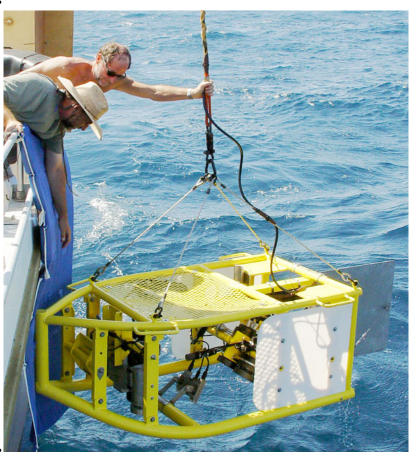


Figure 2. Location of study area on a map of post-glacial sediment isopachs and major fault traces of the coastal zone from San Pedro to Dana Point, California (after Sommerfield and others, 2009). Fault traces are from Vedder and others (1986) and Clarke and others (1987). Abbreviations: LAR, Los Angeles River; PVFZ, Palos Verdes Fault Zone; NIFZ, Newport-Inglewood Fault Zone; SAR, Santa Ana River; SGR, San Gabriel River; SJC, San Jose Creek.



A.



B.

Figure 3. *A*, Locations of a subset of still photographs presented in this report and sediment samples taken on San Pedro Shelf in 2004 to ground-truth features detected in underlying acoustic backscatter image. Acoustic backscatter image of San Pedro Shelf and slope, California, generated from multibeam data collected by the U.S. Geological Survey in 1998 (off shelf) and 1999 (on shelf) (Dartnell and Gardner, 1999). Differences in data collection equipment, processing, and data resolution account for shading contrast between data from the two years. *B*, Camera sled with still and video cameras, strobe lamps, and related photographic equipment. Photograph by Tom Parker (LACSD) from Edwards and others (2005).

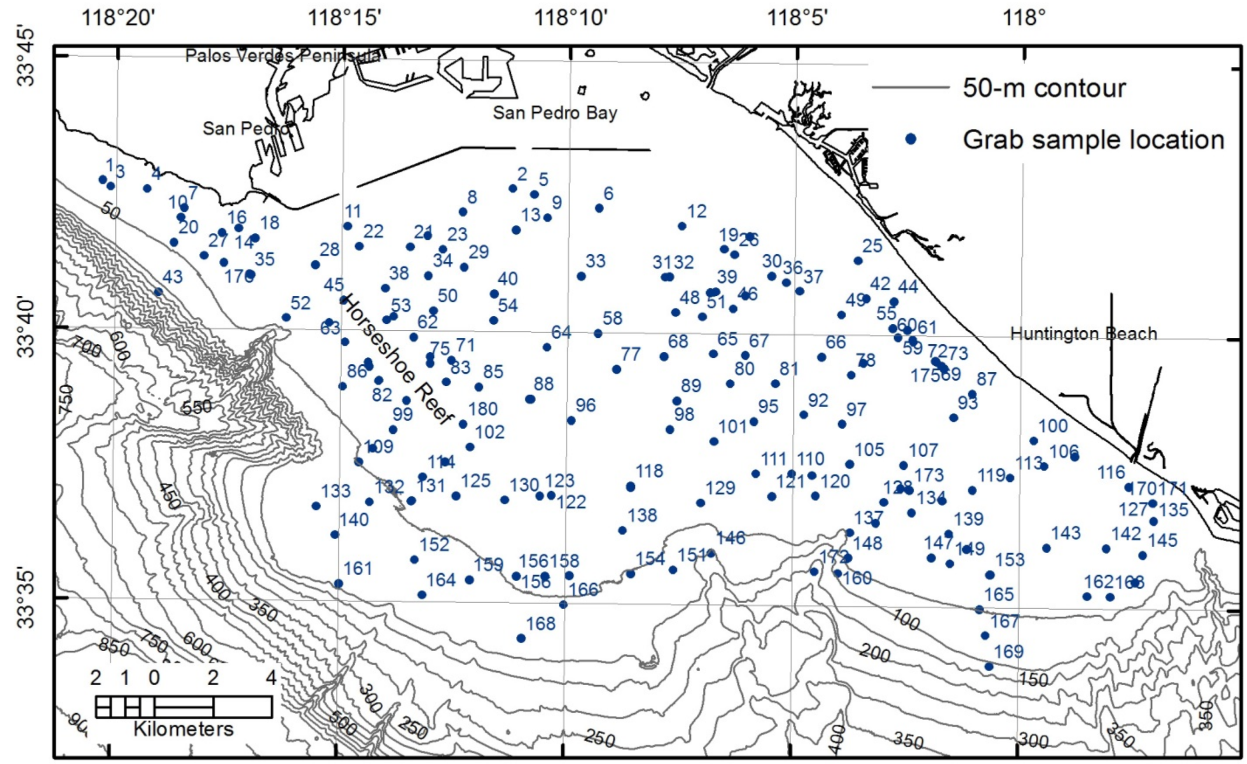
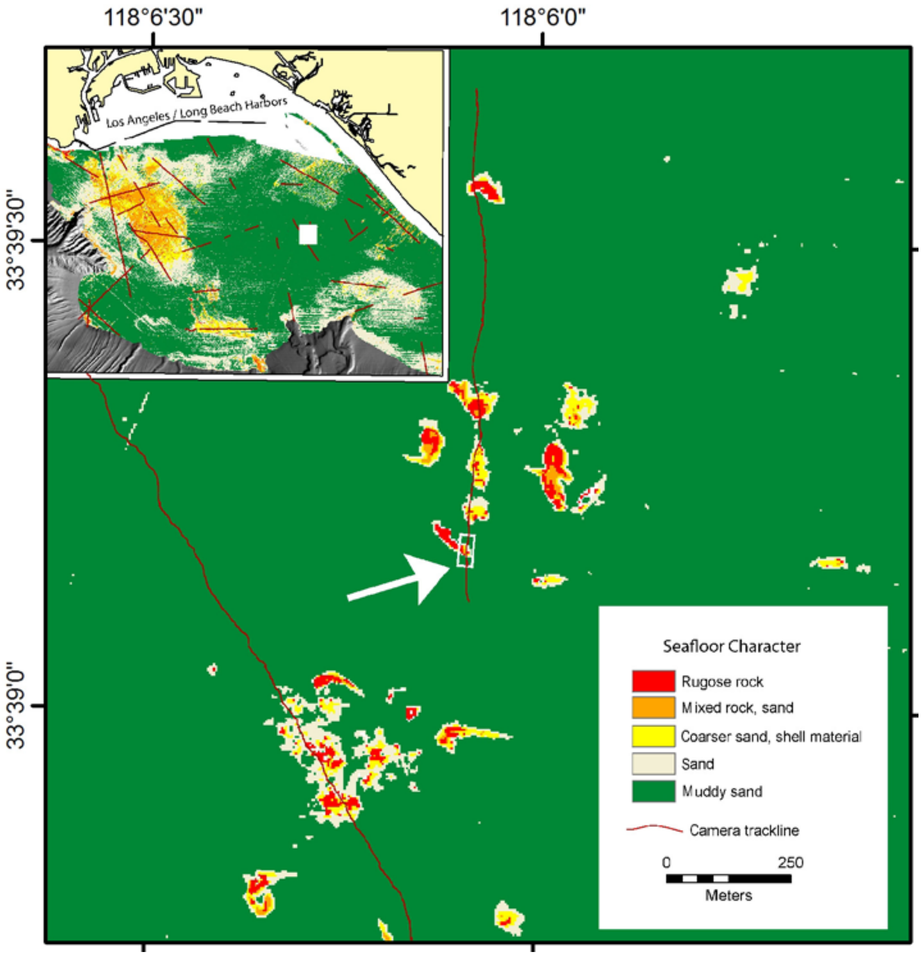


Figure 4. Locations and sample numbers of grab samples taken from San Pedro Shelf, California, in 2004 (U.S. Geological Survey, E-2-04-SC).

Figure 5. Examples of seafloor photographs taken from San Pedro Shelf in 2004. *A*, Northwest of Horseshoe Reef, San Pedro Shelf, California (location 32 in fig. 3); *B*, Within Horseshoe Reef (location 56 in fig. 3). Width of images is approximately 60–80 cm. Where present, two green laser points are 15 cm apart.



A.

B.

Figure 6. *A*, Camera track of a short piece of video (spshelf_videoclip.mov) collected over Izor's Reef (white box outline next to arrow on map) in relation to San Pedro Shelf seafloor character map. Video clip runs from south to north for approximately 32 m over 1:27 min. *B*, Screenshot of video.

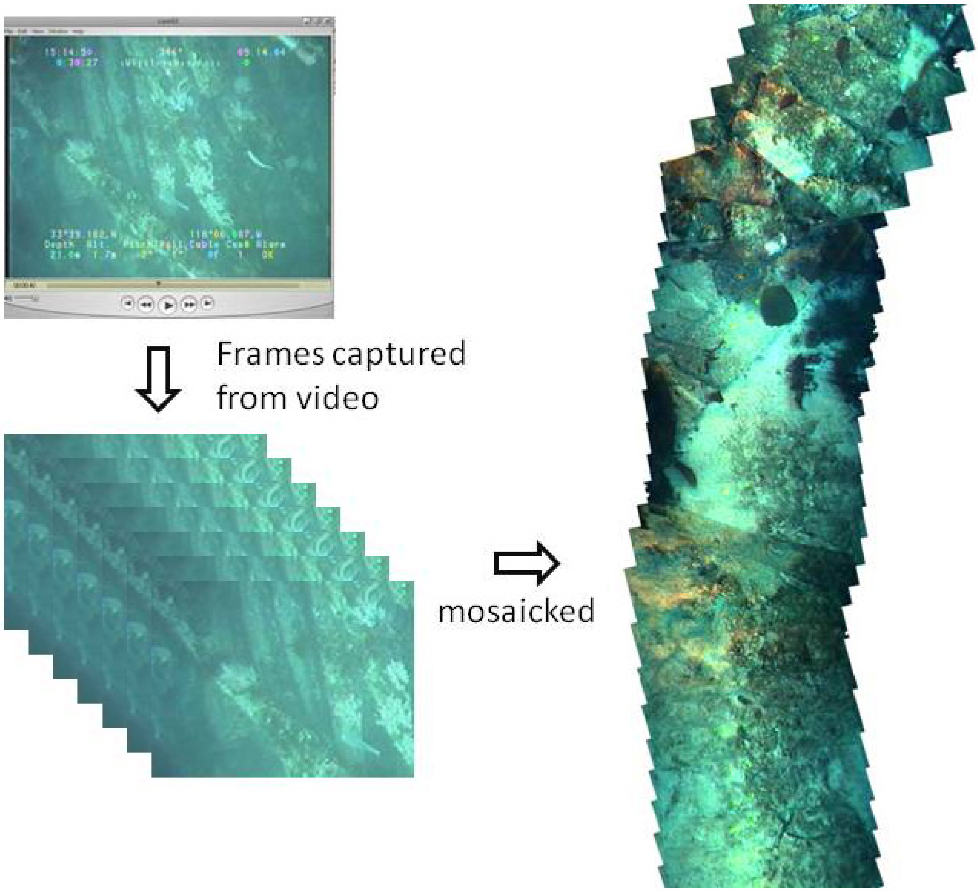


Figure 7. Frames captured from seafloor video are mosaicked into continuous strips representing a swath of seafloor approximately 2 m wide and as long as 100 m.

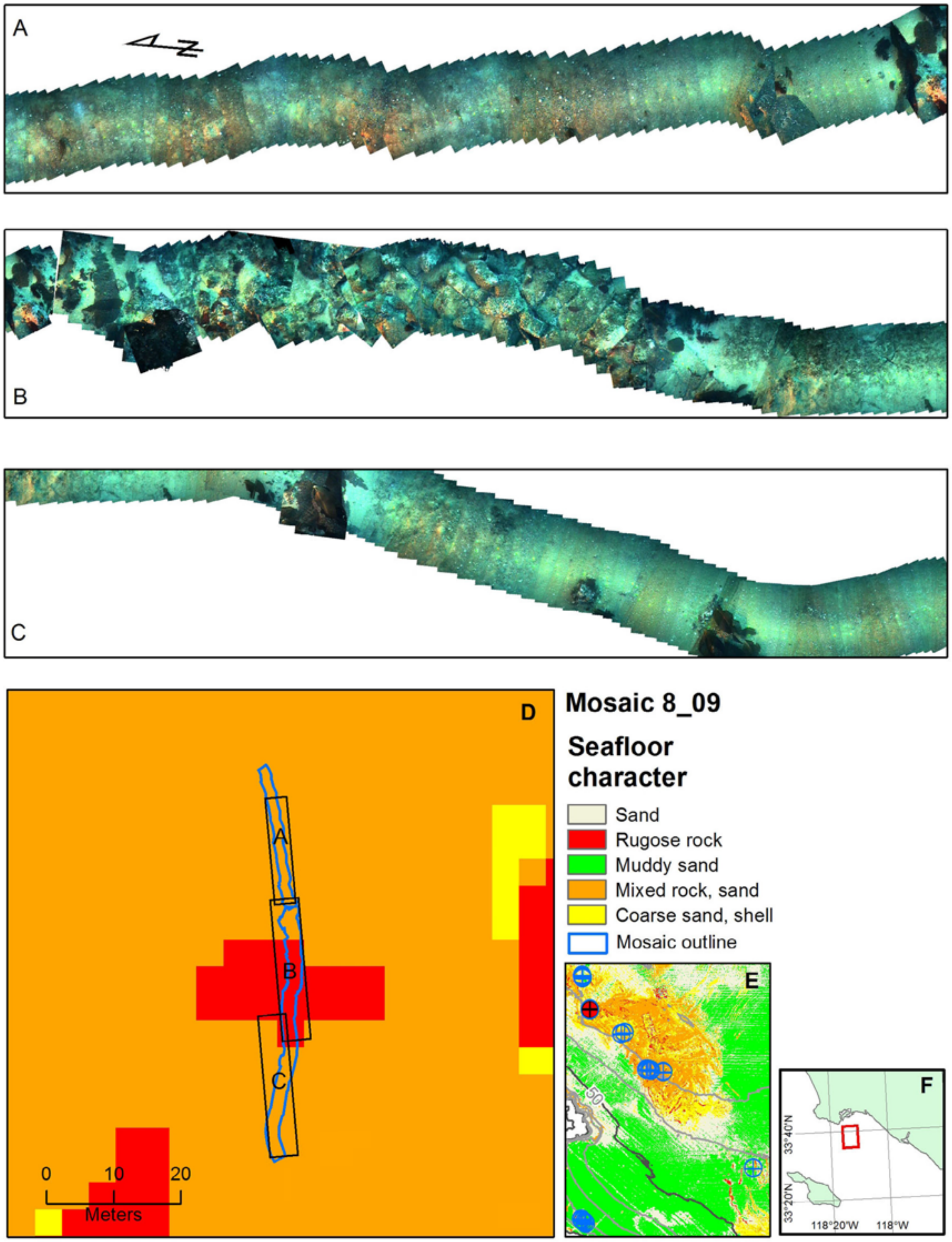


Figure 8. Video mosaic image from northwestern part of Horseshoe Reef, San Pedro Shelf, California. Seafloor character changes from mixed rock and sand to rugose rock and back to mixed rock and sand along video mosaic. Image is verified by seafloor character map. *A*, *B*, and *C* are adjoining segments of a mosaic assembled from images extracted from video images. Width of image strip is ~2 m. *D*. Outline of mosaic plotted on seafloor character map. *E*. Index map of video mosaics; red symbol marks area in D. *F*, Area index map.

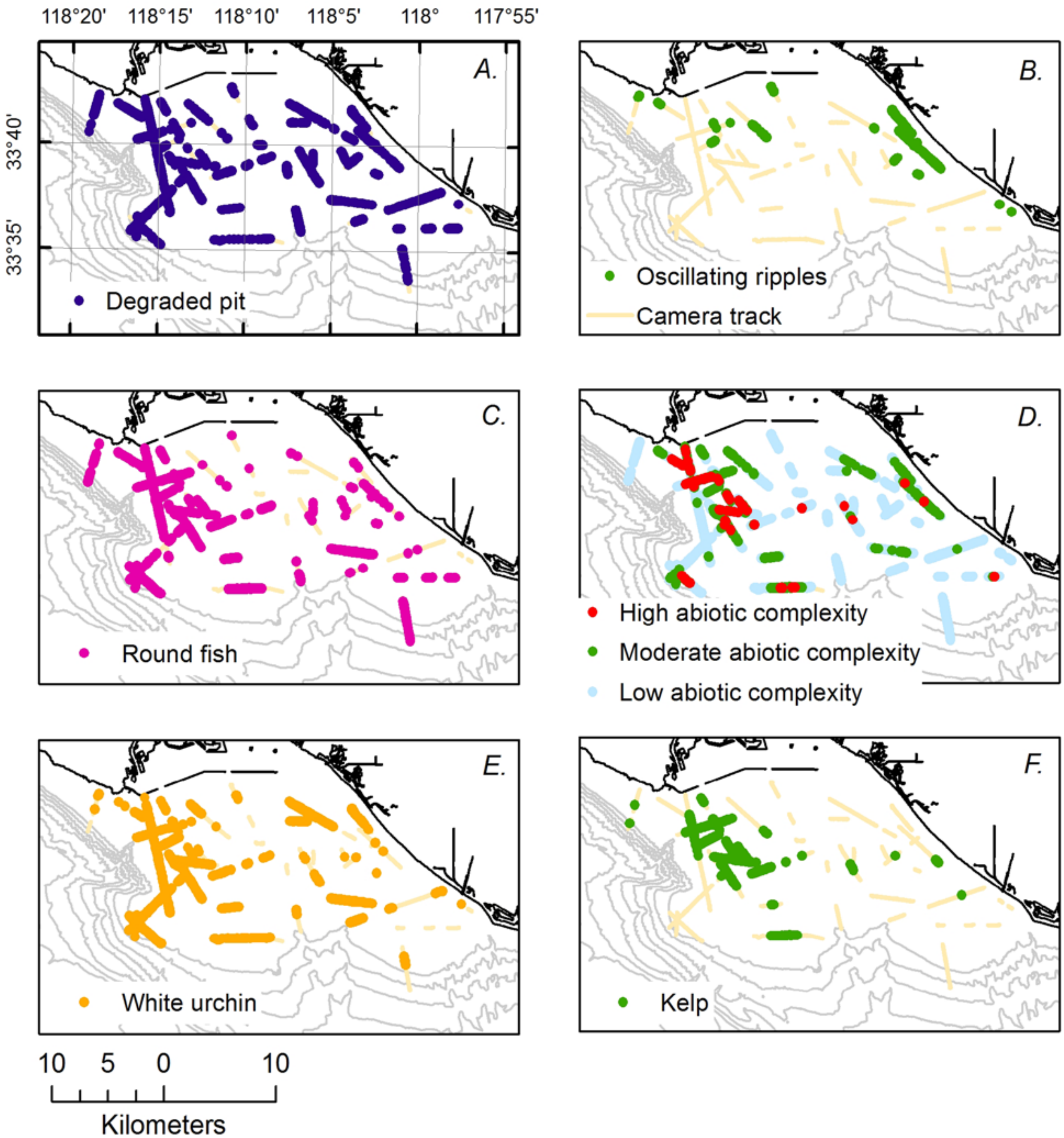


Figure 9. Distribution of selected seafloor biotic and abiotic components or characteristics on the San Pedro Shelf, California, from as many as 120 characteristics identified in real time during video capture (fig. 3).

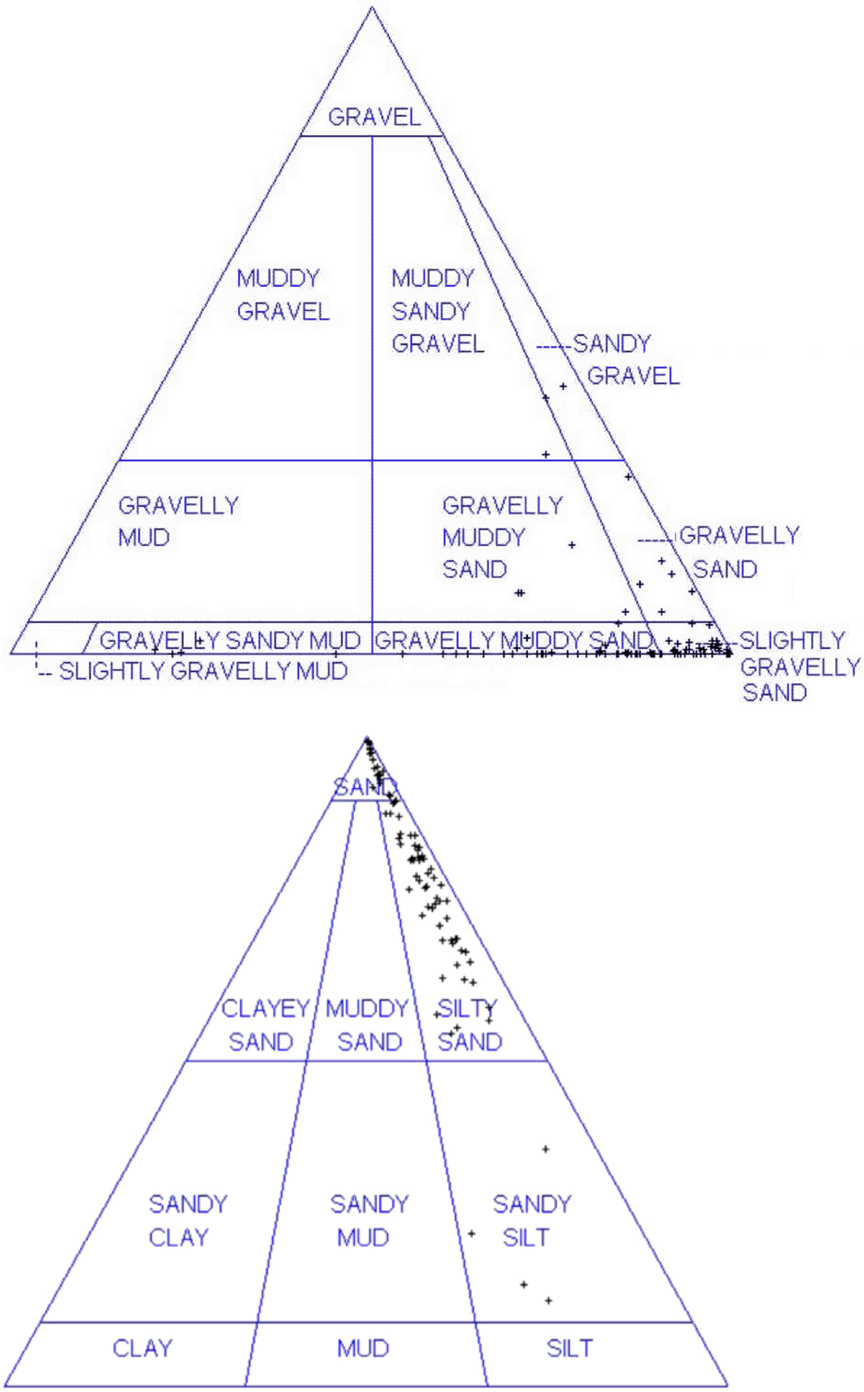


Figure 10. Classification of sediment samples from San Pedro Shelf, California, after Folk (1954, 1974). Ternary plot of samples with *A*, gravel >0.1 percent; and *B*, gravel ≤0.1 percent. Plot software by Poppe and Eliason (2008).

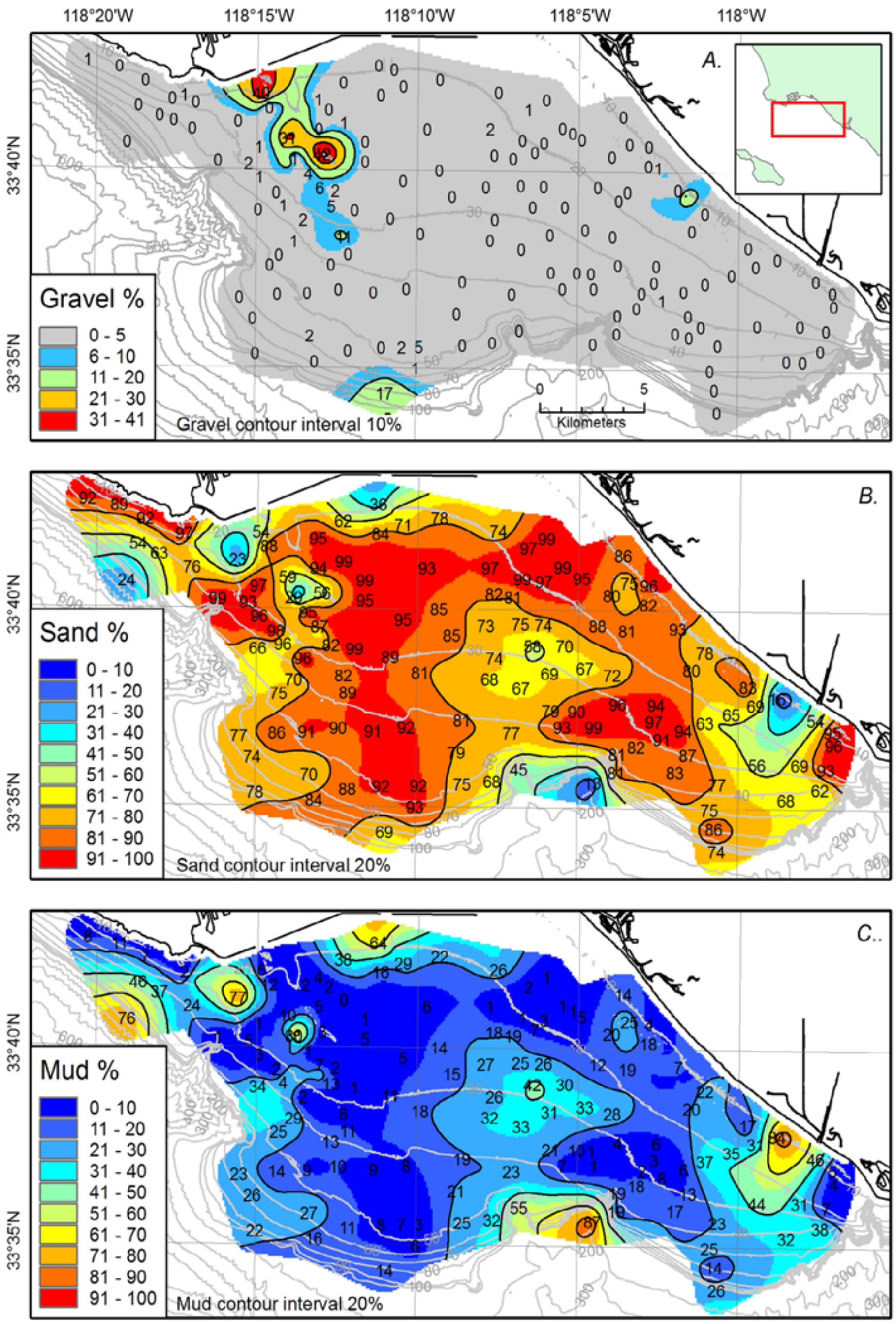


Figure 11. Surface gravel, sand, and mud distribution on the San Pedro Shelf, California. Values plotted on maps are percent of each component. Bathymetric contour interval is 20 m to 100 m depth, then 100 m to maximum depth. *A*, Percent gravel; *B*, Percent sand; *C*, Percent mud.

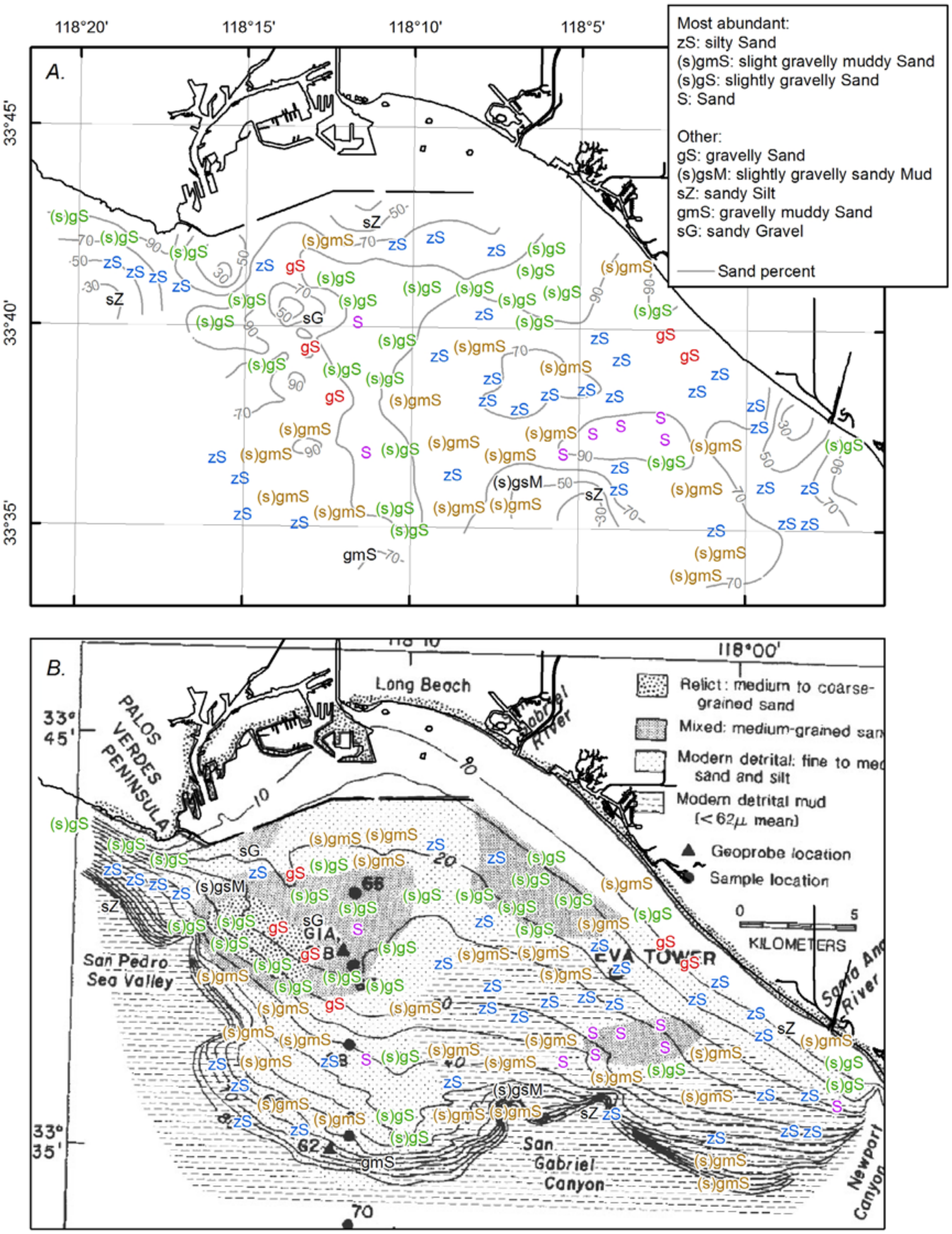


Figure 12. *A*, Distribution of sediment texture classes on San Pedro Shelf, California. *B*, Sediment texture classes overlaid on principal sediment types as summarized by Drake and others (1985) from work by Gorsline and Grant (1972) and Karl and others (1980).

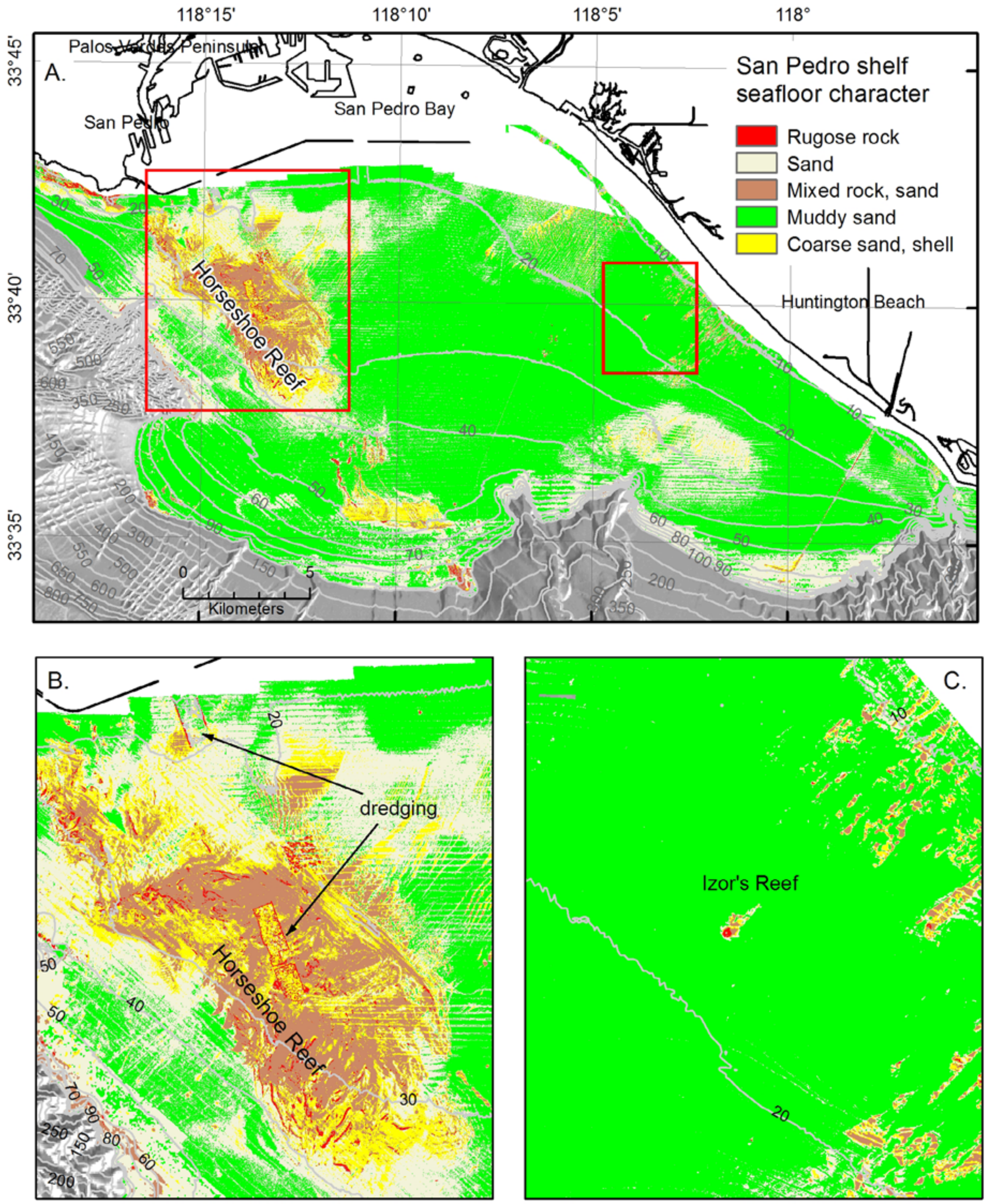


Figure 13. *A*, Seafloor character map for San Pedro Shelf, California, as interpreted from acoustic backscatter data, sample textures, and photographic and video imagery. An earlier iteration of the map based primarily on acoustic backscatter guided the 2004 sampling and camera surveys to generate this final map. *B*, Enlargement over Horseshoe Reef showing dredging for main shipping channel for Los Angeles harbor. *C*, Enlargement over Izor's Reef, a man-made feature created from offloading light poles and other debris.

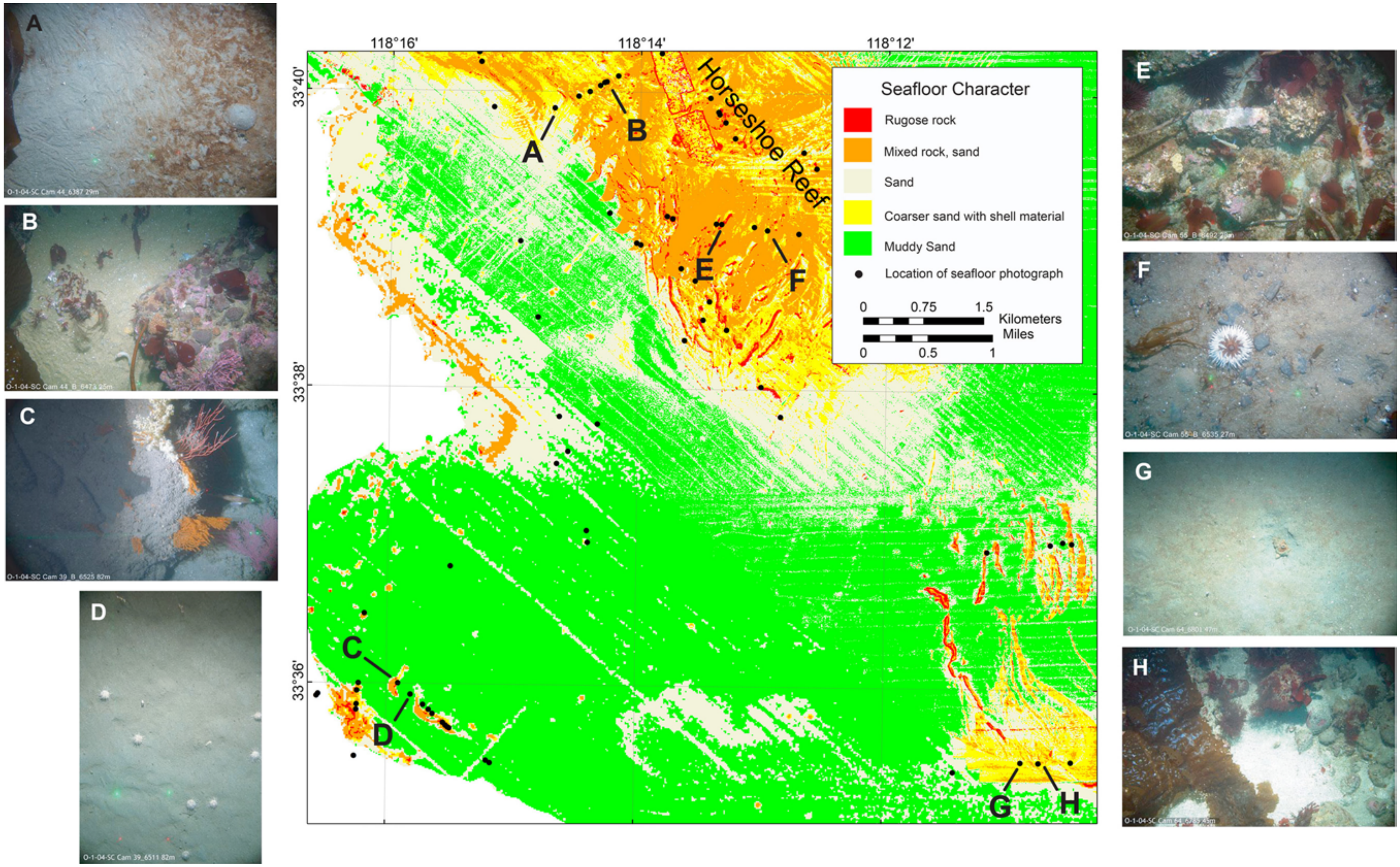


Figure 14. Close-up view of the seafloor character map around the southern portion of the Horseshoe Reef region with a selection of photographs (*A–H*) used as ground-truth in the classification process.

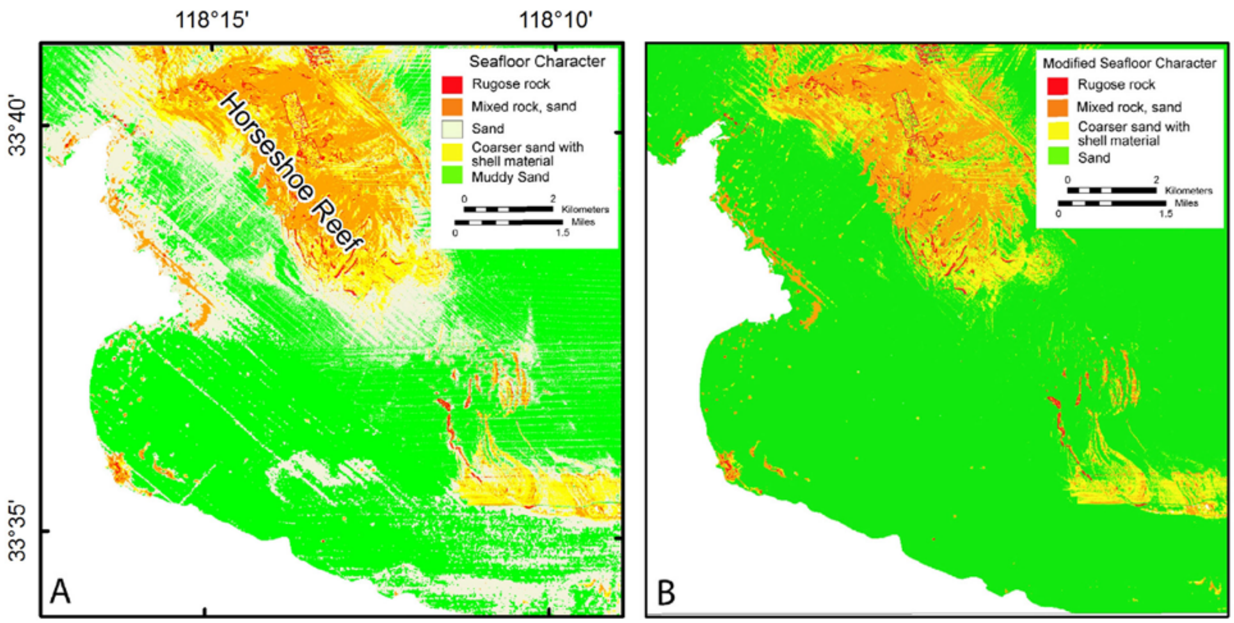


Figure 15. Comparison between the original seafloor character map (*A*) and a modified character map (*B*) where the sand and muddy sand classes have been combined into a more general sand class. Striping within the sand class disappears.

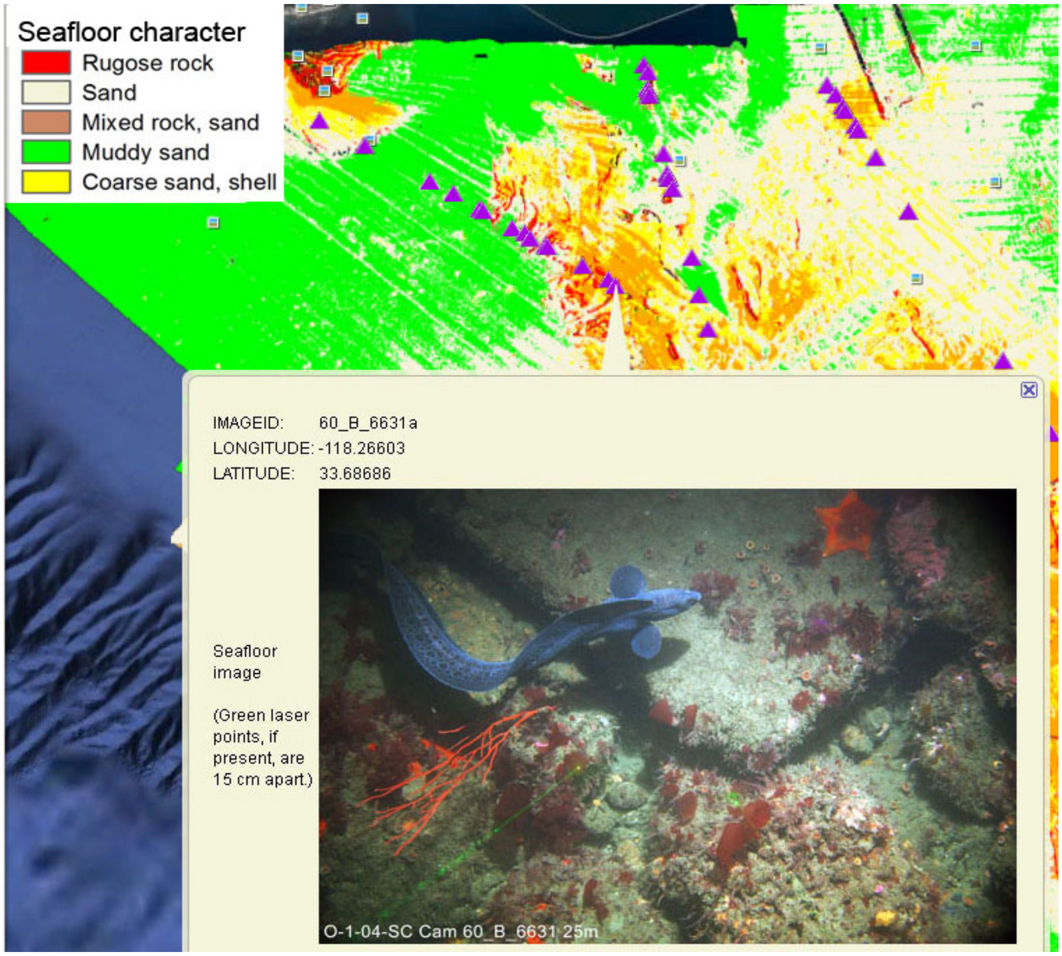


Figure 16. San Pedro Shelf data as portrayed in Google Earth application (appendix E). Photo image is linked to Google Earth placemark, which is displayed on seafloor character map layer.

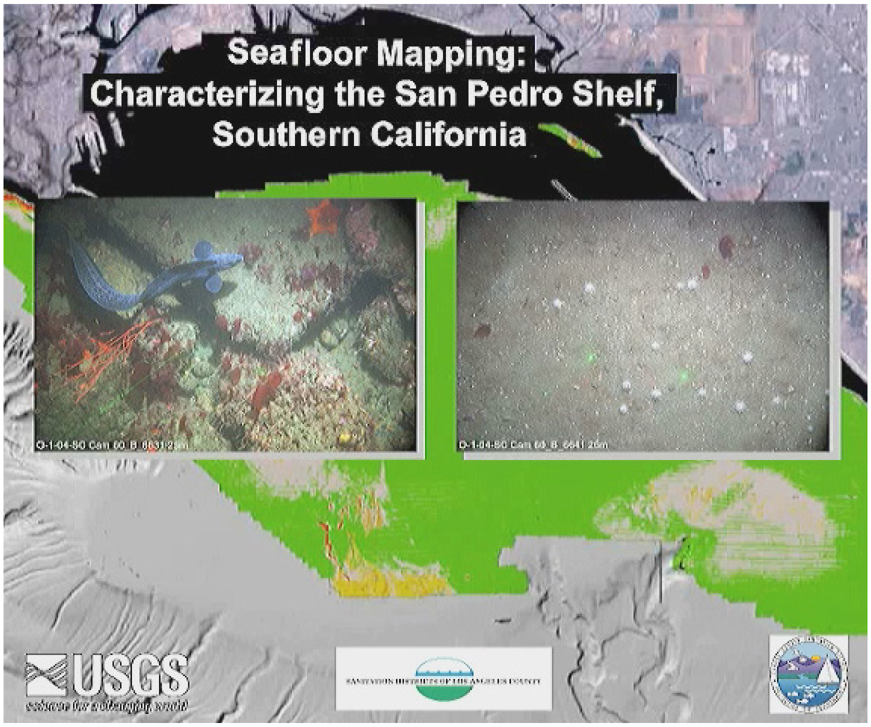


Figure 17. Opening video screen of animated flight through San Pedro Shelf, California (appendix F). Two seafloor photos are superimposed on a map of seafloor character and shaded relief in the study area.

Table 1. Sum of occurrences of biotic and abiotic species or characteristics from video observations sorted from greatest to least Sum in each Category. Observation codes were entered from three keypads during real-time viewing of seafloor video and images at sea.

Category	Observation code	Sum	Description
abiotic complexity	a_low	3956	low abiotic complexity
	a_mod	779	moderate abiotic complexity
	a_hi	145	high abiotic complexity
biotic complexity	b_low	2418	low biotic complexity
	b_mod	549	moderate biotic complexity
	b_hi	1	high biotic complexity
	b_trace	1	trace biotic complexity
biotic coverage	cvr_l	3345	low benthic coverage
	cvr_b	1220	barren benthic coverage
	cvr_m	312	moderate benthic coverage
	cvr_h	6	high benthic coverage
maj, min	sand	4130	sand
	mud	1944	mud
	rock	515	rock
	int	183	INTERFACE- change in seafloor type
	boulder	111	boulder
	cobble	79	cobble
	und	67	UNDEFINED- seafloor could not be seen/determined
	gravel	37	gravel
	kelp_cvr	14	kelp forest coverage
anthropogenic	ath_o	163	anthropogenic other
	ath_tw	11	anthropogenic trawl mark
	ath_fg	7	anthropogenic fish gear
	ath_gh	0	anthropogenic hole/gouge
bedform type	rp_d	453	degraded ripple
	rp_c	433	confused ripple
	rp_oc	393	oscillating ripple
	rp_sh	309	sharp ripple
	rp_m	98	mega ripple
	rp_a	63	asymmetrical ripple
	rp_su	25	subtle ripple
	rp_or	24	other ripple
burrow type	sb	3006	small burrow
	hum	1268	bioturbated/hummocky
	lb	873	large burrow
	ob	97	other burrow
current indicators	cur_b	404	current bowed
	cur_sc	109	current scour
	cur_wn	53	current winnowed
	sed_w	39	sediment wave

Category	Observation code	Sum	Description
	cur_sm	27	current smooth
	cur_ln	3	current lineations
	fls	1	featureless
pit type	pg	1512	pit gentle
	psh	635	pit sharp
	pu	11	pit undefined
rock type	rx_s	760	sedimentary rock
	rx_sb	756	outsized clast
	rx_i	83	rock island
	rx_f	30	fractured rock
	rx_bb	3	broken/blocky
	rx_t	0	talus
slope	flat	4651	low relief
	slope	147	slope relief
	cliff	89	extreme relief
visibility	vp	562	poor visibility
	vm	535	moderate visibility
	vn	116	nephloid visibility
	vh	102	high visibility
other	rf	1837	round fish
	ur_w	1695	white urchin
	mnd	1544	mound
	dia	1324	diatomaceous cover
	st_s	1283	sand star
	tck	1180	track/trail
	pn	1154	pennatulid
	trf	998	turf
	alg	896	algae
	pn_ft	877	pennatulid - feather
	kel	839	kelp - not obscuring
	st_o	723	star other
	dwd	676	drift weed
	sh_db	671	shell debris
	bdt	632	body trace
	inv	570	invertebrate
	anm	523	anemone
	gor_p	509	prostrate gorgonian
	anm_s	496	sand rose anemone
	ff	410	flat fish
	pn_sw	303	sea whip
	fan_r	272	red gorgonian
	gst	268	gastropod
	tbw	254	tube worm
	st_br	239	brittle star
	cir	209	circle scribe
	fan_bg	168	bushy golden gorgonian
	scu	168	sea cucumber

Category	Observation code	Sum	Description
	scu_c	155	California cucumber
	poo	143	fecal coil
	cb_o	128	other crab
	gor_e	118	erect progonian
	fan_p	115	purple gorgonian
	pn_fsp	108	fat sea pen
	ur_pr	83	purple/red urchin
	spg_e	72	encrusting sponge
	lfy	68	scattered leaf
	bpl	53	biotic plowing
	spg_s	50	solitary sponge
	met	47	metridium anemone
	ur_f	43	fragile urchin
	fan_o	40	other gorgonian
	btw	33	tool mark
	ur_r	31	urchin regular
	brc	25	brachiopod
	anm_b	22	burrowing anemone
	ur_di	21	deep water irregular urchin
	egg	20	egg case
	cb_s	11	spider crab
	cor	11	coral
	els	10	elasmobranch
	cri	9	crinoid
	oct	9	octopus
	sar	8	sardine/anchovy
	scu_w	4	warty cucumber
	st_ba	3	basket star
	biv	2	bivalve
	cru	2	crustacean
	ftw	2	feather worm
	sq	1	squid

Appendices

Appendix A. Data catalog
http://pubs.usgs.gov/ds/552/catalog.html
Appendix B. Grain size data
http://pubs.usgs.gov/ds/552/data/shp_files/ds552_gsz.xls
Appendix C. Seafloor photographs
http://pubs.usgs.gov/ds/552/photos.html
Appendix D. Seafloor video clip
http://pubs.usgs.gov/ds/552/data/movies/spshelf_videoclip.mov
Appendix E. Google Earth visualization
http://pubs.usgs.gov/ds/552/data/kmz/San_Pedro_Shelf_CA.kmz
Appendix F. Animated fly-through video
http://pubs.usgs.gov/ds/552/data/movies/SPShelf_Character.mov