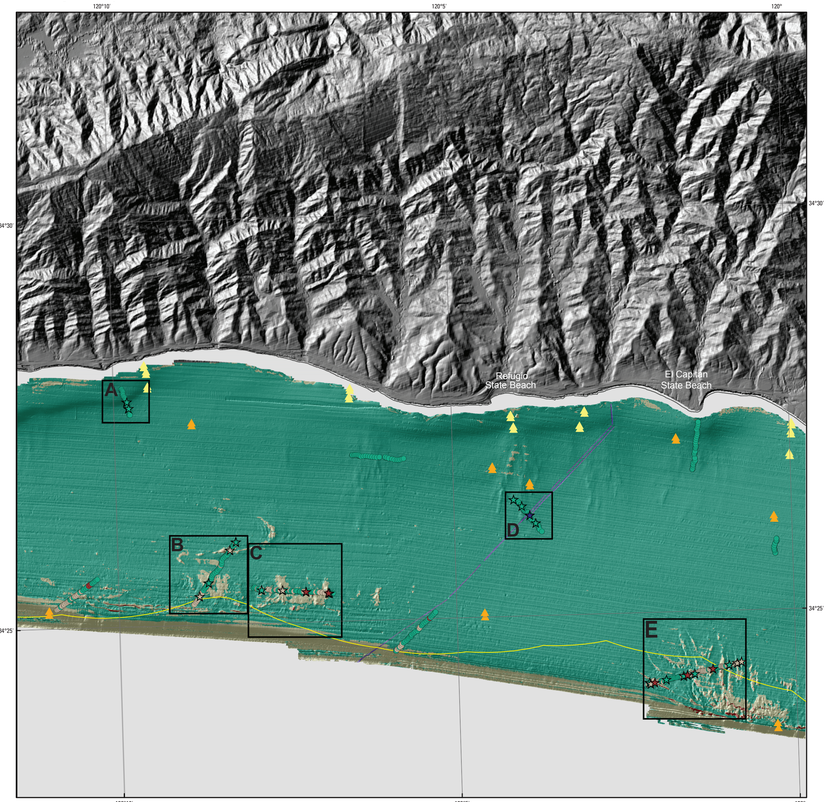
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3319
Sheet 6 of 11
Pamphlet accompanies map



Onshore elevation data from NOAA Coastal Services Center (data collected by EarthData International in 2002-2003) and from U.S. Army Corps of Engineers (data collected by Fugro Pelagos in 2009). Offshore shaded-relief bathymetry from map on sheet 2, this report. California's State Waters limit from NOAA Office of Coast Survey

Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

12°

APPROXIMATE MEAN DECLINATION, 2015

SCALE 1:50 000

2 1 0 2 MILES
7000 3500 0 7000 FEET
1 0.5 0 1 KILOMETER
1 0.5 0 1 NAUTICAL MILE
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Seafloor-character map simplified from map on sheet 5, this report. Video observations recorded and digital still photographs taken in 2007-2008. Sample localities from usSEABED (Reid and others, 2006) and from Barnard and others (2009)

GIS database and digital cartography by Nadine E. Golden and Elwyne L. Phillips

Edited by Sarah E. Nagorsen

Manuscript approved for publication February 4, 2015

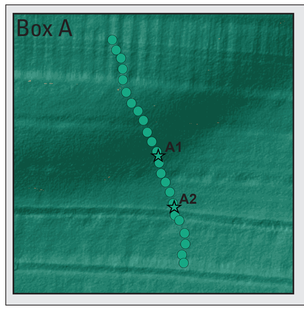


Figure 1A. Detailed view of seafloor character mapped west of Refugio State Beach, approximately 0.5 km offshore (see Box A, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 1B, 1C) from camera line CAM10, cruise S–1C–08–SC.

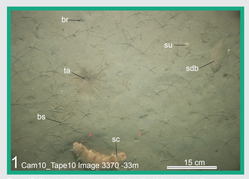


Figure 1B. Digital still photograph no. A1 (see fig. 1A for location). Fine sand and mud, at the base of terrace flank (water depth, 33 m). Abiotic complexity is low, biotic complexity is absent, and biocover is high. Biocover includes burrows (br); Pacific sanddab, *Citharichthys sordidus* (sdb); California sea cucumber, *Parastichopus californicus* (sc); brittle star (bs); tube anemone (ta); and sea urchin (su). Distance between lasers (red dots) is 15 cm.

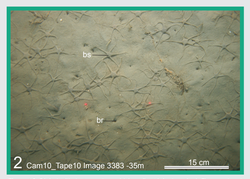


Figure 1C. Digital still photograph no. A2 (see fig. 1A for location). Fine sand and mud (water depth, 35 m). Abiotic complexity is low, biotic complexity is absent, and biocover is high. Biocover includes small burrows (br) and brittle star (bs). Distance between lasers (red dots) is 15 cm.

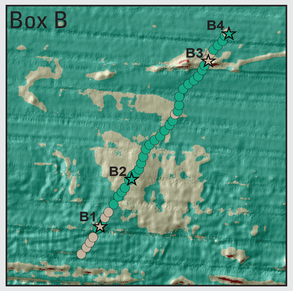


Figure 2A. Detailed view of seafloor character mapped southwest of Refugio State Beach, approximately 4.5 km offshore (see Box B, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 2B through 2E) from camera line CAM9, cruise S–1C–08–SC.

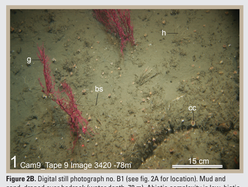


Figure 2B. Digital still photograph no. B1 (see fig. 2A for location). Mud and sand, draped over bedrock (water depth, 78 m). Abiotic complexity is low, biotic complexity is present, and biocover is high. Biocover includes gorgonian (g), hydroid (h), brittle star (bs), and cup coral (cc). Distance between lasers (red dots) is 15 cm.

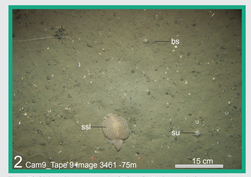


Figure 2C. Digital still photograph no. B2 (see fig. 2A for location). Mud and sand, with scattered shells and gravel (water depth, 75 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes sea slug (ssl), sea urchin (su), and brittle star (bs). Distance between lasers (red dots) is 15 cm.

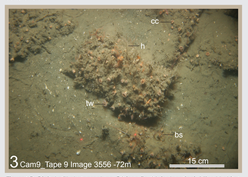


Figure 2D. Digital still photograph no. B3 (see fig. 2A for location). Mixed habitat of mud and boulders on edge of rocky area (water depth, 72 m). Abiotic complexity is low, biotic complexity is absent, and biocover is moderate. Biocover includes cup coral (cc), hydroid (h), tubeworm (tw), and brittle star (bs). Distance between lasers (red dots) is 15 cm.

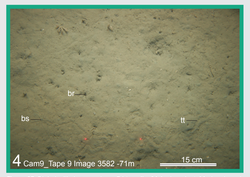


Figure 2E. Digital still photograph no. B4 (see fig. 2A for location). Mud and sand (water depth, 71 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br), brittle star (bs), and trails (tt). Distance between lasers (red dots) is 15 cm.

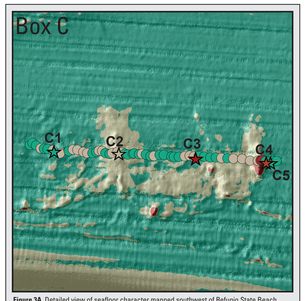


Figure 3A. Detailed view of seafloor character mapped southwest of Refugio State Beach, approximately 4.5 km offshore (see Box C, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 3B through 3F) from camera line CAM14, cruise S–1C–08–SC.

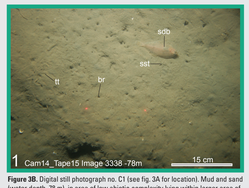


Figure 3B. Digital still photograph no. C1 (see fig. 3A for location). Mud and sand (water depth, 78 m), in area of low abiotic complexity lying within larger area of highly deformed sedimentary rocks (outside of image area) that has high abiotic complexity. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br); Pacific sanddab, *Citharichthys sordidus* (sdb); sea star (sst); and trails (tt). Distance between lasers (red dots) is 15 cm.

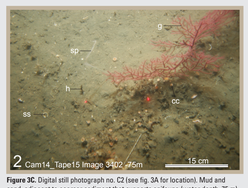


Figure 3C. Digital still photograph no. C2 (see fig. 3A for location). Mud and sand, adjacent to coarser sediment that supports epifauna (water depth, 75 m). Abiotic complexity is low, biotic complexity is present, and biocover is moderate. Biocover includes cup corals (cc); hydroid (h); scattered shells (ss); tall sea pen, *Halipteris* spp. (sp); and gorgonian (g). Distance between lasers (red dots) is 15 cm.

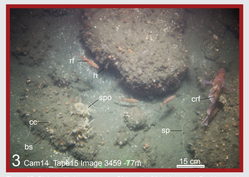


Figure 3D. Digital still photograph no. C3 (see fig. 3A for location). Boulders and cobbles, surrounded by mud and shells (water depth, 77 m). Abiotic complexity is low, biotic complexity is absent, and biocover is high. Biocover includes sponge (spo); halfbanded rockfish, *Sebastes semicinctus* (rf); copper rockfish, *Sebastes caurinus* (crf); tall sea pen, *Halipteris* spp. (sp); brittle star (bs); cup coral (cc); and hydroid (h). Distance between lasers (green dots) is 15 cm.

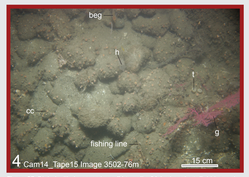


Figure 3E. Digital still photograph no. C4 (see fig. 3A for location). Cobbles and gravel, with sand and shells in interstices (water depth, 76 m). Abiotic complexity is low, biotic complexity is present, and biocover is moderate. Biocover includes cup coral (ccc), gorgonian (g), hydroid (h), tunicates (t), and blackeye goby (beg). Anthropogenic material includes fishing line. Distance between lasers (red dots) is 15 cm.

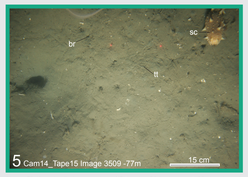


Figure 3F. Digital still photograph no. C5 (see fig. 3A for location). Mud and sand, with scattered shells, adjacent to rocky outcrop (water depth, 77 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br), sea cucumber (scc), and trails (tt). Distance between lasers (red dots) is 15 cm.

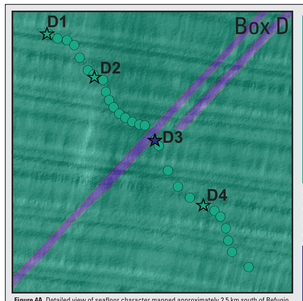


Figure 4A. Detailed view of seafloor character mapped approximately 2.5 km south of Refugio State Beach (see Box D, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 4B through 4E) from camera line CAM46, cruise S–1C–08–SC.

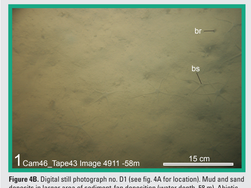


Figure 4B. Digital still photograph no. D1 (see fig. 4A for location). Mud and sand deposits in larger area of sediment-fan deposition (water depth, 58 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br) and brittle star (bs). Distance between lasers (green dots are just out of view in this image but are visible in previous video frame) is 15 cm.

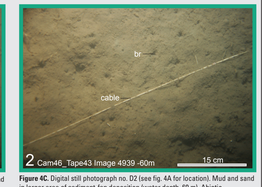


Figure 4C. Digital still photograph no. D2 (see fig. 4A for location). Mud and sand in larger area of sediment-fan deposition (water depth, 60 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br). Anthropogenic material includes cable. Distance between lasers (green dots are just out of view in this image but are visible in previous video frame) is 15 cm.

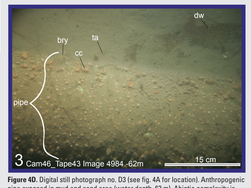


Figure 4D. Digital still photograph no. D3 (see fig. 4A for location). Anthropogenic pipe exposed in mud and sand area (water depth, 62 m). Abiotic complexity is low, biotic complexity is absent, and biocover is high. Biocover includes cup coral (cc), bryozoan (bry), tube anemone (ta), and drift weed (dw). Distance between lasers (green dots) is 15 cm.

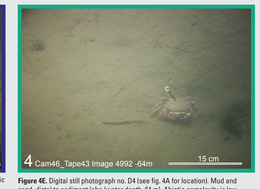


Figure 4E. Digital still photograph no. D4 (see fig. 4A for location). Mud and sand, distal to sediment lobe (water depth, 64 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes crab (c). Distance between lasers (green dots are just out of view in this image but are visible in previous video frame) is 15 cm.

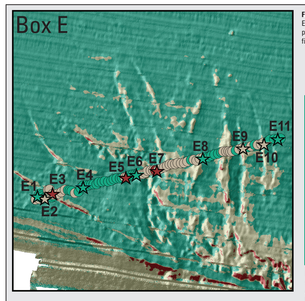


Figure 5A. Detailed view of seafloor character mapped approximately 6 km south of El Capitan State Beach (see Box E, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 5B through 5L) from camera line CAM12, cruise S–1C–08–SC.

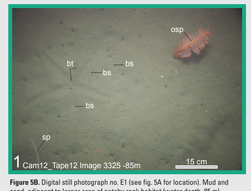


Figure 5B. Digital still photograph no. E1 (see fig. 5A for location). Mud and sand, adjacent to larger area of patchy rock habitat (water depth, 85 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes body trace (bt); orange sea pen, *Ptilosarcus gurneyi* (osp); tall sea pen, *Halipteris* spp. (sp); and brittle star (bs). Distance between lasers (red dots) is 15 cm.

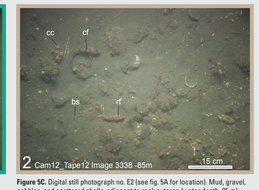


Figure 5C. Digital still photograph no. E2 (see fig. 5A for location). Mud, gravel, cobbles, and scattered shells, adjacent to rock outcrop (water depth, 85 m). Abiotic complexity is low, biotic complexity is absent, and biocover is moderate. Biocover includes halfbanded rockfish, *Sebastes semicinctus* (rf); cornflish (cf); cup coral (cc); and brittle star (bs). Distance between lasers (red dots) is 15 cm.

Figure 5D. Digital still photograph no. E3 (see fig. 5A for location). Rock outcrop (water depth, 85 m). Abiotic complexity is low, biotic complexity is present, and biocover is high. Biocover includes halfbanded rockfish, *Sebastes semicinctus* (rf); gorgonian (g); cup coral (ccc); tubeworm (tw); hydroid (h); and sea star (sst). Distance between lasers (green dots) is 15 cm.

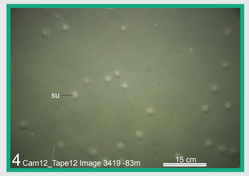


Figure 5E. Digital still photograph no. E4 (see fig. 5A for location). Unconsolidated sand and mud (water depth, 83 m). Abiotic complexity is low, biotic complexity is absent, and biocover is moderate. Biocover includes sea urchin (su). Distance between lasers (red dots) is 15 cm.

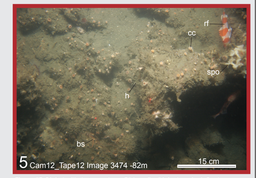


Figure 5F. Digital still photograph no. E5 (see fig. 5A for location). Rock outcrop (water depth, 82 m). Abiotic complexity is moderate, biotic complexity is absent, and biocover is high. Biocover includes cup coral (cc); flag rockfish, *Sebastes rubrivinctus* (rf); brittle star (bs); sponge (spo); and hydroid (h). Distance between lasers (red dots) is 15 cm.

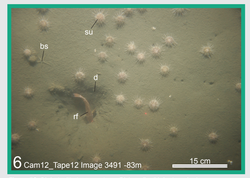


Figure 5G. Digital still photograph no. E6 (see fig. 5A for location). Unconsolidated mud and sand (water depth, 83 m). Abiotic complexity is low, biotic complexity is absent, and biocover is high. Biocover includes sea urchin (su); greenstriped rockfish, *Sebastes elongatus* (rf); and brittle star (bs). Also labeled on photograph is depression (d). Distance between lasers (red dots) is 15 cm.

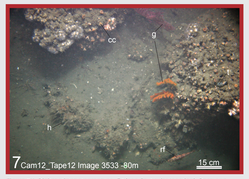


Figure 5H. Digital still photograph no. E7 (see fig. 5A for location). Rock and interstitial sediment, with scattered shells (water depth, 80 m). Abiotic complexity is moderate, biotic complexity is present, and biocover is high. Biocover includes gorgonian (g); halfbanded rockfish, *Sebastes semicinctus* (rf); cup coral (cc); tunicate (t); and hydroid (h). Distance between lasers (green dots) is 15 cm.

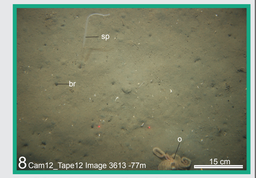


Figure 5I. Digital still photograph no. E8 (see fig. 5A for location). Unconsolidated mud and sand (water depth, 77 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br); octopus (o); and tall sea pen, *Halipteris* spp. (sp). Distance between lasers (red dots) is 15 cm.

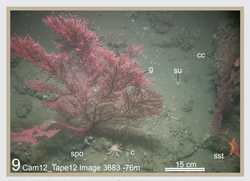


Figure 5J. Digital still photograph no. E9 (see fig. 5A for location). Mud and cobbles, with scattered shells (water depth, 76 m). Abiotic complexity is low, biotic complexity is present, and biocover is high. Biocover includes crab (c), sea star (sst), gorgonian (g), cup coral (ccc), sea urchin (su), and sponge (spo). Distance between lasers (red dots) is 15 cm.

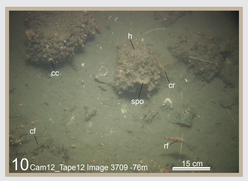


Figure 5K. Digital still photograph no. E10 (see fig. 5A for location). Mud and cobbles, with scattered shells (water depth, 76 m). Abiotic complexity is low, biotic complexity is absent, and biocover is moderate. Biocover includes halfbanded rockfish, *Sebastes semicinctus* (rf); cornfish (cf); crinoid (cr); cup coral (cc); hydroid (h); and sponge (spo). Distance between lasers (red dots) is 15 cm.

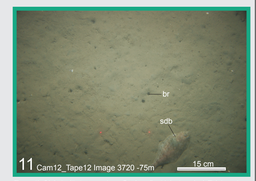
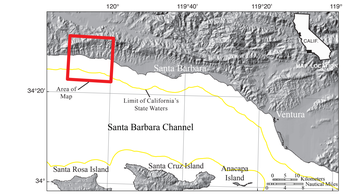


Figure 5L. Digital still photograph no. E11 (see fig. 5A for location). Thick mud and sand, at periphery of patchy rock area (water depth, 75 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Biocover includes burrows (br) and Pacific sanddab, *Citharichthys sordidus* (sdb). Distance between lasers (red dots) is 15 cm.



DISCUSSION

In 2008, the seafloor of the Offshore of Refugio Beach map area in southern California was mapped by the U.S. Geological Survey (USGS), using bathymetric sidescan sonar (see sheets 1, 2, 3). This mapping mission collected bathymetry and acoustic-backscatter data from about the 10-m isobath to out beyond the 3-nautical-mile limit of California's State Waters. In order to characterize the bathymetry and acoustic-backscatter data into geologically and biologically useful information, the USGS ground-truth-surveyed the data by towing camera sleds (fig. 6) over specific locations throughout the map area.

The ground-truth survey occurred over several weeks in 2008. The camera sled was towed 1 to 2 m above the seafloor, at speeds of between 1 and 2 nautical miles/hour. During the ground-truth cruise, a camera sled was used that housed two standard-definition (640×480 pixel resolution) video cameras (one forward looking, the other downward looking), a high-definition (1,080×1,920 pixel resolution) video camera, and an 8-megapixel digital still camera that captured a digital still photograph once every 30 seconds. The video was relayed in real time to the research vessel, where USGS and National Oceanic and Atmospheric Administration (NOAA) scientists recorded both the geologic and biologic character of the seafloor once every minute, using programmable keypads. The location and directions of the camera-sled tracklines were chosen in order to visually inspect areas thought to represent the full range of bottom hardness and rugosity in the map area.

In the context of marine-fisheries management, benthic-habitat complexity can be divided into abiotic (geologic) and biotic (biologic) components. Benthic-habitat complexity refers to the visual classification of local abiotic and biotic vertical relief and structure that may provide potential refuge for both juvenile and adult forms of various species (Tissot and others, 2006). Only abiotic attributes (primary- and secondary-substrate composition) were used in the production of the seafloor-character map on sheet 5. Classifications of primary and secondary substrate are based on the Wentworth (1922) scale of sediment grain-size categories, and the sand, cobble, and boulder sizes are classified as in Wentworth (1922). However, the difficultly in distinguishing the finest division in the Wentworth (1922) scale during video observations made it necessary to aggregate some grain-size classes: the granule and pebble sizes have been grouped together into a class called "gravel," and the clay and silt sizes have been grouped into a class called "mud." In addition, hard bottom and clasts larger than boulder size are classified as "rock." Primary and secondary substrate, by definition, constitute greater than 50 and 20 percent of the seafloor during an observation, respectively.

This sheet contains a smaller, simplified (depth-zone symbology has been removed) version of the seafloor-character map (sheet 5), on which the camera-sled tracklines used to ground-truth-survey the sonar data are indicated by aligned colored dots, each dot representing the location of a recorded observation. Primary- and secondary-substrate compositions are shown by differently colored dots. The map also shows the locations of the detailed views of seafloor character along some of the tracklines (Boxes A through E) that are highlighted on this sheet (figs. 1A, 2A, 3A, 4A, 5A, respectively). Also shown are locations of samples (triangles) from usSEABED (Reid and others, 2006) and by Barnard and others (2009) that were used to supplement the ground-truth surveys. The seafloor-character map shows that this area is predominantly covered by sediment, but it also includes with two areas of low-relief rock outcrops towards the edge of the shelf. The more rugose rock outcrops are surrounded by areas of either mixed rock and sediment or flat rock outcrops.

Each detailed view (figs. 1A, 2A, 3A, 4A, 5A) shows the locations of camera-sled tracklines (aligned colored dots), as well as of the photographs (colored stars) taken along the tracklines. These photographs, which are representative of the seafloor, are displayed with a description of the observed seafloor characteristics recorded by USGS and NOAA scientists (figs. 1B, 1C; 2B through 2E; 3B through 3F; 4B through 4E; 5B through 5L). Only primary and secondary substrates are reported, although individual photographs may show more substrate types. Organisms, when present, are labeled on the photographs.

Ground-truth surveys in the Offshore of Refugio Beach map area include approximately 7.85 trackline kilometers of video and 838 still photographs, in addition to 457 seafloor observations of abiotic and biotic attributes. A visual estimate of slope also was recorded.

GLOSSARY

Rugosity—A GIS-derived characterization of seafloor roughness, calculated as the ratio of the three-dimensional surface area of seafloor to the two-dimensional planar-base area, for each cell in the bathymetry grid.

Backscatter intensity—The amplitude of the reflected sonar signal (see sheet 3) used to infer the hardness of the bottom, determined after sonar-data processing has removed (as much as possible) the effects of water depth, angle of reflection, and bottom roughness.

Biocomplexity—The assessment of the presence or absence of biological structures that have the potential of providing shelter for fauna, determined by estimating the scale, the amount, and the morphology of biological relief (as described by Tissot and others, 2006).

Biocover—The visual estimate of the proportion of biologic cover by encrusting organisms: high, greater than 50 percent; moderate, between 50 percent and 10 percent; low, less than 10 percent.

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EXPLANATION

Substrate class

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Anthropogenic material**—Related to development by humans

Location of real-time video observation and interpreted substrate class of seafloor

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock

Location of digital still photograph and interpreted substrate class of seafloor

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Anthropogenic material**—Related to development by humans

Interpreted substrate class depicted in digital still photograph—Indicated by colored frame around photograph (not shown on map; shown in figures only)

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Anthropogenic material**—Related to development by humans

Sample localities

- **From usSEABED (Reid and others, 2006)**
- **From Barnard and others (2009)**
- **Area of "no data"**—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data; areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program
- **3-nautical-mile limit of California's State Waters**

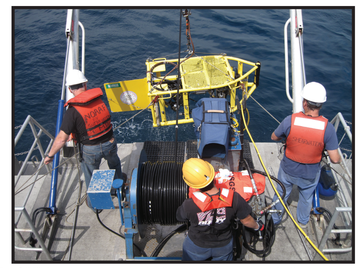

Figure 6. USGS-designed camera sled being launched off research vessel for ground-truth studies. Components onboard sled include four digital video camcorders, one 8-megapixel digital SLR camera, lasers for scale, and various strobes and video lights, as well as telemetry instrumentation that records depth, altitude, and compass heading.

Ground-Truth Studies, Offshore of Refugio Beach Map Area, California

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