Deep-sea corals and resource protection at the Davidson Seamount, California, U.S.A.

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Abstract. The Davidson Seamount is located 120 km to the southwest of Monterey, along the California coast, USA. It is 2,400 m tall; yet, it is still 1,250 m below the sea surface. In May 2002, 90 hours of digital video was recorded from all depths of the Davidson Seamount, using a remotely operated vehicle, and deep-sea coral specimens were collected. Preliminary analyses indicate that 20 coral taxa were found, and they were almost exclusively located in high relief, ridge areas. Other species were noted on or adjacent to the corals. Because of its pristine nature, as well as human threats and great potential for education, the Davidson Seamount is under consideration for protection as part of the Monterey Bay National Marine Sanctuary.

Keywords: Davidson Seamount, resource protection, coral distribution, habitat, education, *Paragorgia*

Introduction

With recent advances in technology, the description of deep-sea coral communities is a growing subject (Genin et al. 1986; Malakoff 2003). In addition, a sense of urgency has developed for this work because of human impacts to these corals [e.g., from deep sea fisheries (Koslow et al. 2000; Roberts and Hirshfield 2003)] and their

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slow recovery rates (Andrews et al. 2002). Moreover, these corals may provide essential fish habitat and a structural base for some deep-sea species assemblages (e.g., Husebø et al. 2002). Seamounts are one important habitat for deep-sea corals, and they also have a high degree of endemism of all species associated with them (de Forges et al. 2000). The taxonomy of deep-sea corals is challenging, as there are still relatively few scientific collections or high quality, *in situ* images of the corals. The body of literature on deep-sea coral ecology is growing, and the natural cause of some distribution patterns has been related to substratum type and currents (e.g., Genin et al. 1986). Our interest was in the deep-sea corals of the Davidson Seamount, including the assessment of: the distribution and abundance of species, a description of their associated fauna, and the need for resource protection. A related project, not addressed here, was to involve the public, through a range of outreach techniques and education materials, in a multidisciplinary exploration of the Davidson Seamount (NOAA 2002; DeVogelaere et al. in press).

Methods

Study site

Davidson Seamount is located 120 km to the southwest of Monterey and is one of the largest known seamounts along the Western United States (Fig. 1). It is 42 km long and 13.5 km wide. From base to crest, Davidson Seamount is 2,400 m tall; yet, it is still 1,250 m below the sea surface. Davidson Seamount has an atypical seamount shape, having northeast-trending ridges created by a type of volcanism only recently described (Davis et al. 2002); it last erupted about 12 million years ago. Davidson Seamount was first surveyed in 1933 by the United States Coast and Geodectic Survey (a forerunner of the National Ocean Service of the National Oceanic and Atmospheric Administration). This large geographic feature was the first to be characterized as a "seamount" in 1938 by the United States Board on Geographic Names, and was named in honor of the United States Coast and Geodectic Survey scientist George Davidson (1825-1911), a leader in charting the waters of the west coast (Davidson Seamount 1990).

Transects and collections

It is only with recent technological advances that we can effectively access the Davidson Seamount. The Monterey Bay Aquarium Research Institute (MBARI) has developed innovative remotely operated vehicle (ROV) technology to record images and collect organisms from the deep sea. In May 2002, we used the unmanned ROV, *Tiburon*, a state-of-the-art platform for exploring the deep sea to depths of 4,000 meters. The vehicle is equipped with cameras, lights, manipulator arms, accurate positioning systems, and *in situ* pressure, temperature, dissolved oxygen, and conductivity sensors. ROV dives were selected to include all depths and habitats (base, flank, and crest) of the seamount with the available ship time. Six full-day dives were completed: two dives were conducted from base to crest on either side of the seamount (to include all depths and representative habitats); and four dives were conducted at the seamount crest, along ridges, or at deeper cones (to focus on the most diverse and interesting habitats relative to corals). To document habitat

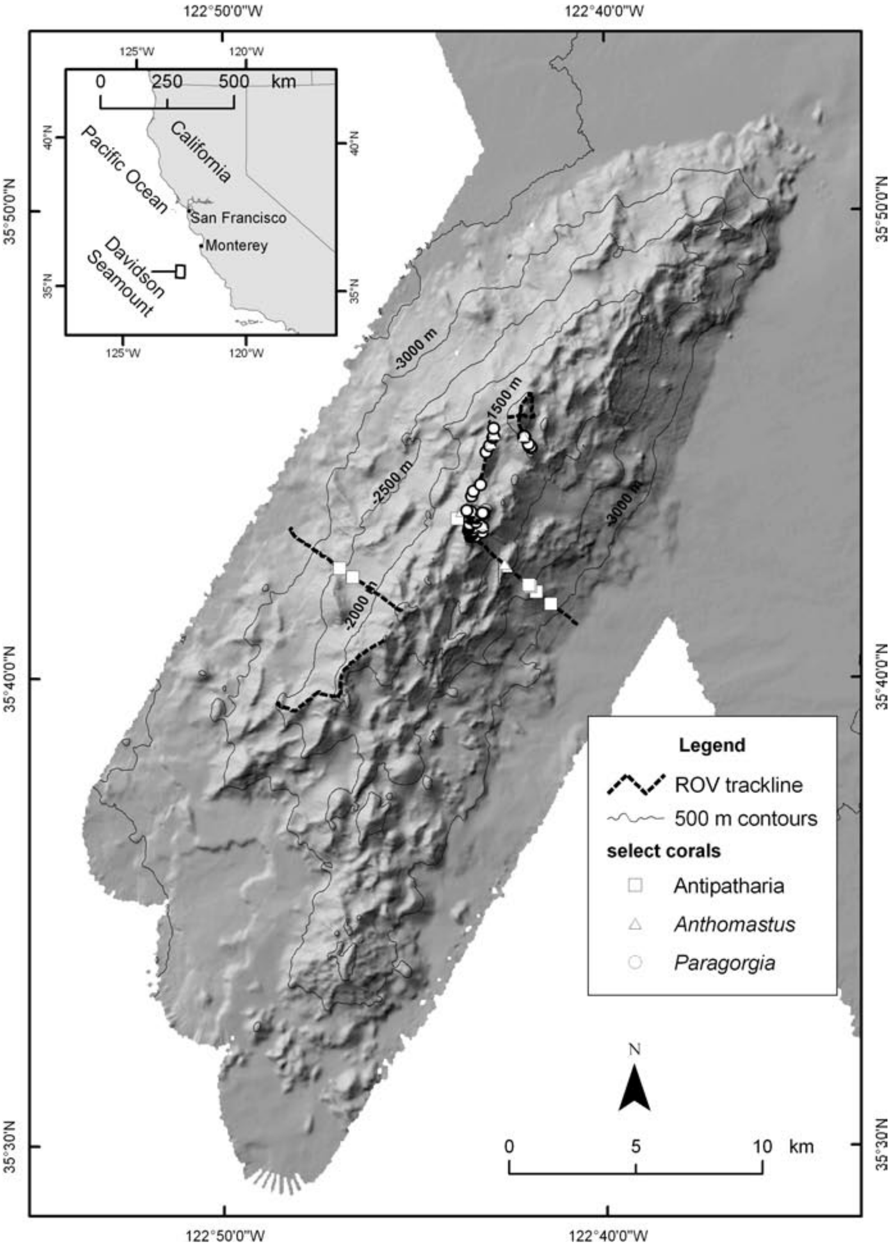


Fig. 1 Observed distribution of three corals during May 2002 Davidson Seamount Exploration using ROV *Tiburon*. Bathymetric data derived from Monterey Bay Multibeam Survey (MBARI 2000)

and species occurrence at the Davidson Seamount, 90 hours of digital video was continuously recorded from all seamount depths (Fig. 1), supplemented by high-quality digital still images during periods of intense observation. Moreover, during each ROV dive, video frame grabs were recorded and annotated on-board using MBARI's computer video annotation program. Following the cruise, preliminary frame grab annotations were refined and edited at MBARI's Video Lab. Animals captured on the videotapes were identified as accurately as possible, although it was often the case that species names were not known. In some cases, images (and tissue samples, if collected) of the unknown animals were provided to taxonomic experts to determine whether the animals could be identified or described. Cup coral (Scleractinia) were observed, but not counted in this analysis.

Analyses

All corals were classified into taxa and given a descriptive name. The frequency of each taxon, excluding cup corals, was estimated by reviewing 2,507 digital frame grabs taken throughout the cruise, selecting those which were annotated as having coral species present, and subtracting frame grabs with multiple images of the same individual. This estimate of coral frequency using frame grabs is an underestimate, because not all corals seen throughout the dive transects received a frame grab, especially if they were small and very numerous in one location. Moreover, there were many individuals of some coral taxa in a single frame grab. The depth at which each frame grab was taken was used to develop an observed depth range for each taxon. Finally, to determine species associations with corals, each frame grab was analyzed for the presence of species either on or adjacent to the corals.

Topographic Position Index (TPI) was used to characterize ROV transects and the entire Davidson Seamount "landscape" into categories of ridges, valleys, and slopes. TPI is a quantification of how deep a given location is, relative to its surrounding area. The TPI algorithm used in this study was adapted from Weiss (2002). Multibeam sonar data were used in the TPI analyses (MBARI 2000; 40 x 40 m resolution). TPI was calculated by subtracting the mean depth of an area of 25 x 25 cells (1 km^2) from the depth of the cell in the center of that area. This process was automated for all 280,613 cells of bathymetric data surrounding the Davidson Seamount. This neighborhood size was chosen arbitrarily as optimal for resolution of valleys and ridges. There is no quantitative guide for neighborhood size selection; a larger neighborhood will not reveal ridges and valleys on the seamount, while a smaller neighborhood tends to mask overall morphological features of the seamount. Resulting negative values represent areas below the average depth of the surrounding areas (valleys), while positive values represent areas above (ridges). Flat plains and slopes are values around zero. In our graphic representation of the seamount "landscape" (Fig. 2), we classified a TPI range to three topographic layers, based on the Jenks optimization method (Minami 2000) to represent valleys (-130 to -29), slopes and flat areas (-30 to 49), and ridges (50 to 196). TPI analyses were performed with GIS software (ArcMap 8.1 and Spatial Analyst, copyright Environmental Systems Research Institute). Position data from ROV transects and from each coral sighting were assigned a geospatially corresponding TPI value and mapped (Figure 2).

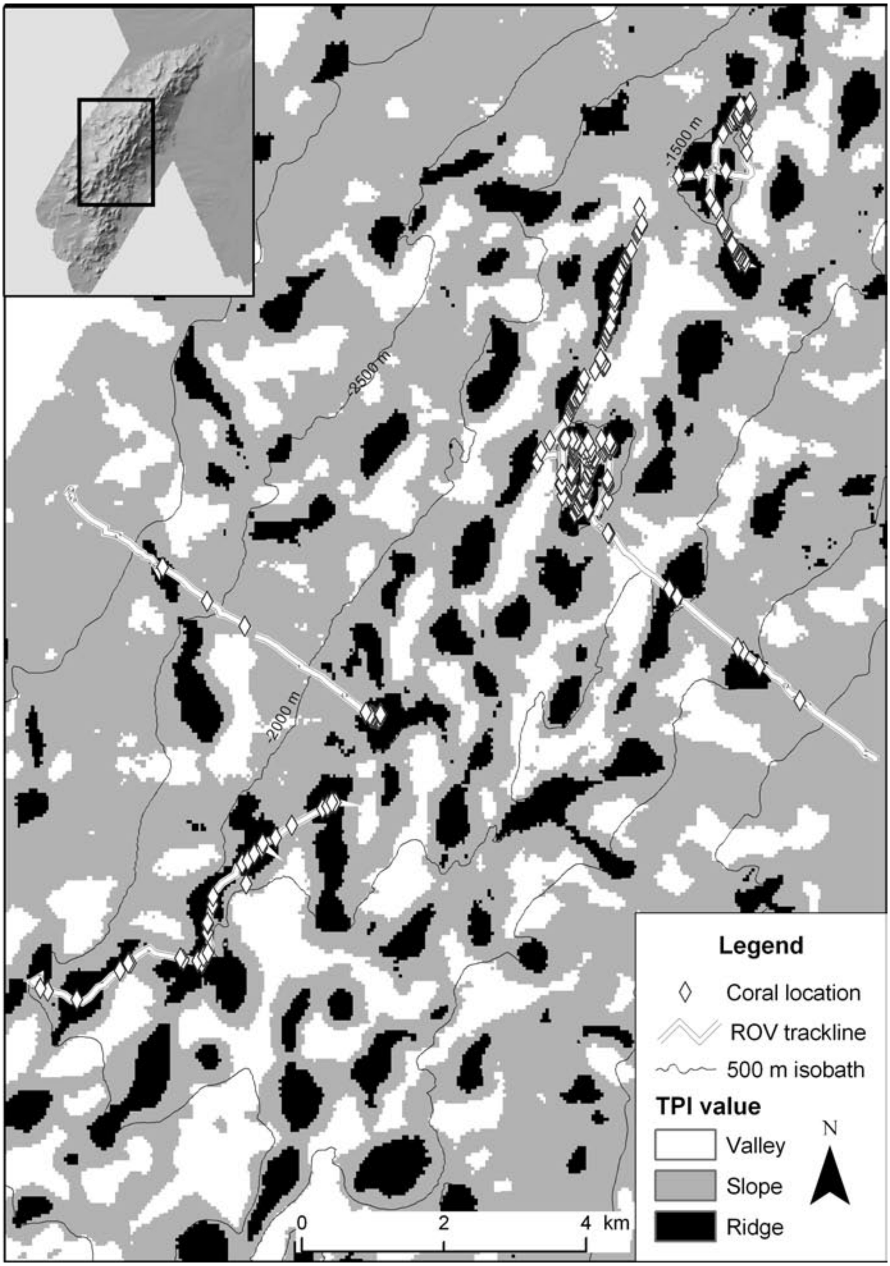


Fig. 2 Topographic Position Index (TPI) characterizing ROV transects and coral distribution at the Davidson Seamount

Results

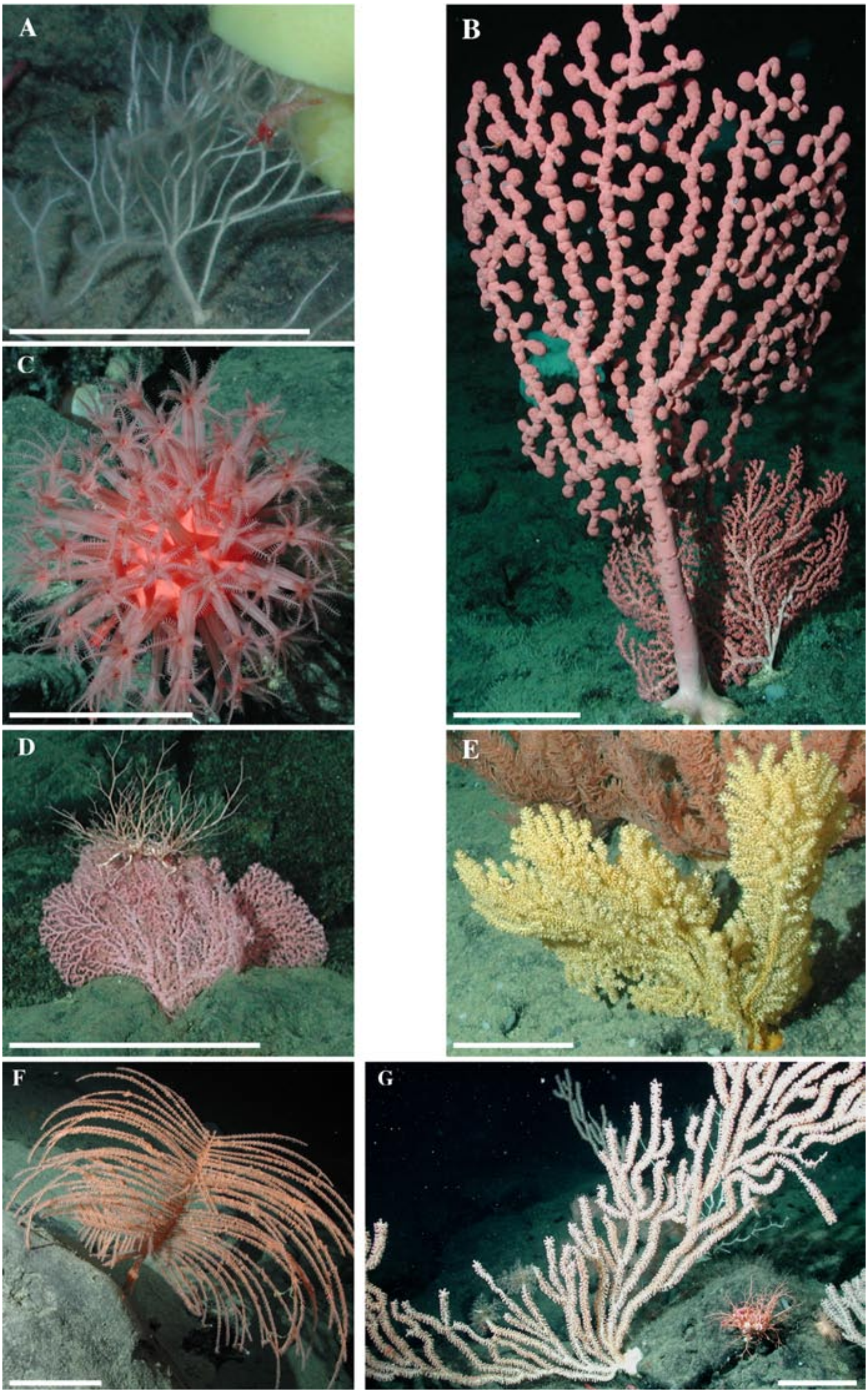
A total of 20 deep-sea coral taxa were seen during 90 hrs of diving on the Davidson Seamount (Table 1; Fig. 3). During the 6 dives, the ROV traversed a bottom distance of 43,537 linear meters. Of the total distance traveled, 56 % of the distance was traversed on ridges, 41 % on slope and flat areas, and 3 % in valleys. While many of the corals have yet to be conclusively identified, we have specimen collections of 12 taxa and high-resolution images of all of them. The depth range of the corals was from 2,846 m to the top of the seamount at 1,248 m. Frequently observed *Paragorgia* sp. were the most dramatic coral in their size (>2 x 2 meters in height and width) and their extensive "forests" along several ridges at the top of the

Table 1 Corals of the Davidson Seamount, with frequency of framegrabs with taxa present (F), depth range observed, and topographic position index (TPI). The cup coral was not analyzed (NA) because it was not originally identified as a coral

Order / Genus	Descriptive Name	F	Depth (m)	Mean TPI (± SE)
*Unknown	White Coral 1	89	1296-1935	99 ± 33
*Alcyonacea / *Paragorgia*	Bubblegum Coral	79	1248-1743	94 ± 6
*Alcyonacea / *Corallium* [a]	Small Pink Coral 1	58	1357-2447	89 ± 7
*Unknown	Orange Bottlebrush Coral	35	1345-2254	74 ± 9
*Alcyonacea / *Keratoisis* [b]	Bamboo Coral	28	1374-1707	66 ± 6
Alcyonacea / *Anthomastus*	Mushroom Soft Coral	23	1307-1927	77 ± 12
*Unknown	Gold Coral	21	1374-2073	71 ± 7
Unknown	White Coral 2	14	1496-1690	44 ± 15
Unknown	Small Yellow Coral	11	1325-1840	100 ± 13
Unknown	Orange Bottle-bushy Coral	8	1880-2056	105 ± 21
*Unknown	Orange Bushy Coral	7	1953-2320	83 ± 14
*Antipatharia / unknown	Black Coral	7	1336-2846	38 ± 16
*Unknown	Big White Coral	6	1374-1904	38 ± 23
*Unknown	Small Red Coral	2	1346-1352	84 ± 10
Unknown	Small Pink Coral 2	2	1493-1524	79 ± 4
Unknown	Carpet Coral	2	1511-1779	126 ± 2
Unknown	Leaning Tower of Coral	2	1950-1973	88 ± 13
Unknown	White Coral 3	1	2710	78 ± 0
*Unknown	Glassy Coral	1	2486	61 ± 0
*Scleractinia / unknown	Cup Coral	NA	NA	NA

* Specimen collected
[a] One collection identified as *Corallium*
[b] One collection identified as *Keratoisis*

Fig. 3 Several coral taxa observed at the Davidson Seamount. **A** White coral 1. **B** Bubblegum coral (*Paragorgia* sp.). **C** Mushroom soft coral (*Anthomastus* sp.). **D** Small pink coral 1 (*Corallium* sp.). **E** Gold coral. **F** Black coral (Antipatharian). **G** Bamboo coral (*Keratoisis* sp.). Scale bar = 15 cm


A
B
C
D
E
F
G

seamount, but other species were also abundant. While regular observations of trash (bottles, cans, fabric, paper, etc.) were made on the seamount, the area appeared pristine as there was no damage to large fragile corals and no indication of direct human disturbance from trawling or other collecting.

A clear pattern in the distribution of the corals was that they were almost exclusively on ridge areas (Table 1; Fig. 2). Some genera were found exclusively on ridges at the top of the seamount (e.g., *Paragorgia*), while others (e.g., *Anthomastus*) were found on shallow and deeper water ridges developed from promontories along the sides of the seamount (Fig. 1). Black coral, order Antipatharia, had one of the lowest TPI values, but its positive value still indicates association to areas with topographic relief.

With the exception of *Anthomastus*, all of the deep-sea corals had other obvious megafauna associated with them. Living on the corals were polychaete worms, isopods, shrimps, crabs, basket stars, crinoids, brittle stars, and anemones. Present adjacent to corals were rattails (*Coryphaenoides* sp.), thornyheads (*Sebastolobus* sp.), sponges, other corals, seastars, clams, sea cucumbers, and octopi (*Graneledone* sp.). Invariably, as the ROV transects reached the highest crests of the seamount, diversity of corals and associated species increased dramatically. The organisms were often visibly oriented to maximize surface area towards the current.

Discussion

The Davidson Seamount is populated by a diversity of deep-sea corals, most of which have other species associated with them. *Paragorgia* sp. was abundant, forming dense and expansive patches. An unidentified blue polychaete (scale worm) was present in large numbers on almost all of the *Paragorgia* sp. corals. Similar associations were observed on seamounts in the Gulf of Alaska (pers. comm. Amy Baco, Woods Hole Oceanographic Institute). While most of the corals were found at the highest peak areas of the seamount, others were found deeper, and still, almost exclusively on ridge formations. The cause of this pattern is possibly higher current velocities and less sediment deposition, enhancing food availability and minimizing the smothering of new recruits (e.g., Genin et al. 1986).

The Davidson Seamount is a relatively pristine area with coral abundance and diversity. However, many of the species are large and fragile to physical disturbance, and some individuals may be hundreds of years old (Andrews et al. 2005). Trawling has been achieved at depths as deep as the Davidson Seamount (Koslow et al. 2000; Koslow et al. 2001), and there is potential for bioprospecting for medicinal chemistry of these corals. The high degree of endemism on seamounts argues for regional protection of this type of habitat. For these reasons, and the great potential for public education on seamounts and deep-sea corals, the Monterey Bay National Marine Sanctuary (MBNMS) is formally assessing the option of providing National Marine Sanctuary status to the Davidson Seamount. In August 2003, the MBNMS Sanctuary Advisory Council unanimously voted to agree with a working group initial finding that the Davidson Seamount meets Sanctuary designation standards. This opinion was developed by scientists, educators, marine policy experts, marine resource managers, conservation interests, and fishermen; however, fishing organizations currently oppose designation because it may lead to future regulations on fishing. Sanctuary designation documents are currently being drafted and will include proposed: limited collection deeper than 915 m (currently all commercial fishing occurs at depths shallower than 50 m in this area); increased physical and biological characterization of the area; development of a monitoring program for the seamount; resource protection and regulation plans; and development of education materials at local and national levels. Currently, there are no government education programs broadly focusing on seamount biology and conservation in the United States. A draft management plan for the Davidson Seamount, and the entire MBNMS, will be available for public comment in mid 2005, with a final decision expected in 2006 (NOAA 2002).

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