ABUNDANCE AND DISTRIBUTION OF STRUCTURE-FORMING INVERTEBRATES AND THEIR ASSOCIATION WITH FISHES AT THE CHANNEL ISLANDS "FOOTPRINT" OFF THE SOUTHERN COAST OF CALIFORNIA

By

JENNIFER L. BRIGHT

A thesis submitted as partial fulfillment
of the requirements for the degree of

Master of Science in Earth and Environmental Science

WASHINGTON STATE UNIVERSITY
School of Earth and Environmental Science

December 2007

To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation/thesis of JENNIFER L. BRIGHT find it satisfactory and recommend that it be accepted.

____
Chair

____

____

ACKNOWLEDGEMENTS

I thank my advisor Dr. Brian N. Tissot for guidance, encouragement, patience, leadership and support throughout all stages of this project. This study would not have been possible without the assistance of Dr. Milton Love and his team Linda Snook, Donna Schroeder, Mary Yoklavich, Mary Nishaimoto, and M. McRea. Thanks to Dr. Milton Love for bringing me on the research cruise in 2005, sharing his abundant knowledge of the Footprint and participating on my graduate committee; the National Undersea Research Program (West Coast Polar Region), NOAA Habitat Conservation and Washington State University Vancouver for funding support; Dr. Gretchen Rollwagen-Bollens for participating on my graduate committee and reviewing this thesis. Thanks to the crew of Delta and the R.V. Velero for making these surveys possible; the Benthic Ecology Lab and especially Kaitlin Graiff for assisting with invertebrate and fish counts, encouragement and helpful comments; David Banis for GIS advice and assistance; Maria Schenk for Microsoft Access support; Dr. Steve Sylvester for encouragement and advice; Brie Aliabadi for her lighthearted encouragement and helpful draft review; Sherry Swayze, Bob Blackman and Sean Lyons for administrative assistance. A special thanks to my son Jason Kuchar who has been my most loving and encouraging supporter and served as an excellent role model for me to follow; Friends Carol Scheel and Barbara Bray for their unending encouragement; my mother for her encouragement as long as she was able to provide it while suffering from the affects of Alzheimer’s disease.

TABLE OF CONTENTS

ABUNDANCE AND DISTRIBUTION OF STRUCTURE-FORMING INVERTEBRATES AND THEIR ASSOCIATION WITH FISHES AT THE CHANNEL ISLANDS "FOOTPRINT" OFF THE SOUTHERN COAST OF CALIFORNIA

Abstract

by Jennifer L. Bright, M.S.
Washington State University
December 2007

Chair: Brian N. Tissot

The Footprint is a submerged rock ridge located on the edge of the continental shelf in the southern Anacapa Passage within the boundaries of the Channel Islands National Marine Sanctuary. The area supports a wide diversity of marine life that is commercially, recreationally and intrinsically valuable including a rich and diverse group of megafaunal benthic invertebrates. The Footprint is a high-relief rock ridge at 150-350 m depths and is an important habitat for many demersal fishes previously open to many types of fishing activities. The feature is now part of a federal marine protected area. In the past this area has provided large numbers of groundfishes, especially rockfishes of the genus *Sebastes*, for both commercial and recreational fishers.

Underwater surveys were conducted by direct observations using the two-person occupied research submersible *Delta;* a total of 28 dives were conducted between 1995-2004 at depths from 97-314 meters. Physical habitat types were categorized and direct counts of

megafaunal invertebrates and fishes were determined from analyzing videotaped transects from the submersible.

Megafaunal invertebrate observations totaled 90,307 individuals from 53 taxa representing 7 phyla and varied in abundance across habitat types. Structure-forming invertebrates, megafaunal invertebrates ≥ 20 cm, were classified using the characteristics of large size, complex morphology, or the ability to form high density aggregations. Structure-forming invertebrates include black corals, fan corals, gorgonian corals, crinoids, a diverse group of sponges, and sea anemones.

Associations between fishes and structure-forming invertebrates were described using four categories measuring the degree of association. Observed associations were distinguished by close proximity of several fish species to structure-forming invertebrates. Several species of fish co-occurred with structure-forming invertebrates. Smaller rockfishes were more abundant and occurred at higher densities with structure forming invertebrates. The extent of fish-invertebrate associations may depend on the availability of an underlying geologic framework where there are few small-scale shelter crevices for fish. Considering the unique geologic feature and the negative impacts from commercial and recreational fisheries in the area, this site is a good candidate for further protection of the invertebrates and fishes found at the Footprint.

List of Tables   Page

List of Figures Page

Introduction

Much of the world's fish populations are experiencing overexploitation and degradation to the ecosystems that sustain them. For decades, dramatic declines in several groundfish populations have occurred along the U.S. West Coast (Feder, 1996; Nasby-Lucas et al., 2002; Pikitch et al., 2004). Fishery management programs have often been ineffective, for they tend to focus on maximizing the catch of a single target species while ignoring habitat and other ecosystem components and interactions. A broader ecosystem perspective is essential to ensure the protection and health of habitats and the multiple dimensions of habitat, collectively, described as essential fish habitat (EFH) (Rosenberg et al., 2000).

The goals of this project were to assess the abundance, distribution and associated habitat of large-structure forming invertebrates found on the continental shelf off the west coast of southern California. Several studies have used submersibles to observe species in association with the physical habitat. These studies have reported human-caused disturbance to the habitat and associated megafaunal invertebrates living within or on the seabed, including large black corals (*Antipathes dendrochristos*) and various sponges, including foliose, vase, barrel and upright sponges (Brodeur; 2001, Freese, 2001; Krieger, 2001; Blanchard et al., 2004). The disturbed areas are characterized by an increased dominance of small, mobile, fast-growing species, and reductions in species diversity and evenness (Blanchard et al., 2004)

The Sustainable Fisheries Act has developed a mandate to identify and describe EFH for managed species, minimize adverse effects on habitats from fishing, and identify other actions to encourage the conservation, protection, and restoration of these habitats.

Suitable habitat is vital for spawning, feeding and nursery areas. Most habitats perform only a portion of these functions (Brown, 1998). Essential Fish Habitat is defined by Congress as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” The EFH implementing regulations identify “waters” as all aquatic areas and substrate which includes the associated biological communities that make these areas suitable fish habitats (Hsu and Wilen, 1997; Brown, 1998; Rosenberg et al., 2000; Berkeley et al., 2004). EFH is described by specifying those components of the ecosystem that must be present for different life history stages of a species to occur. The Act’s mandates require an end to overfishing and a significant reduction in by-catch. After the most valuable habitats have been identified, corresponding to one or more life stages or species, the information can be used to reduce adverse effects on EFH.

Management of fisheries is changing from consideration of single species toward a more holistic consideration of interactions among components of the ecosystem and through the application of adaptive management; (Botsford et al; 1997; Rosenberg et al., 2000; Peterson et al., 2000; Brodziak et al., 2002; Pikitch et al., 2004). This new approach to ecosystem-based fishery management reverses the order of management priorities, to sustain healthy marine ecosystems and the fisheries they support (Pikitch et al., 2004). Historically, fisheries scientists rarely took ecosystem approaches to management because marine ecosystems are extremely complex and difficult to sample (Botsford et al., 1997).

Currently, there is a growing concern by scientists that commercial fishing, especially bottom trawling, removes and/or damages invertebrates and their ecosystems. This concern has led to an increase in studies investigating the role of invertebrates as important components of marine ecosystems, providing critical structural habitat for groundfish (Botsford et al., 1997; Koslow et al., 2000; Freese, 2001; Tissot et al., 2004; Auster, 2005; Tissot et al., 2006). Tissot (2006) reported the ecological importance of structure-forming invertebrates on Pacific continental shelf ecosystems in southern California. These invertebrates (>5 cm in height) add structure to the seafloor due to their larger size, complex morphology and/or high density aggregations. They also contribute to biodiversity and are an important structural component of fish habitat sensitive to impacts by some fisheries.

Background

Until recently, the Footprint (Figure 1), a rocky ridge located on the edge of the continental shelf in the southern Anacapa Passage, was open to many kinds of fishing activities and in the past provided large numbers of groundfish for both commercial and recreational fishers (Schroeder and Love, 2002). Schroeder and Love (2002) studied three locations off the southern California coast and found that density of rockfish species was highest at the Footprint compared to an area open only to recreational fishing (Santa Monica Bay) and an oil and gas platform (Platform Gail), which was considered in their study to be a de facto Marine Protected Area (MPA). The Footprint had a species composition dominated by dwarf rockfish species, squarespot (*Sebastes hopkinsi*), swordspine (*Sebastes ensifer*), and pygmy (*Sebastes wilsoni*) rockfishes (Schroeder and Love, 2002). In their study, densities of larger rockfish, such as boccacio and cowcod showed contrasting results. Cowcod densities at Platform Gail were 32 times greater than at Santa Monica Bay and 8 times greater than at the Footprint. Boccacio densities at

Platform Gail were 408 fold greater than Santa Monica Bay and 18 fold greater than the Footprint (Schroeder and Love, 2002).

The Channel Islands National Marine Sanctuary (CINMS) supports a wide diversity of marine life that is commercially, recreationally and intrinsically valuable (Cochrane and Lafferty, 2002). The Footprint lies within the CINMS and is an important habitat for many rockfish species south of Anacapa Island. The Footprint, a unique geologic feature, was recently designated as a federal marine reserve (NOAA, 2007).

Of particular interest and importance in this study is the newly described black coral, *Antipathes dendrochristos*. As early as 1995 scientists conducting submersible surveys to observe rockfish populations in the southern California Bight, within the boundaries of the CINMS, observed a population of large antipatharian colonies (Opresko, 2005). These multi-branched, bushy colonies were found at depths of 150-300m and in complex rocky habitats (Tissot et al. 2006). Some colonies reached a size of 2 m or more and it was determined that the specimens represented an undescribed species that may live for 160 years or more (Love et al, 2007). Black corals can occur in various colors ranging from white, pinkish-orange, orange, red, pink, and red-brown (Aburto-Oropeza and Balart, 2001; Opresko, 2005).

New species of black corals (Antipatharian) have also been discovered in vertical environments and overhangs in Jamaica, (*A. rubusiformis,* Aburto-Oropeza and Balart, 2001; Warner and Opresko, 2004) and along the Caribbean coast of Colombia (*Aphanipathes colombiana,* Opresko and Sanchez, 1997). Studies in New Zealand (Grange, 1991) suggest a mutualism between black corals (*A. fiordensis*) and other invertebrates such as euryalinid brittle-stars (*Astrobrachion constrictum*), where the brittle stars feed at night by waving their arms through black coral colonies, picking up mucus and small prey items collected by the polyps. Deepwater corals are largely restricted to temperatures between 4^0C and 12^0C, are found below 30m (Roberts et al., 2006) and are poorly studied due to their deep habitat and scarcity (Montgomery, 2002). Cold-water black corals are important for their significant intrinsic value (Tissot et al., 2006; Thiem et al., 2006) and recent studies show that the biological diversity in cold-water coral habitats is three times higher than the surrounding habitats (Thiem et al., 2006).

Roberts and Hirshfield (2004) discussed the importance of coral and sponge species as untapped resources of natural products with potential applications in pharmaceuticals, nutritional supplements, enzymes, pesticides, cosmetics and other commercial products (Bruckner, 2002). For example, compounds found in deep sea sponges (*Discodermia* spp. and *Lissodendoryx* sp.) have been found to be potent immunosuppressive and anticancer agents (Roberts and Hirshfield, 2004). Cold-water coral reefs have frequently been observed in association with seamounts (Roberts et al., 2006). It has been suggested that cold-water coral reefs may be major speciation centers due to their species diversity, propensity to aggregate in localized circulation patterns, and their longevity. Heifetz et al. (2005) discussed that in the Aleutian Islands, corals and sponges form large groves, which may provide habitat and refuge for fish species and invertebrates.

Deepwater corals and their ecological role as potential fish habitat has only recently emerged as an area of scientific interest (Fossa et al., 2002; Tissot et al., 2004; Heifetz et al., 2005; Auster, 2005; Auster et al., 2005; Tissot et al., 2006). To better understand ecological relationships between invertebrates and demersal fishes there is a continued need to identify important habitat for supporting megafaunal invertebrates in areas like the Footprint in the CINMS. Deep rocky habitats and their megafaunal invertebrates are in the early stages of study and it is unclear whether the complete replacement of damaged or destroyed ecosystems may be possible (Love and Yoklovich, 2006).

In some areas megafaunal invertebrates and benthic habitat have been greatly degraded and or destroyed by direct effects of trawling, longlining and dredging (Peterson et al., 2000). Corals are slow growing and sensitive to disturbance, and damage caused by fishing gear such as trawling has been well documented in the United States, Canada and Norway (Freese, 2001; Krieger and Wing, 2002; Risk et al., 2002; Fossa et al., 2002; Wakefield et al., 2005; Tissot et al., 2006; Thiem et al., 2006). According to Freese (2001), invertebrates most likely to be damaged or destroyed by trawling include gorgonian corals and large sponges. Sponges provide most of the invertebrate biomass due to their large size and high population densities. In Alaska, these corals and sponges, along with boulders, account for most of substratum's three-dimensional relief (Freese, 2001).

Corals and other megafaunal invertebrates (> 5 cm) are an important component of marine ecosystem biodiversity. A diversity of taxa in this category include deep cold-water corals, sponges, crinoids, anemones, and sea pens. These invertebrates may function as a living component of habitat especially if they aggregate in high numbers or in areas where there are few refuges in the substratum (Tissot et al., 2006). Invertebrates that have the ability to form high density aggregations in association with the physical substrate include the crinoid *Florometra serratissima* and brittle stars (Ophiacanthidae). For complex morphology, invertebrates such as the black coral, gorgonians and foliose sponges were noted. Although it is unclear whether structure-forming invertebrates create additional shelter for fish and other invertebrates, Tissot et al. (2006) showed a strong relationship between benthic invertebrates, seafloor habitat and ground fish assemblages. A study by Puniwai (2002) on the Oregon continental shelf showed that the abundant crinoid species (*Florometra serratissma*) provide structural habitat and protection for juvenile rockfishes (*Sebastes spp.*).

Auster (2005) observed that characteristics of some coral sites associated with fish assemblages represent an underlying geologic framework with few small-scale shelter crevices for fishes. Husebo et al. (2002) described that redfish (*Sebastes* spp.) are often associated with wrecks off Finnmark in northern Norway. In areas where wrecks were absent they were often found in the vicinity of large sponges, often resting or hiding in their concavities or among rocky habitats that form distinct features. It is possible that physical structure encountered by fishes, such as wrecks and coral habitats, rather than the special nature of corals, is attractive to some rockfish species. Thus, the degree of interaction between groundfish and structure-forming invertebrates is unclear, and therefore warrants further study to better understand the importance of these structure-forming invertebrates and their contribution to the complexity of the habitat structure of marine ecosystems.

The overall goal of this study was to determine patterns in abundance and distribution of structure-forming invertebrates and associated physical habitat at the Footprint, with emphasis on the new species of black coral (*Antipathes dendrochristos*).

The objectives of this study were 1) to determine the patterns in abundance and distributions of megafaunal invertebrates; 2) to evaluate changes in these patterns between 1995-2004; 3) to determine if particular megafaunal invertebrates provide structure for fishes; and 4) to assess if fish are ecologically associated with these invertebrates.

Materials and Methods

Study site

The Footprint is located in the Channel Islands National Marine Sanctuary off southern California at the edge of the continental shelf (33^0 57’0” N - $33^0$58’0”N and between $119^0$28’0”W - $119^0$29’30”W) (Figure 1).

Underwater surveys were conducted by direct observations at the Footprint using the two-person occupied research submersible *Delta* between 1995-2004; dives were not made in 1996, 1997, or 2002.

Observers documented dives during daylight hours by verbally annotating video tapes while making observations on fishes and physical habitats. The submersible observation techniques were patterned after those of Stein et al. (1992), which consisted of running visual belt transects. Observers looked downward through a viewing port in the starboard side of the submersible to identify fishes and habitats. The transect was documented using an externally mounted high-8 video camera positioned above the middle viewing porthole on the starboard side of the submersible pointing down at an angle 27^0 below the horizontal. Additional digital still and video cameras were used inside the submersible to assist in documenting habitat, fishes and invertebrates.

The location of the submersible was tracked using an ORE Trackpoint II that integrates with the surface vessel's differential GPS position and gyroscope heading using a USBL acoustic tracking system and WINFROG navigational software. The tracking system was linked to an ArcView GIS seafloor mapping program that tracked the submersible in real-time in relationship to depth and seafloor habitat maps. These advanced technologies and combined geophysical and geological methodologies provided an integrated systems approach to mapping seafloor features that aid in the understanding of fisheries habitats.

Dives consisted of one to four 30-minute transects with a course heading chosen to keep transects at a uniform depth. Using two parallel lasers, transect width was delineated at 2 m when the submersible was 2 m off the bottom. Several observers participated in the surveys and included M. Love, D. Schroeder, L. Snook, M. McRea, and M. Yoklavich. Observers recorded observations of fish species identification and size estimates for all individuals within each transect, on the audio portion of the videotape. Video tapes were later analyzed to quantify fish, identify habitat type and determine invertebrate abundance. Videotaped fish observations along each transect were verified for identification, counted, lengths were estimated to the nearest cm, and the data were entered into a relational database by L. Snook.

Bottom habitat type was categorized using seven different categories of geological substratum, which have been used in previous studies (see Stein et al., 1992; Greene et al., 1999; Yoklavich et al., 2000; Wakefield et al., 2005). The substratum types range across decreasing particle size and vertical relief: rock ridge (R, high relief), boulder (B, high to low relief), cobble (C, high to low relief), pebble (P, low relief), gravel (G, low relief), sand (S, grains distinguishable), and mud (M, noticeable organic particles). Transects were sub-divided into unique segments of continuous habitat types using a two character code system (Stein et al., 1992). The first or primary character represented the substratum type accounting for > 50% and ≤ 80% of the patch, and the secondary character accounts for ≥20% and <50% of the patch (e.g., RB represented a patch with at least 50% cover by rock ridge and at least 20% cover by boulders). Patches less than 10 seconds in duration were not recorded as unique patches. The area of each habitat patch was determined by multiplying the transect width of 2 m by the length of the habitat patch as determined by the geographic position at the beginning and end of the patch.

Direct counts of megafaunal invertebrates (height ≥ 5 cm) were made from videotapes within each habitat patch and identified to the lowest taxonomic level. Densities of megafaunal invertebrates were estimated by standardizing species abundance relative to the area of their associated habitat patch. For structure-forming invertebrates the geographic position was recorded and an estimation was made of their height. All corals were counted and color was noted for black corals. Gorgonians were difficult to distinguish taxonomically and were generally categorized into one group (order Gorgonacea). Solitary sponges were categorized into eight groups based on their structure and shape classified by general morphological structure: foliose, vase, barrel, flat, branching, and shelf sponges. Additional observations were made of associations between structure-forming invertebrates and fishes and other benthic invertebrates. Invertebrate associations with other structure-forming invertebrates were noted when their was physical contact. Associations between fishes and structure-forming invertebrates were categorized using four levels of associations: 1) fishes in the water column hovering ≤1 m from invertebrate; 2) fishes at rest ≤1 m from invertebrate; 3) at rest ≤1 fish body length from invertebrate; 4) fish in physical contact with invertebrate. Voucher specimens of invertebrates were collected for taxonomic identification, and damaged or dead invertebrates were noted from video observations as well as fishing gear impacts.

Data Analysis

Log transformed data from a Kruskal-Wallis; Tukey one-way ANOVA was used to determine if habitat types and depths varied significantly between years.

Results

Physical habitats

A total of 28 dives were completed and 609 habitat patches were surveyed between 1995 and 2004 (Figure 2). Dives were conducted between 97-314 m depths and ranged in distance from 0.43-9.11 km covering a total area of 9.65 h (Table 1). The distributions of the number of patches was similar to the total surface area of habitats distributed in habitat types (Figure 3). Overall, rock-ridge (RR), cobble-boulder (CB), and boulder-cobble (BC) habitats reflected the largest habitat areas, rock-ridge and cobble-boulder were the most frequent habitat types (Figure 3 and 4). The number of patches for each substratum type varied according to depth (Figure 5). Patches at all depths show a high incidence of rock ridge habitats. More cobble-boulder habitats were found at depths <150 m than at other depths. Cobble-boulder habitats were more common at depths between 150-225 m and > 275 m. Cobble-ridge habitats occurred at deeper depths >275 m. Habitat patches at depths between 226-275 m had more boulder-ridge habitat patches (Figure 5). Patches with sand and mud habitats were rare.

Invertebrate distributions

Megafaunal invertebrate observations at the Footprint totaled 90,307 individuals from 53 taxa representing 7 phyla. The most common structure-forming invertebrates (79% of total) were the crinoid *Florometra serratissima,* (43%), brittle stars (Ophiacanthidae) (19%), foliose sponge (10%), and the fragile sea urchin *Allocentrotus fragilis* (7%) (Table 2); (Figures 6-7).

A total of eighteen megafaunal invertebrates were classified as structure-forming invertebrates (Table 3). These invertebrates were classified on the basis of size, morphology and density. Structure-forming invertebrates ranged in size from 5 cm for some sponges and gorgonians to 240 cm for black corals. After black corals, sponges were the largest structure-forming invertebrates, with the largest being the barrel sponge at 120 cm. Structure-forming invertebrates varied in abundance across habitat types (Figures 8-14). Some species were found over a wide range of habitats. Fan corals, galitheid crabs, crinoids, and fragile sea urchins were found across all habitat types but fan corals and galitheid crabs were most dense in boulder areas. Fan corals and galitheid crabs were most dense in ridge and boulder habitats (Figures 8-14). Fan corals were also dense in cobble habitats along with crinoids. Fragile sea urchins were most dense in boulder-cobble habitats (Figure 12).

The density of invertebrates varied among years from 1995 to 2004 (Figures 15-20). Crinoids were denser in 1995 than in any other year. Black corals, fan corals, gorgonians, and sea pens reflected a low abundance in 1995 compared to the subsequent years. Other taxa experienced a similar low abundance for 1995 (fragile sea urchins, brittle stars, galatheid crabs, and basket stars). However, some sponge groups (foliose, barrel and vase) varied in abundance from year to year (Figures 15-20).

Invertebrate Size Distributions

Black corals, fan corals, and gorgonians had different size distributions (Figures 21 and 22). Black corals varied from 15–240 cm in height (mean=22.4; SE=0.3; *n*=1155) with most individuals ranging in size from 10 – 30 cm. Colors of individuals were placed in three categories: gray-to-white (93.42%), rusty-brown-to-red (6.15%), and gold (0.43%). Fan corals ranged in size from 10 – 60 cm (mean=21.8; SE=0.2; *n*=805) and gorgonians ranged from 10 – 80 cm (mean=18.9; SE=0.2; *n*=508) and were found in a variety of morphological forms (Figures 21 and 22).

Size distributions of sponges displayed similar mean sizes (Figure 21), foliose, barrel, vase, flat, shelf, and branching sponges were not significantly different (pooled mean=20.5 cm; SE=0.01; *n*=17,441). The maximum height observed for barrel sponges was 120 cm, for foliose sponges 60 cm, vase sponges 70 cm and flat sponges 90 cm.

The seven groups of sponges were distributed across nine habitat types primarily consisting of high-relief rock habitat areas and were especially dense in boulder substratum. Barrel sponges were found at deeper depths (mean=205 m; SE=1; *n*=1,993) than other sponge groups. Foliose sponges were found at shallower depths (foliose sponge mean=178 m; SE=1; *n*=8,797: vase sponge mean=166 m; SE=1; *n*=3,331: flat sponge mean=173 m; SE=1; *n*=2,429).

Habitat types and depths surveyed varied significantly between years (Log transformed data for Kruskal-Wallis; H=1773; df=6; P<0.01: Tukey one-way ANOVA; F=331.1; df=10,594; P<0.01). In 1995, dives were predominately in rock ridge habitats at an average depth of 291 m (Figure 23) and dives conducted in 1995 were similar to those conducted in 1999 and 2004. In 1998, dives were predominately in cobble-boulder areas with rock ridge and mud-cobble at an average depth of 284 m and were not similar to other years. In 1999 and 2000 the dives were at deeper depths with an average depth of 300 m (1999) and average depth of 340 m, in 2000. In both 1999 and 2000 cobble-boulder habitat was the most predominant followed by rock ridge; however, the percent area of rock ridge habitat visited in 2000 was similar to 1998. In 2001, shallower rock ridge habitats were predominant at an average depth of 183 m. The area covered in 2003, was more evenly distributed across habitat types, again with cobble-boulder areas more predominant and at average depths of 126 m. Dives in 2004 were predominantly in rock ridge habitats at an average depth of 291 m.

Associations with Structure-forming Invertebrates

Overall, branching sponges, basket stars and gorgonians did not have any other invertebrates associated with them (Table 4). Black corals, sponges, fan corals and gorgonians were associated with few other invertebrates. Black corals had the largest incidence of associated animals: 7.5% had galatheid crabs living on them. Both upright sponges and vase sponges had crinoids living on them (1.3% and 1.2% respectively). Fan corals had both crinoids (0.75%) and galatheid crabs (0.12%) living on them. No invertebrates were observed living on gorgonians (Table 4).

Associations Between Fishes and Structure-forming Invertebrates

Overall, flat sponges (33%), vase sponges (21%), basket stars (18%), foliose sponges (17%) and barrel sponges (17%) had the highest percent of fish associations, which included one of the four categories. More than 75% of observed associations of foliose sponges, shelf sponges and basket stars had fishes hovering or swimming in the water column ≤ 1 m from the sponge. Fishes were observed a higher percent of the time (0.67%) at rest ≤ 1 m from branching sponges, flat sponges, vase sponges, black corals and gorgonians than other structure-forming invertebrates. Invertebrates with fishes (0.86%) at rest ≤ 1 body length away were branching sponges, fan corals, barrel sponges, vase sponges and upright sponges. Black corals had the highest percent of fishes making physical contact, followed by barrel sponges, vase sponges and upright sponges. None of the fish were observed in physical contact with foliose sponges, branching sponges, shelf sponges or basket stars (Table 5).

Fishes occurred at high densities with structure-forming invertebrates at the Footprint in the predominately rock ridge habitat, including squarespot rockfish (*Sebastes hopkinsi*), pygmy rockfish (*Sebastes wilsoni*), swordspine rockfish (*Sebastes ensifer*), widow rockfish (*Sebastes entomelas*), pinkrose rockfish (*Sebastes simulator*) and members of the rockfish subgenus *Sebastomus* (Table 6 and 7).

Damaged or Dead Invertebrates

Observations revealed fishing gear debris, such as traps, longlines, trawl nets, and gill nets from commercial fishing efforts. There was also evidence of recreational fishing efforts with observations of monofilament line, traps, bricks and a fishing pole. Dislodged and damaged invertebrates such as corals and sponges were noted from video observations. Lost fishing gear was found draped over a rock ridge at the Footprint; showing the impacts of fishing activities.

The overall incidence of damaged and dead black corals, fan corals and sponges was low (0.04% of total number observed). Of these taxa fan corals were more commonly damaged or dead (3.1%). Fan corals (0.87%) and gorgonians (0.79%) were more commonly broken or knocked over. Black corals (0.53%) had a low incidence of damaged or dead organisms. For sponges, vase sponges were more commonly damaged (0.09%) or dead (1.47%), followed by foliose sponges (0.16%) (Table 8).

Long line fishing gear was evident at depths ranging from 177-266 m and observed more often in 2000 and 2001. Fishing nets, cages and traps were observed at depths from 145 – 218 m with most observations occurring in 2001 (Table 9).

Discussion

The Footprint represents a unique geologic area consisting mostly of rock ridge and cobble-boulder habitat areas of high relief and structural complexity. Habitats have a high range in depths and large scale vertical relief.

This complexity in habitats may increase species diversity by providing more crevices and additional areas for shelter. Associated with these complex habitats were a high density and diversities of large invertebrates such as black corals, gorgonians, and a wide variety of sponges, basket stars, anemones and crinoids. Most of these invertebrates ranged from 15-30 cm in height, but barrel sponges occasionally exceeded 1m and black corals 2m in height.

Exposure to ocean currents may have been an important factor in the density and distribution of filter-feeders such as crinoids and basket stars. High density aggregations of these structure-forming invertebrates have been found to occur in areas of high water motion at Heceta Bank, Oregon (Puniwai, 2002) and Cordell Bank, California (Pirtle, 2005). The Channel Islands area is characterized by a complex ocean current system and flow structure with seasonal variations in alongshore wind stress, temperature, and salinity variations (Batteen et al., 2003). Northward surface flows occur shoreward of the Channel Islands within the Southern California Bight and are part of the Southern California Eddy (Batteen et al., 2003). The Bight, which experiences year-round cyclonic circulation, consists of a series of complex topographic features such as islands, basins and ridges that influence circulation patterns at every depth (Hickey et al., 2003). The Santa Barbara Channel experiences a cyclonic westward flow along the northern boundary and influences the circulation patterns of the Channel Islands with a cyclonic eastward flow along the Channel Islands southern boundary (Nishimoto & Washburn, 2002; Dever, 2003). A poleward flowing California undercurrent beneath the sea surface (~100-200m depth) is the dominant feature of circulation in the Bight (Hickey et al., 2003). These observations support the presence of strong oceanographic currents where the flow regime may be favorable to feeding and growth of structure-forming invertebrates.

Megafaunal invertebrates were predominantly found associated with high to moderate-relief rock ridge and boulder habitats and with mixed-substrate cobble boulder habitats. In rock ridge and boulder habitats foliose sponges, barrel sponges, upright sponges and brittle stars were most abundant. Black corals, fan corals and gorgonians were found predominantly in boulder habitats and boulder-cobble habitats. These same invertebrates and other taxa such as crinoids were found in abundance in mixed-substrate cobble boulder habitats.

Black corals and gorgonians are found more often in current-swept areas near drop-offs and under ledges (Parrish, 2004; Warner and Opresko, 2004; Thiem et al, 2006). In this study, black corals, gorgonians and sea pens were found in mixed boulder-cobble habitats. Many of these corals were found in boulder-cobble areas in high current areas but not located near drop-offs. Other large structure-forming invertebrates with complex morphology found in high-relief boulder areas were a wide variety of sponges. Foliose sponges were the most abundant structure-forming invertebrate in the study, and these large invertebrates added structure and micro-scale complexity to rocky habitats.

The density of invertebrates varied among years, however, this was likely due to the differences in dives and depths. Crinoids were most dense in 1995 when black corals, gorgonians and sea pens were low in abundance. Other taxa (fragile sea urchins, brittle stars, galatheid crabs, and basket stars) also experienced a low abundance in 1995. Some sponge groups (foliose, barrel and vase) varied in abundance from year to year (Figures 16-20).

Black corals had the largest incidence of associations with other invertebrates, with 7.5% having galatheid crabs living on them. The galatheid crabs were primarily observed perching on the top of small black corals in the current, presumably to feed. Exposure to currents may be an important factor contributing to the distribution of crabs on black corals. The complex structures of black corals, basket stars, crinoids and gorgonians may be an important factor contributing to the availability of microhabitats and create more surface area for settlement or retention of other organisms (Tissot et al, 2006).

The high abundance of structure-forming invertebrates added additional complexity to the physical habitat of the Footprint that may be important to fish communities. Based on 20,844 observations of structure-forming invertebrates, fishes were closely associated (< 1m) with invertebrates in 4.1% of the total number of observations, a total of 6,710 observations.

At the Footprint, fishes were observed hovering near, sheltering under, hiding in or perching on invertebrates. Fishes were commonly associated with flat sponges (33%), vase sponges (21%), basket stars (18%) and foliose and barrel sponges (17%). Fish associations with larger black corals (13%) were also observed. However, most of the black corals observed were ≤ 30 cm and few of the smaller black corals had fish associations. Previous studies (Parrish, 2004; Tissot et al, 2006) indicate there is no clear evidence that black corals serve to aggregate fish, but rather fishes and black corals may be co-occurring in habitats with similar physical relief. An important question in recent studies is whether the presence of structure-forming invertebrates contributes to the spawning, breeding, feeding, or growth-to-maturity of economically important fishes (Tissot et al, 2006). In Tissot's study less than 1% of observations of organisms account for fishes sheltering in or located on invertebrates (Tissot et al, 2004). In this study I observed many fish resting in or on sponges from the submersible *Delta* during a dive at dusk. This may be an important factor for future research since most submersible observations are limited to daylight hours. It is possible that more associations between structure-forming invertebrates and fishes may be documented if dives were conducted during evening hours when certain fish species seek shelter to rest.

Fish-invertebrate associations may depend on the availability of an underlying geologic framework. Where there are few small-scale shelter crevices for fishes there may be an increased reliance on structure-forming invertebrates (Auster, 2005). It is likely that the combination of structure-forming invertebrates in association with specific physical habitats contributed to the fish community structure. It may be that large, complex, and/or densely aggregated invertebrates change the structural complexity of the physical habitats to create more favorable framework for structurally oriented fishes. In Norway, redfish are associated with ship wrecks and in areas where wrecks were absent they were found in the vicinity of large sponges, often resting or hiding in their concavities or among rocky habitats that form distinct features. It is possible that physical structure encountered by fishes, such as coral habitats, wrecks or distinct rocky habitats with crevices rather than the special nature of corals or other structure-forming invertebrates, is attractive to some rockfish species. The degree of interaction is unclear between fishes and structure-forming invertebrates and therefore warrants further study to better understand the importance of these structure-forming invertebrates and their contribution to the complexity of the habitat structure of marine ecosystems.

Boland and Parrish (2005) concluded that black corals may be used as shelter by fishes part of the time, making use of their branches to orient themselves. Auster (2005) suggests fishes use corals as shelter where there are few refuges and may provide vertical structural habitat in lieu of rocky substrata containing vertical relief. It may be that corals and sponges provide useful structure to mobile organisms that potentially use the living structure for shelter or to decrease the energetic expense of keeping position on exposed rock walls.

The Footprint is dominated primarily by smaller rockfish species (Schroeder and Love, 2002). Thus, fishes that occurred at high densities with structure-forming invertebrates were predominantly pygmy rockfish (*Sebastes wilsoni*), squarespot rockfish (*Sebastes hopkinsi*), swordspine rockfish (*Sebastes ensifer*), widow rockfish (*Sebastes entomelas*), pinkrose rockfish (*Sebastes simulator*), juvenile rockfish and members of the rockfish subgenus *Sebastomus.* Larger rockfish species, such as cowcod and bocaccio, were observed at an adjacent site with an 18-fold greater density than at the Footprint (Schroeder and Love, 2002). Love and Yoklavich (2006) describe how fish assemblages on deep rock habitats have been altered by continual commercial and recreational fishing, resulting in habitats dominated by dwarf fish species that are more productive and able to avoid capture. It is likely that fish assemblages at the Footprint have been impacted in this way.

At the Footprint, observations of large invertebrates either damaged or dead appeared higher than in Tissot (2006). In the study, 1.80% of invertebrates were broken or knocked over, 0.80% were partly dead and 3.73% were dead. Schroeder and Love (2002) observed large amounts of commercial fishing gear debris at the Footprint during fish surveys (traps, longlines, trawl nets, and gill nets) and recreational fishing debris (lead weights, artificial lures, monofilament line and beer cans). In this study, there were similar observations of multiple longlines, fishing nets, large traps and cages, a fishing pole and a brick. These observations are consistent with the observed negative impacts due to commercial and recreational fisheries in other areas (Freese et al. 2001; Schroeder and Love, 2002; Tissot et al. 2006).

In conclusion, structure-forming megafaunal invertebrates were predominantly associated with fish in high to moderate-relief rock ridge and boulder habitats and with mixed-substrate cobble-boulder habitats. It is likely that structure-forming invertebrates in this study are important ecologically and contribute to the heterogeneity of continental shelf ecosystems and thus are potentially important for fish, including some species of groundfish. Although the density of invertebrates varied significantly among years, this pattern may be due to the differences in dives and depths among years rather than to any natural variation. There is no bottom trawling at the Footprint as in other areas. However, due to past commercial and recreational fishing activities in the area, gear impacts are visible. Damage to invertebrates can potentially harm fish communities due to their role in fish associations and thus need conservation. Structure-forming invertebrates are an important part of essential fish habitat and potentially necessary to fish for spawning, breeding, feeding or growth to maturity. Management of fisheries is changing to a more holistic approach considering interactions among components of the ecosystem. The ecosystem-based fishery management approach prioritizes sustaining a healthy marine ecosystem and the fisheries they support.

It is essential to consider these organisms as important in their own right and thus their conservation should not be solely dependent on their real or perceived association with commercially important fishes.

Bibliography

Aburto-Oropeza, O. and E.F. Balart. 2001. Community structure of reef fish in several habitats of a rocky reef in the Gulf of California. Marine Ecology. 22(4): 283-305.

Auster, P.J. 2005. Are deep water corals important habitat for fishes? Cold-water corals and ecosystems, A. Freiwald and J.M. Roberts (editors). Springer, New York.: 1244 pp.

Auster, P.J., and R.T. Tusting. 1997. Scientific sampling systems for submersible vehicles. Marine Technology Society Journal. 31(3): 3-4.

Batteen, M.L., N. J. Cipriano and J.T. Monroe. 2003, A large-scale seasonal modeling study of the California current system. Journal of Oceanography, 59: 545-562.

Berkeley, S.A., M.A. Hixon, R.J. Larson, M.S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries. 29(8): 23-32.

Blanchard, F., F. Leloc'h, C. Hily, J. Boucher, 2004. Fishing effects on diversity, size and community structure of the benthic invertebrate and fish megafauna on the Bay of Biscay coast of France. Marine Ecology Progress Series, 280: 249-260.

Boland, R.C., and F.A. Parrish. 2005. A description of fish assemblages in the black coral beds off Lahaina, Maui, Hawai'i. Pacific Science. 59(3): 411-420.

Botsford, L.W., J.C. Castilla, C.H. Peterson. 1997. The management of fisheries and marine ecosystems. Science. 277: 509-514.

Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (*Sebastes alutus*) in Pribilof Canyon, Bering Sea. Continental Shelf Research. 21:207-224.

Brodziak, J. and J. Link. 2002. Ecosystem-based fishery management: What is it and how can we do it? Bulletin of Marine Science. 70(2): 589-611.

Brown, D.W.1998. Habitat essential for sustainable fisheries. Journal of Shellfish Research. 17(5): 1481-1482.

Bruckner, A.W. 2002. Life Saving products from coral reefs. Issues in Science and Technology. 18(3): 39.

Cochrane, G.R. and K.D. Lafferty. 2002. Use of acoustic classification of sidescan sonar data for mapping benthic habitat in the Northern Channel Islands, California. Continental Shelf Research. 22: 683-690.

Dever, E.P. 2003. Objective maps of near-surface flow states near Point Conception, California. Journal of Physical Oceanography, 34: 444-461.

Feder, J. (version). 1996. Magnuson-Stevens fishery conservation and management act. www.nmfs.noaa.gov/sfa/magact/mag1.html. Retrieved 10/24/2003.

Fossa, J.H., P.B. Mortensen and D.M. Furevik.2002. The deep-sea coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471: 1-12.

Freese, J.L., 2001. Trawl-induced damage to sponges observed from a research submersible. Marine Fisheries Review. 63(3): 7-13.

Grange, K.R. 1991. Mutualism between the antipatharian *Antipathes fiordensis* and the ophiuroid *Astrobrachion constrictum* in New Zealand fjords. Hydrobiologia. 216/217: 297-303.

Greene, H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, M.E. McRae Jr., G.M. Calliet, 1999. A classification scheme for deep seafloor habitats. Oceanologica Acta. 22(6): 663-678.

Heifetz, J., B.L. Wing, R.P. Stone, P.W. Malecha and D.L. Courtney. 2005. Corals of the Aleutian Islands. Fisheries Oceanography. 14(1): 131-138.

Hickey, B.M., E.L. Dobbins and S.E. Allen. 2003. Local and remote forcing of currents and temperature in the central California Bight. Journal of Geophysical Research, 108 (C3) (26) 3081: 1–25.

Hixon, M.A., B.N. Tissot, W.G. Pearcy. 1991. Fish assemblages of rocky banks of the Pacific northwest (Heceta, Coquile and Daisy Banks). USDI Minerals Management Service, OCS Study MMS 91-0052, Camarillo, CA.

Husebo, A., L. Nottestad, J.H. Fossa, D.M. Furevik, S.B. Jorgensen. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia. 471: 91-99.

Hsu, S.L., J.E. Wilen. 1997. Ecosystem management and the 1996 sustainable fisheries act. Ecology Law Quarterly. 24: 799-811.

Johnston, K., J.M. Ver Hoef, K. Krivoruchko, and N. Lucas. 2001. Using ArcGIS Geostatistical Analyst. ESRI, Redlands, CA.

Koslow, J.A., G.W. Boehlert, J.D. M. Gordon, R.L. Haedrich, P. Lorance, N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science. 57: 548-557.

Krieger, K.J. 2001. Coral (Primnoa) impacted by fishing gear in the Gulf of Alaska. In Proceedings of the First International Symposium on Deep-Sea Corals. Edited by Willison et al., Ecology Action Centre, Halifax. Pp 106-116.

Krieger, K.J. and B.L. Wing. 2002. Megafaunal associations with deepwater corals (*Primnoa sp.*) in the Gulf of Alaska. Hydrobiologia 471: 83-90.

Love, M.S., M.M. Yoklavich. 2006. Deep rock habitats. The Ecology of Marine Fishes: California and Adjacent Waters. University of California Press, Berkeley. 253-266.

Love, M.S., M.M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Berkeley.

Love, M.S., M.M. Yoklavich, B.A. Black, and A.H. Andrews. 2007. Age of black coral (*Antipathes dendrochristos*) colonies, with notes on associated invertebrate species. Bulletin of Marine Science. 80(2): 391-400.

Montgomery, A.D. 2002. The feasibility of transplanting black coral (Order *Antipatharia*). Hydrobiologia. 471: 157-164.

Nasby-Lucas, N., B.W. Embley. M.A. Hixon, S.G. Merle, B.N. Tissot, and D.J. Wright. 2002. Integration of submersible transect data and high-resolution multibeam sonar imagery for a habitat-based groundfish assessment of Heceta Bank, Oregon. Fisheries Bulletin. 100: 739-751.

Nishimoto, M.M. and L. Washburn. 2002. Patterns of coastal eddy circulation and abundance of pelagic juvenile fish in the Santa Barbara Channel, California, USA. Marine Ecology Progress Series, 241: 183-199.

NOAA, Establishment of Marine Reserves and a Marine Conservation Area within the Channel Islands National Marine Sanctuary; Final Rule. Federal Register, May 24, 2007.

NOAA, National Marine Sanctuaries, State of the Sanctuaries, 2005 Accomplishments Report, Channel Islands National Marine Sanctuary. Website: http://sanctuaries.noaa.gov/sos05/channelislands.html. Viewed 2/19/2007.

Opresko, D.M. 2005. A new species of antipatharian coral (Cnidaria: Anthozoa: Antipatharia) from the southern California Bight. Zootaxa. 852: 1-10.

Opresko, D.M., and J.A. Sanchez. 1997. A new species of Antipatharian Coral (Cnidaria: Anthozoa) from the Caribbean Coast of Colombia. Caribbean Journal of Science 33 (1-2): 75-81.

Parrish, F.A. 2004. Foraging landscape of the Hawaiian monk seal. Ph.D. diss., p 146. Univ. of Hawaii, Manoa.

Peterson, C.H., H.C. Summerson, E. Thomson, H.S. Lenihan, J. Grabowski, L. Manning, F. Micheli, G. Johnson. 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat.

Pikitch, E.K, C. Santora, E.A. Babcock, A. Bakun, R. Bonfil, D.O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman, E.D. Houde, J. Link, P.A. Livingston, M. Mangel, M.K. McAllister, J. Pope, and K.J. Sainsbury. 2004. Ecosystem-based fishery management. Science. 305: 346-347.

Pirtle, J. 2005. Habitat-based assessment of structure-forming megafaunal invertebrates and fishes on Cordell Bank, California. M.S. Thesis. Washington State University Vancouver.

Puniwai, N.P.F. 2002. Spatial and temporal distribution of the crinoid *Florometra serratissima* on the Oregon continental shelf. M.S. Thesis, Washington State University.

Risk, M.J., J.M. Heikoop, M.G. Snow, R. Beukens. 2002. Lifespans and growth patterns of two deep-sea corals: *Primnoa resedaeformis* and *Desmophyllum cristagalli*. Hydrobiologia. 471: 125-131.

Roberts, J.M., A.J. Wheeler, A. Freiwald. 2006. Reefs of the deep: The biology and geology of cold-water coral ecosystems. Science. 312: 543-547.

Roberts, S. and M. Hirshfield. 2004. Deep-sea corals: out of sight, but no longer out of mind. Front. Ecol. Environ. 2(3): 123-130.

Rogers-Bennett. 2001. Ecosystem-based fishery management in nearshore environment. California cooperative oceanic fisheries investigation. 42: 63-65.

Rosenberg, A., T.E. Bigford, S. Leathery, R.L. Hill, K. Bickens. 2000. Ecosystem approaches to fishery management through essential fish habitat. Bulletin of Marine Science. 66(3): 535-542.

Schroeder, D.M., M.S. Love. 2002. Recreational fishing and marine fish populations in California. CalCOFI Rep. 43.

Starr, R.M., D.S. Fox, M.A. Hixon, B.N. Tissot, G.E. Johnson, W.H. Barss. 1996. Comparison of submersible-survey and hydroascoustic-survey estimates of fish density on a rocky bank. Fishery Bulletin. 94: 113-123.

Stein, D.L., B.N. Tissot, M.A. Hixon, and W. Barss. 1992. Fish habitat associationa on a deep reef at the edge of the Oregon continental shelf. Fisheries Bulletin. 90: 540-551.

Thiem, O., E. Ravagnan, J.H. Fossa, J. Berntsen. 2006. Food supply mechanisms for cold-water corals along a continental shelf edge. Journal of Marine Systems. 60: 207-219.

Tissot, B.N.,W.F. Walsh, L.E. Hallacher. 2004. Evaluating effectiveness of a marine protected area network in west Hawai'i to increase productivity of an aquarium fishery. Pacific Science. 58(2): 175-188.

Tissot, B.N., M.M. Yoklavich, M.S. Love, K. York, M. Amend. 2006. Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral. Fisheries Bulletin. 104: 167-181.

University of California, Santa Barbara. 2/9/2005. Press Release. http://www.ia.ucsb.edu/pa/display.aspx?pkey=1242. Viewed 4/9/05.

Wakefield, W.W., C.E. Whitmire, J.E. Clemons, B.N. Tissot. 2005. Fish habitat studies: combining high-resolution geological and biological data. American Fisheries Society Symposium. 41: 000-000.

Warner, G.F. and D.M. Opresko. 2004. A new black coral (Anthozoa: Antipatharia) from a reef wall environment in Jamaica. Bulletin of Marine Science74(1): 169-174.

Yoklavich, M. M., H. G. Green, G.M. Cailliet, R.N. Lea, and M.S. Love. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fisheries Bulletin. 98: 625-641.

Table 1. Submersible dives at the Footprint between 1995 – 2004, identified by year, *Delta* dive number, number of habitat patches and substrate types observed, and total distance (km), area (h) surveyed and mean depth (m) for each dive.

Year	**Dive Number**	**No. of Habitat Patches**	**No. of Substrate Types**	**Total Distance (km)**	**Total Area (h)**	**Mean Depth (m)**
1995	3708	5	3	1.08	0.38	178
1995	3709	18	6	0.72	0.15	150
1998	4581	42	13	1.12	0.22	243
1998	4583	12	6	0.63	0.13	101
1999	5004	27	7	1.49	0.32	205
1999	5005	7	4	1.72	0.30	113
2000	5320	35	6	1.28	0.30	112
2000	5328	22	6	4.96	1.01	116
2000	5329	8	4	0.59	0.12	169
2000	5330	11	6	1.07	0.23	222
2000	5331	17	5	0.85	0.14	193
2000	5332	35	5	1.01	0.20	203
2000	5333	8	4	0.43	0.09	314
2000	5338	35	8	1.20	0.24	272
2000	5339	21	5	1.69	0.36	192
2001	5565	40	7	3.88	0.78	130
2001	5566	27	7	2.38	0.47	190
2001	5567	30	4	1.81	0.35	243
2001	5568	19	3	9.11	1.23	266
2001	5570	24	4	0.71	0.15	176
2003	6143	35	10	0.88	0.19	273
2003	6144	33	6	1.46	0.29	145
2003	6146	16	7	0.97	0.19	108
2003	6148	19	4	0.98	0.18	97
2004	6424	5	2	1.51	0.31	242
2004	6425	23	7	5.45	0.79	138
2004	6426	15	6	1.12	0.22	106
2004	6428	33	13	1.57	0.31	167
TOTAL:	**28**	**622**	**13**	**51.7**	**9.65**	**184**

Table 2. Number of individual observations and percent of total observations for megafaunal invertebrates identified at the Footprint in CINMS between 1995 - 2004.

Phylum	Taxa Name	Number of Observations	Percent of Total Observations
Porifera	foliose sponge	8797	9.7
	barrel sponge	1993	2.2
	shelf sponge	261	0.3
	vase sponge	3331	3.7
	branching sponge	263	0.3
	flat sponge	2449	2.7
Cnidaria	black coral *(Antipathes dendrochristos)*	1155	1.3
	white plumed anemone *(Metridium senile)*	1	<0.01
	plumed anemone *(Metridium gigantium or farcimen)*	9	0.01
	fan coral (gorgonian)	805	0.9
	Corynactis californica	351	0.4
	unknown sea pen spp	296	0.3
	siphonophore *(Siphonophorae)*	17	0.02
	Red Cowcod anemone	13	0.01
	unknown anemone	147	0.2
	sea anemone *(Liponema brevicornis)*	8	0.01
	stony coral *(Lophelia*)	29	0.03
	cup coral	801	0.9
	short sea pen *(Ptilosarcus spp)*	8	0.01
	Gorgonian	509	0.6
Mollusca	*Octopus dofleini*	1	<0.01
	Octopus spp.	1	<0.01
	nudibranch *(Opistobranchia)*	5	0.01
Annelida	serpulid worm *(Serpulid polychaete)*	980	1.1

Table 2: Continued

Phylum	Taxa Name	Number of Observations	Percent of Total Observations
Arthropoda	box crab *(Lopholithodes foraminatus)*	11	0.01
	king crab *(Paralithodes californica)*	1	<0.01
	squat lobster *(Munida quadrispina)*	2	<0.01
	galatheid crab *(Galatheidae)*	3145	3.5
	unknown crab	408	0.5
Echinodermata	fragile sea urchin *(Allocentrotus fragilis)*	6723	7.4
	crinoid *(Florometra serratissima)*	38878	43.1
	brittle star (Ophiacantha sp.)	17023	18.9
	basket star *(Gorgonocephalus eucnemis)*	935	1.04
	Mediaster aequalis	1	<0.01
	blood star *(Henricia spp.)*	227	0.3
	Pycnopodia helianthoides	2	<0.01
	wrinkled star *(Pteraster militaris)*	29	0.03
	Pteraster tesselatus	4	<0.01
	Crossaster papposus	2	<0.01
	Centrodiscus crispatus	5	0.01
	Luidia spp.	2	<0.01
	bat star *(Pateria (Asterina) miniata)*	90	0.10
	Poraniopsis inflata	32	0.04
	cookie star *(Ceramaster spp).*	4	<0.01
	unknown sea star	1	<0.01
	sea cucumber *(Parastichopus spp.)*	29	0.03
	sun star (*Pycnopodia/rathbunaster*)	110	0.1
	Hippasterias/pteraster	1	<0.01
	Pisaster brevispinus	11	0.01
Chordata	*Colonial ascidian*	35	0.04

Table 3. Structure-forming invertebrates criteria and characteristics at the Footprint: total observed (n), density (#/hectare) with standard error, maximum height (cm) and depth (m) with standard error.

Taxa	N	Criteria			Density (#/hectare)		Maximum height (cm)	Depth (m)	
		Size	Morphology	Density	Mean	SE		Mean	SE
Foliose sponge	8,797	X	X		1,543	167	60	178	1
Vase sponge	3,331	X	X		762	101	70	166	1
Upright sponge	2,429	X	X		610	95	90	173	1
Barrel sponge	1,993	X	X		534	74	120	205	1
Black Coral	1,155	X	X		445	65	240	217	1
Fan coral	805	X	X		502	93	60	200	1
Gorgonian	508	X	X		221	60	80	188	4
Basket star	938	X			852	334	20	140	2

31

Table 3. Continued

Unknown sea pen spp.	296	X			231	75	30	184	5
Crinoid	38,878			X	20,527	3,104	20	164	15
Galatheid crabs	3,145				913	147	20	223	14
Serpulid polychaete	980				430	78	20	128	12
Fragile sea urchin	6,723	X			2,647	872	20	229	18
Unknown anemone	147	X			205	39	20	223	4
Henricia spp.	227				315	50	20	233	26
Bat star	90				191	39	20	239	33
Brittlestar	17,023			X	10,793	2,395	5	172	15

Table 4: Associations of invertebrates having physical contact with structure-forming invertebrates.

	Physical contact (% of total observations)				
Taxa	**n**	**crinoids**	**crabs**	**basket stars**	**sea stars**
Foliose sponge	8797	0.20	0.03	0.02	0.03
Barrel sponge	1913	0.60	0.30	0.30	0.15
Vase sponge	3331	1.17	0.69	0.39	-
Flat sponge	2429	1.28	-	0.21	0.08
Branching sponge	263	-	-	-	-
Shelf sponge	261	0.38	-	-	-
Black coral	1155	0.26	7.53	0.52	
Basket star	935	-	-	-	-
Fan coral	805	0.75	0.12	-	-
Gorgonian	509	-	-	-	-
Summary	**20,844**	**0.02**	**0.04**	**0.01**	**<0.01**

Table 5. Associations of fish with large structure-forming invertebrates at the Footprint. Associations listed by category: (Number with associations), (Percent association), (1) in the water column hovering $\leq$1 m; (2) at rest next to $\leq$1 m; (3) at rest next to $\leq$1 fish body length; (4) physical contact.

		Associated Fish (% of total associations)					
		Fish Association Category					
Taxa	**n**	**# with Assoc**	**% of total Obs**	**1**	**2**	**3**	**4**
Foliose sponge	8797	1518	17	87	8	5	0
Barrel sponge	1993	335	17	53	11	20	15
Vase sponge	3331	685	21	52	16	18	14
Flat sponge	2429	796	33	54	17	17	12
Branching sponge	263	14	5	47	21	32	0
Shelf sponge	261	20	8	78	15	7	0
Black coral	1155	148	13	50	17	12	21
Basket star	935	164	18	87	8	5	0
Fan coral	805	49	6	65	0	27	8
Gorgonian	509	67	13	65	17	16	2
Summary	**20844**	**3816**	**18.31**	**13.7**	**1.4**	**2.3**	**0.9**

Table 6: Scientific name with common name of fish species.

Scientific Name	Common Name
Sebastes rufus	Bank
Sebastes paucispinis	Bocaccio
Sebastes pinniger	Canary
Sebastes goodie	Chili
Sebastes levis	Cowcod
Sebastes crameri	Barkblotched
Sebastes eos	Eos
Sebastes rubrivinctus	Flag
Sebastes chlorostictus	Greenspot
Sebastes elongatus	Green stripe
Hydrolagus colliei	Ratfish
Halichoeres semicinctus	Semi
Sebastes semicinctus	Halfbanded
Sebastes helvomaculatus	Helvo
Ophiodon elongatus	Ling cod
Sebastes moseri	Moser
Sebastes ovalis	Ovalis
Unknown agonidae	Poacher
Sebastes simulator	Pinkrose
Sebastes wilsoni	Pygmy
Sebastes rosenblatti	Rosenblatti
Sebastes rosaceus	Rosy
Sebastes rufinanus	Rufy
Sebastes jordani	Shortbelly
Unknown	Sculpin
Sebastes hopkini	Squarespot
Sebastes constellatus	Starry
Sebastolobus alascanus	Sthorn
Unknown sebastomus	Stomus
Sebastes saxicola	Stripe
Sebastes ensifer	Ensifer
Sebastolobus spp.	Thorny
Sebastes miniatus	Vermillion
Sebastes entomelas	Widow
Unknown rockfish	Sebastes spp.
Unidentified	Unknown
Sebastes spp.	Young of year (YOY)

Table 7: Number of each fish species associated with large structure-forming invertebrates, total of all categories (1) in the water column hovering ≤1 m; (2) at rest next to ≤1 m; (3) at rest next to ≤1 fish body length; (4) physical contact.

Invertebrate		**Fish (# of observations)**									
	Total # Fish Obs	**Bank**	**Bocac**	**Canary**	**Chili**	**Cowcod**	**Darkbl**	**Eos**	**Flag**	**Grspot**	**Gstrip**
Basket star	436		3			1				5	
Unknown anemone	1	1									
Gorgonian	124	6							1	4	
Unknown sea pen	1										
Foliose sponge	2,648	78	62	1	1	11	1	6	8	11	1
Barrel sponge	499	35	13			5		4	2	3	
Shelf sponge	41		1								
Vase sponge	1,211	19	14			8	1		8	6	
Black coral	261	7	5			1				2	1
Branching sponge	19	1			1	1					
Flat sponge	1,418	34	36		2	7		1	3	10	
Unknown fan coral	51	2	1						1	1	
Total associations	**6,710**	**183**	**135**	**1**	**4**	**34**	**2**	**11**	**23**	**42**	**2**

Table 7: (Cont.)

Invertebrate	**Fish (# of observations)**											
	Ratfish	**Semi**	**Halfb**	**Helvo**	**Ling**	**Moser**	**Ovalis**	**Poachr**	**Prose**	**Pygmy**	**Rosenb**	**Rosy**
Basket star	1	6	26							36	1	
Unknown anemone												
Gorgonian	1	11	31						1	10		
Unknown sea pen												
Foliose sponge	12	3		14	24	8	88		131	664	3	3
Barrel sponge	4			2	9		4		48	110	2	1
Shelf sponge						1				4		
Vase sponge	8			3	12	1	25	1	66	296	1	
Black coral	1	4	7	3	3				47	5	4	
Branching sponge									4	2		
Flat sponge	9	2	1	2	10	3	19		81	336	3	4
Unknown fan coral	4				1				4			1
Total	**40**	**26**	**65**	**24**	**59**	**13**	**136**	**1**	**382**	**1,463**	**14**	**9**

Table 7: (cont.)

Invertebrate	Fish (# of observations)											
	Rufy	**Sbelly**	**Sculpn**	**Sqspot**	**Starry**	**Sthorn**	**Stomus**	**Stripe**	**Swords**	**Thorny**	**Verm**	**Widow**
Basket star				264		2	21		47			
Unknown anemone												
Gorgonian	1			27		1		4	24			1
Unknown sea pen		1										
Foliose sponge	9	12	1	482	38	13	129	1	657	3	4	151
Barrel sponge	2	1		31		9	26		159			28
Shelf sponge				18					1		1	15
Vase sponge	8	21		205	16	14	54		390		1	29
Black coral				30	3	6	21		54			51
Branching sponge				1					2			6
Flat sponge		11		217	17	14	105	1	454		4	20
Unknown fan coral						1			35			
Total	**20**	**46**	**1**	**1,275**	**74**	**60**	**356**	**6**	**1,823**	**3**	**10**	**301**

Table 7: (cont.)

Invertebrate	Fish		
	Unknown RF	**Unidentified**	**Young of year**
Basket star			23
Unknown anemone			
Gorgonian			1
Unknown sea pen			
Foliose sponge	1	7	10
Barrel sponge		1	
Shelf sponge			
Vase sponge		2	2
Black coral			6
Branching sponge	1		
Flat sponge		5	7
Unknown fan coral			
Total	**2**	**15**	**49**

Table 8: Damaged or dead invertebrates by year, invertebrate taxa, condition and percent of total.

Year	Invertebrate	Broken or knocked over	% of Total	Partly dead	% of Total	Dead	% of Total
1998	Fan coral	4	0.50%	4	0.50%	7	0.87%
1998	Gorgonians	0	0.00%	0	0.00%	1	0.20%
1999	Fan coral	1	0.12%	1	0.12%	0	0.00%
2000	Black coral	0	0.00%	0	0.00%	1	0.09%
2000	Vase sponge	0	0.00%	1	0.03%	17	0.51%
2000	Fan coral	2	0.25%	1	0.12%	3	0.37%
2001	Fan coral	0	0.00%	0	0.00%	2	0.25%
2001	Vase sponge	2	0.06%	0	0.00%	4	0.12%
2001	Gorgonians	4	0.79%	0	0.00%	0	0.00%
2003	Black coral	1	0.09%	0	0.00%	1	0.09%
2003	Vase sponge	0	0.00%	0	0.00%	5	0.15%
2004	Black coral	0	0.00%	0	0.00%	3	0.26%
2004	Vase sponge	0	0.00%	0	0.00%	23	0.69%
2004	Foliose sponge	0	0.00%	2	0.02%	12	0.14%
	Total	14	1.80%	9	0.80%	128	3.73%

Table 9: Lost fishing gears at the Footprint by year, fishing gear type, number of gears and depth (m).

Year	Fishing gear type	Number of observations	Depth (m)
1999	Fishing net	1	192
2000	Long line	15	177-280
2000	Large net	2	187-195
2001	Long line	19	122-266
2001	Large net	2	178-192
2001	Large cage	1	194
2001	Large trap	2	218
2001	Brick	1	218
2003	Long line	2	138-281
2003	Fishing pole	1	170
2004	Long line	4	220-230
2004	Large net	1	145

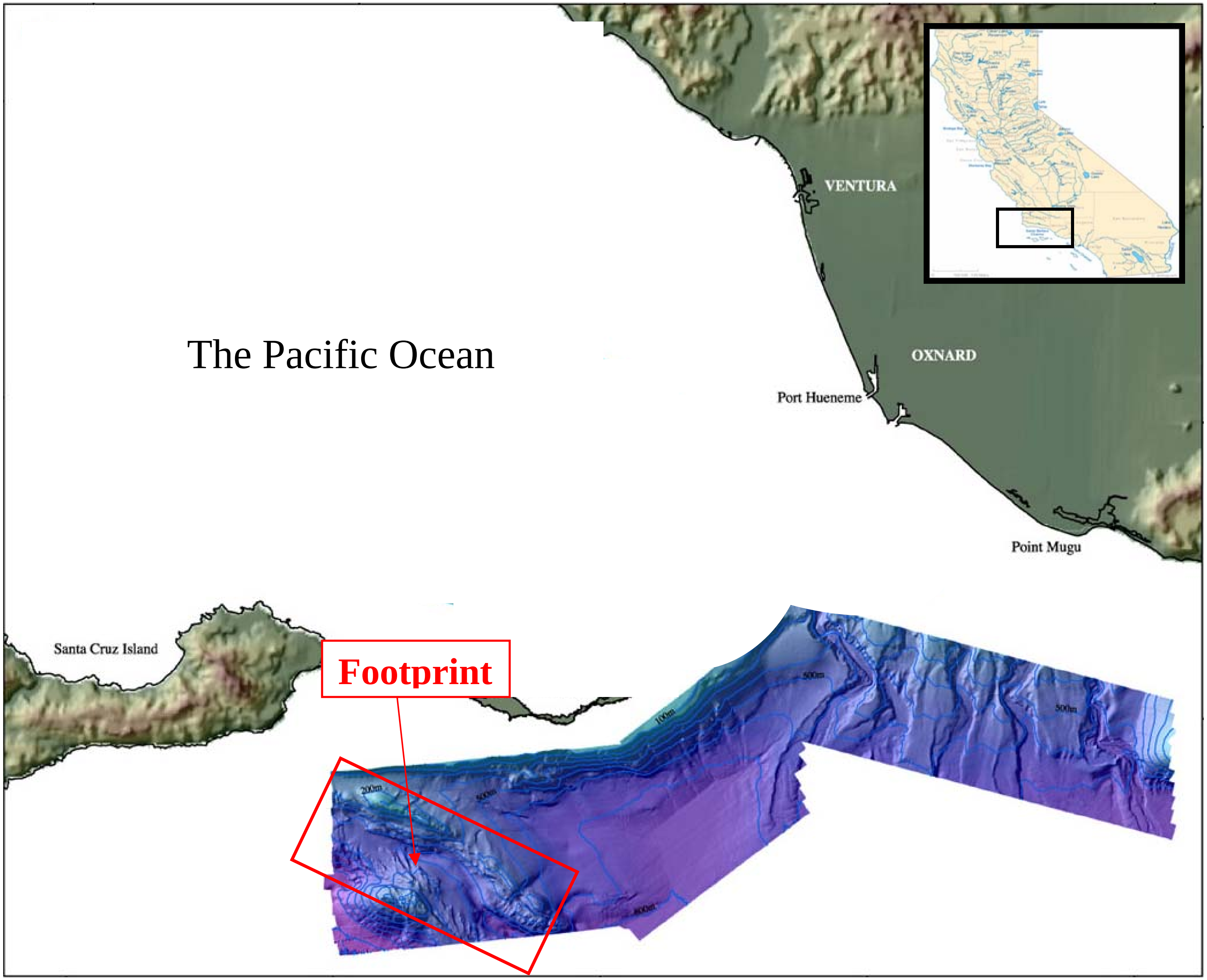

Figure 1. Bathymetry of the Footprint in the Channel Islands National Marine Sanctuary

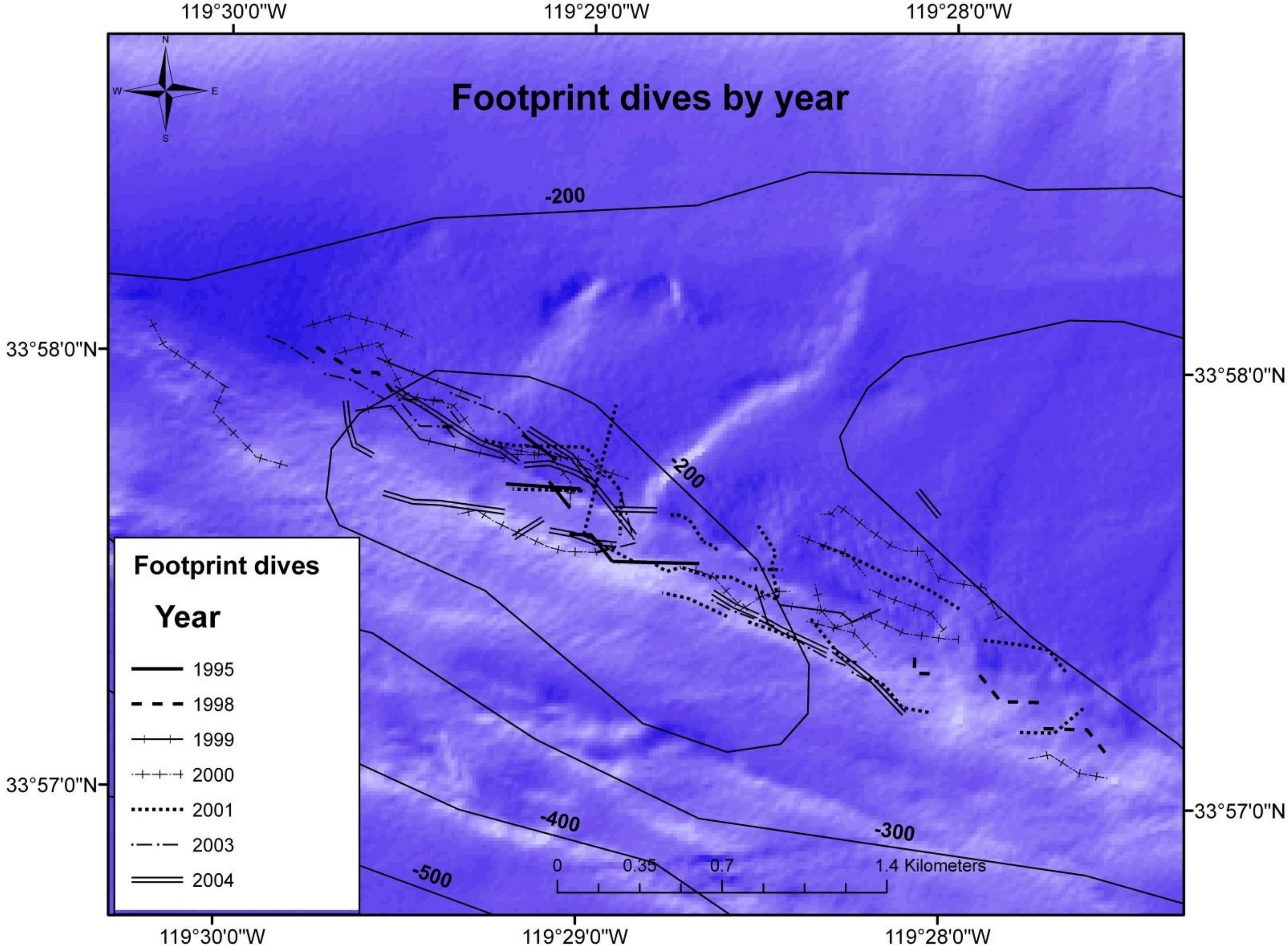

Figure 2: Map of Footprint dives between 1995 – 2004.

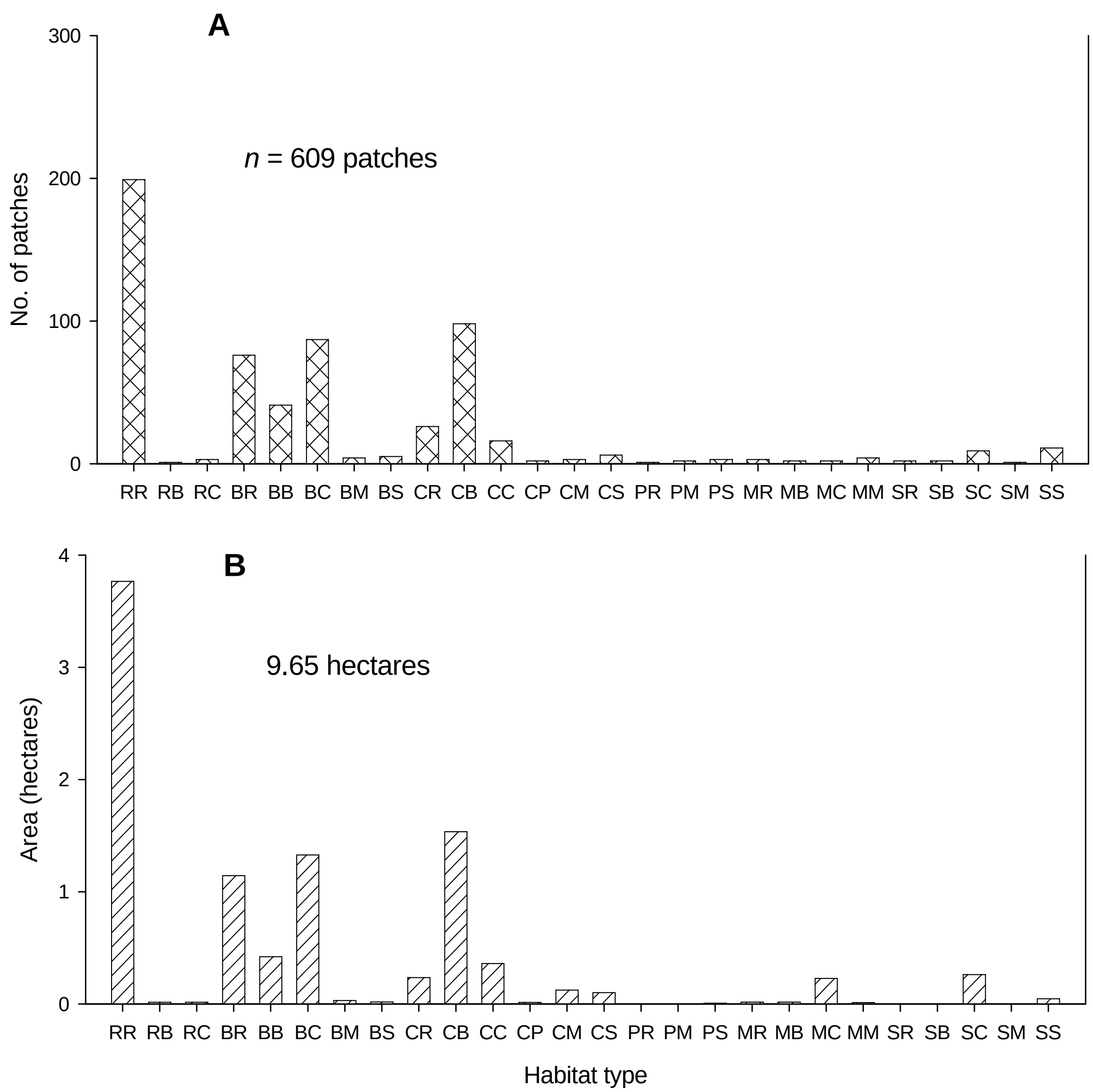

Figure 3. Characteristics of habitat patches surveyed at the Footprint. **(A)** Number of patches in each substratum type. **(B)** Total area of each substratum type. See text for description of method and habitat codes.

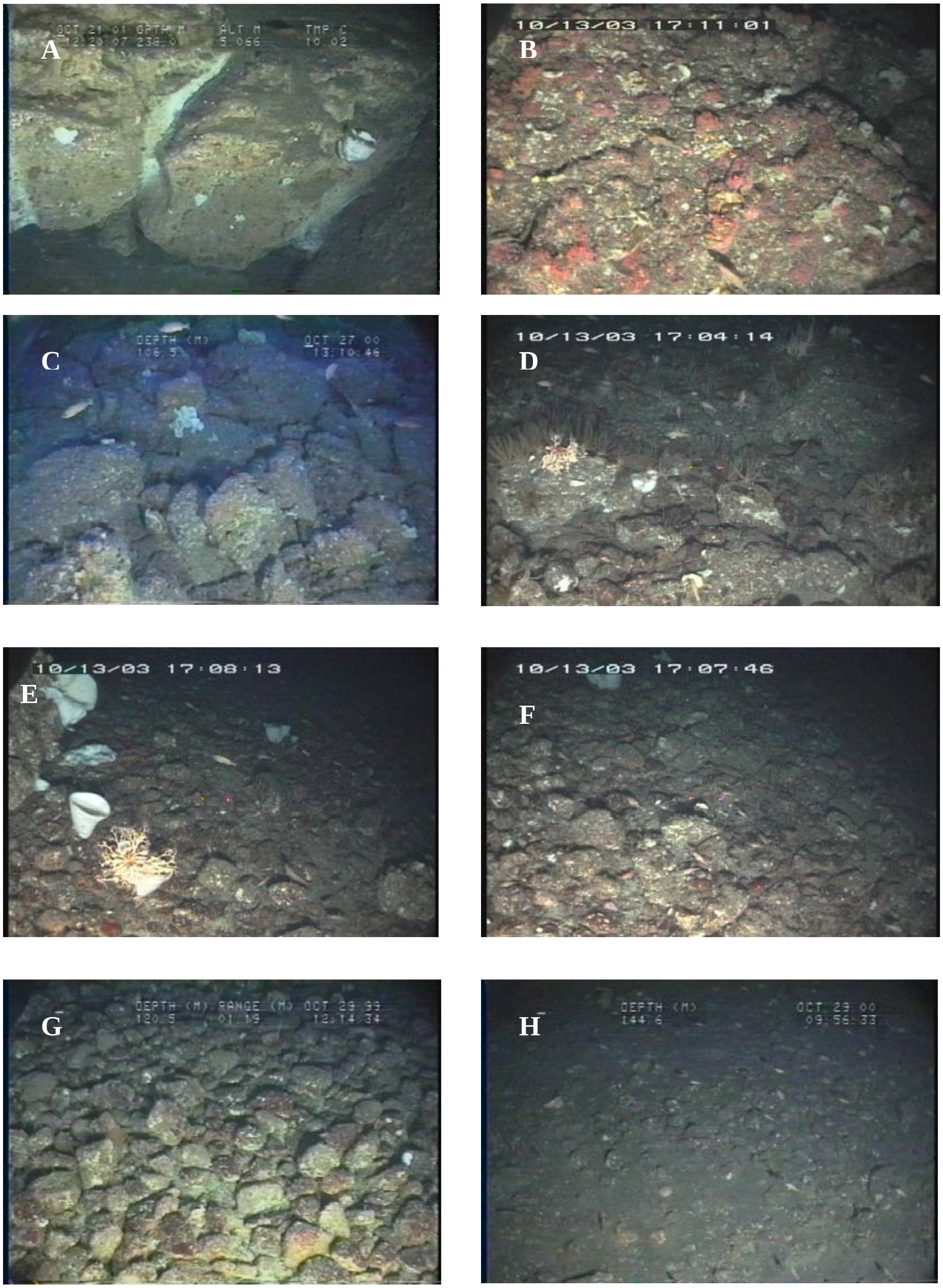

Figure 4. Samples of habitat types at the Footprint, depicted are (A & B) rock-ridge, (C & D) boulder-boulder, (E & F) boulder-cobble, (G) cobble-cobble and (H) sand-cobble habitats.

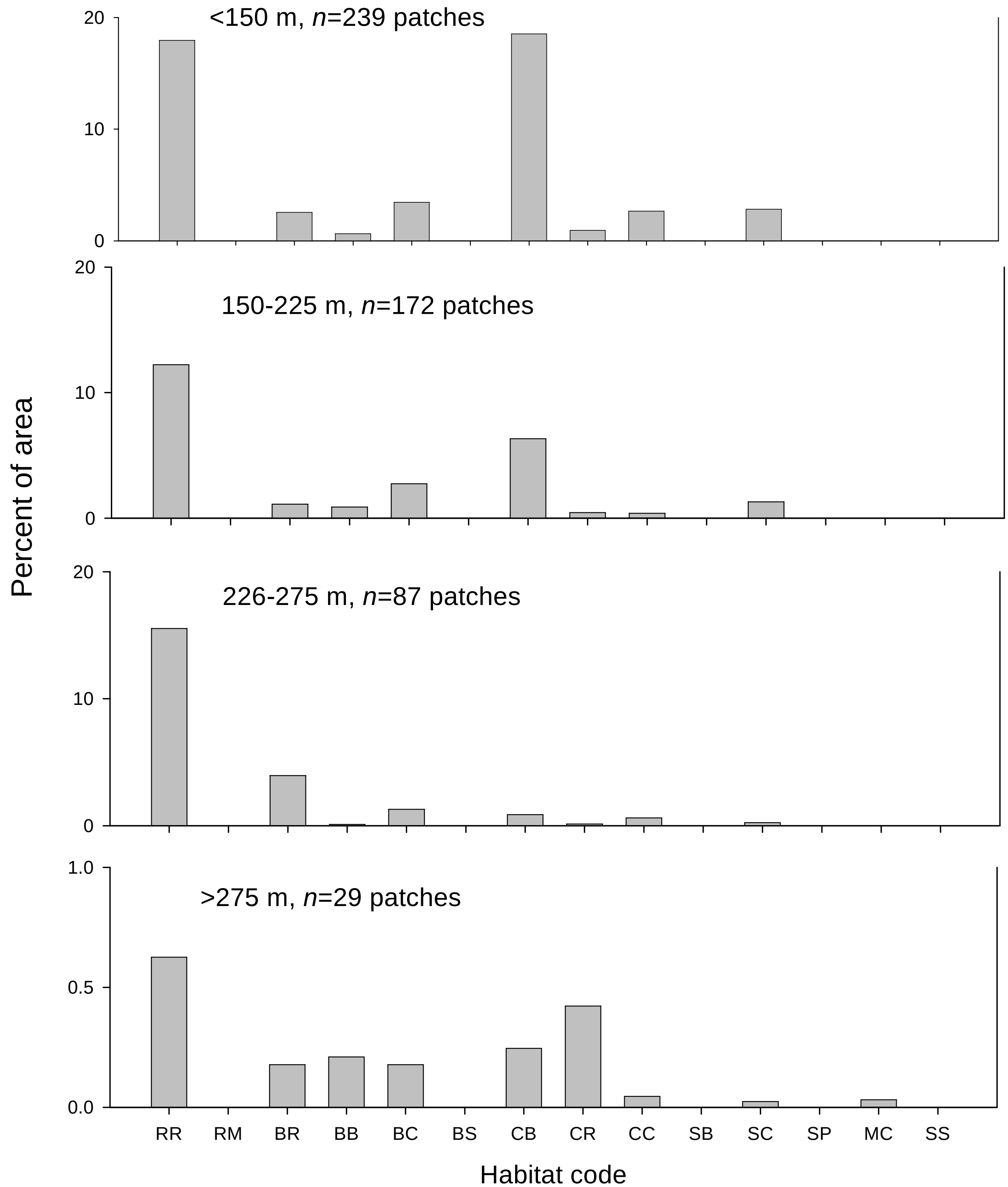

Figure 5: Frequency of habitat of each substratum type, stratified by depth.

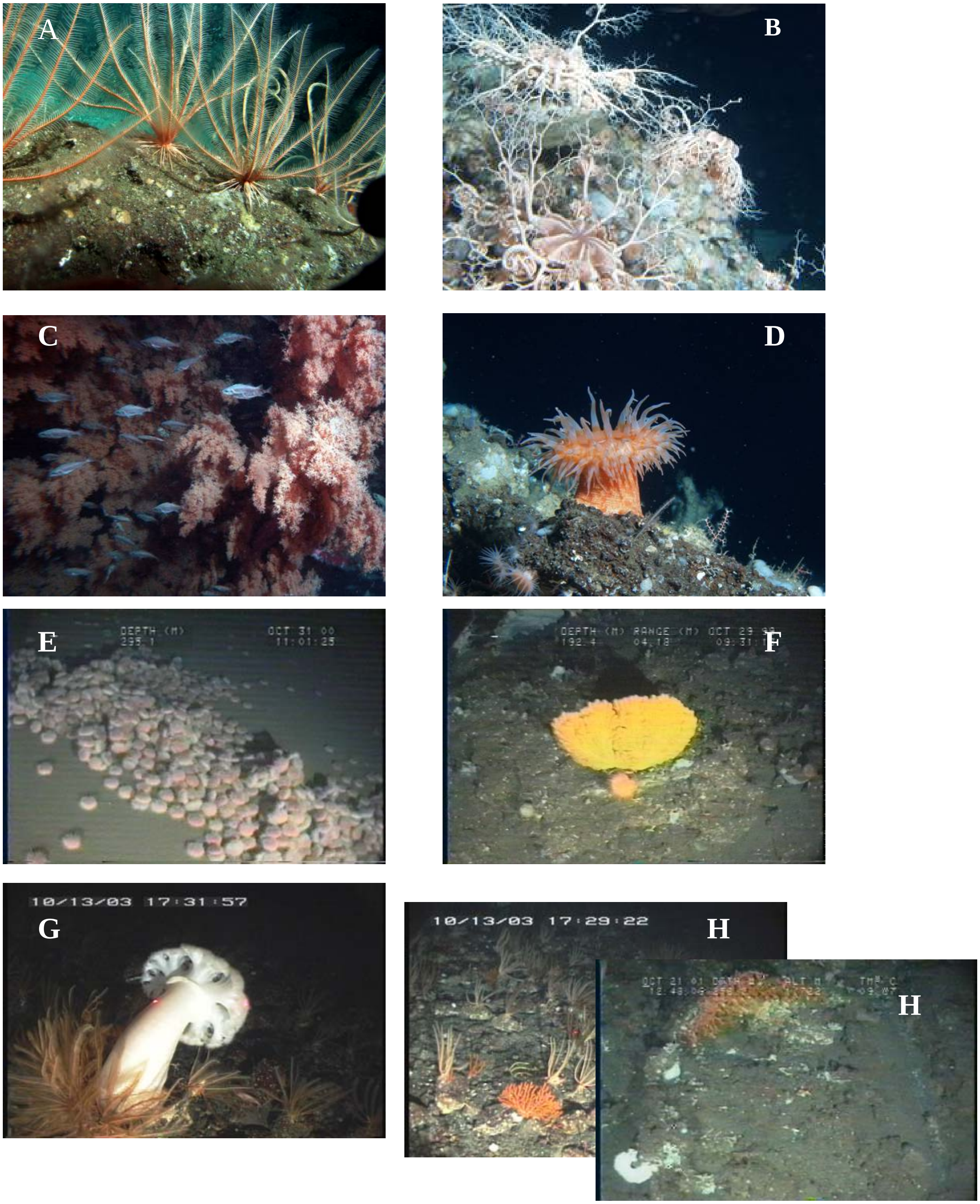

Figure 6. (A) crinoids (*Florometra serratissima*), (B) basket stars (*Gorgonocephalus eucnemis*), (C) black coral (*Antipathes dendrochristos*), (D) anemone (Stompia sp.), (E) fragile sea urchin (*Allocentrotus fragilis*), (F) fan coral, (G) metridium (*Metridium gigantium*), (H) gorgonians (Gorgonacea)

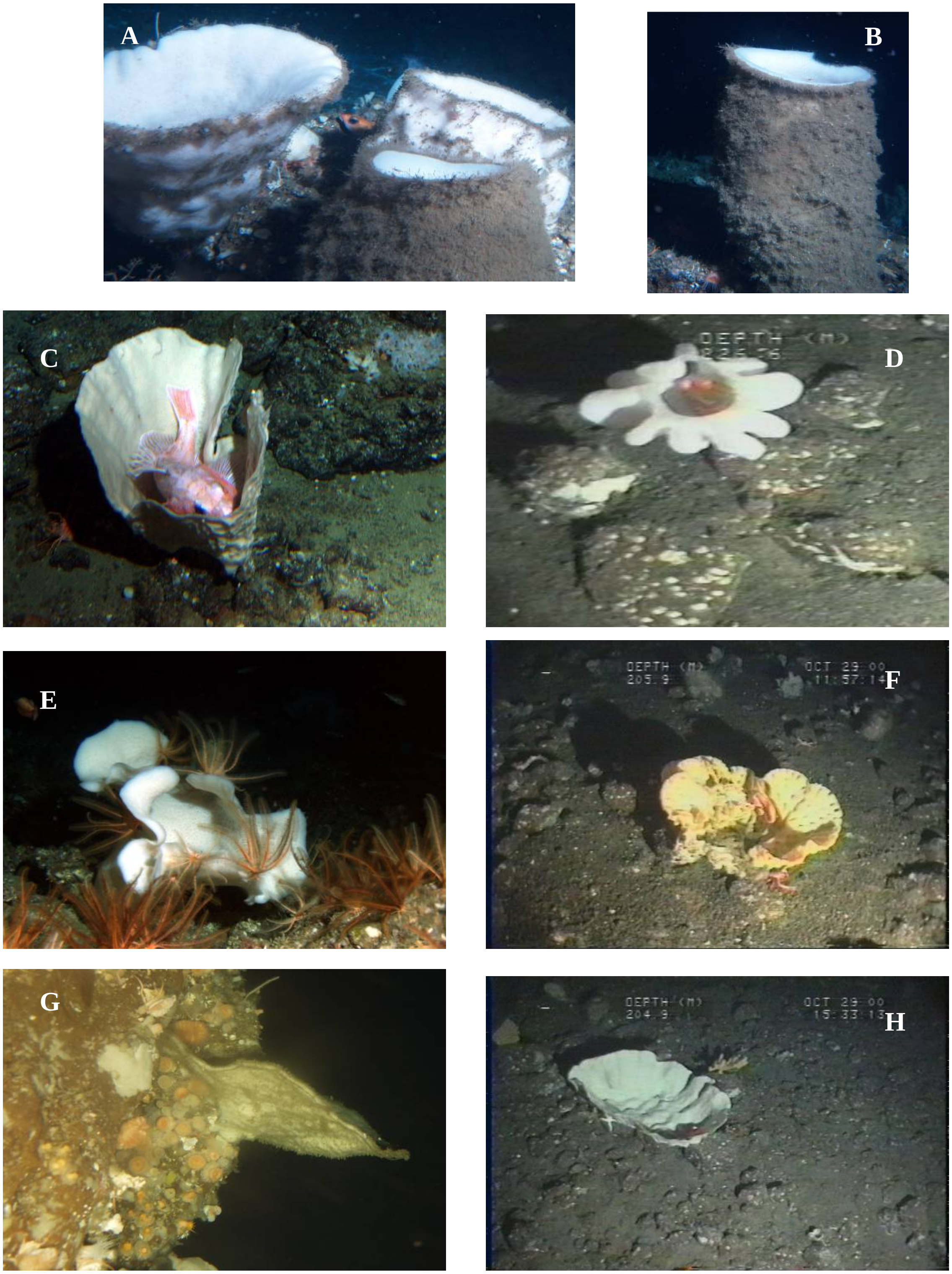

Figure 7. Structure-forming invertebrates- sponges: (A) barrel sponges, (B) hairy barrel sponge, (C) vase sponge with fish inside, (D) scalloped edge vase sponge, (E) foliose sponge, (F) yellow foliose sponge, (G) shelf sponge, (H) upright sponge

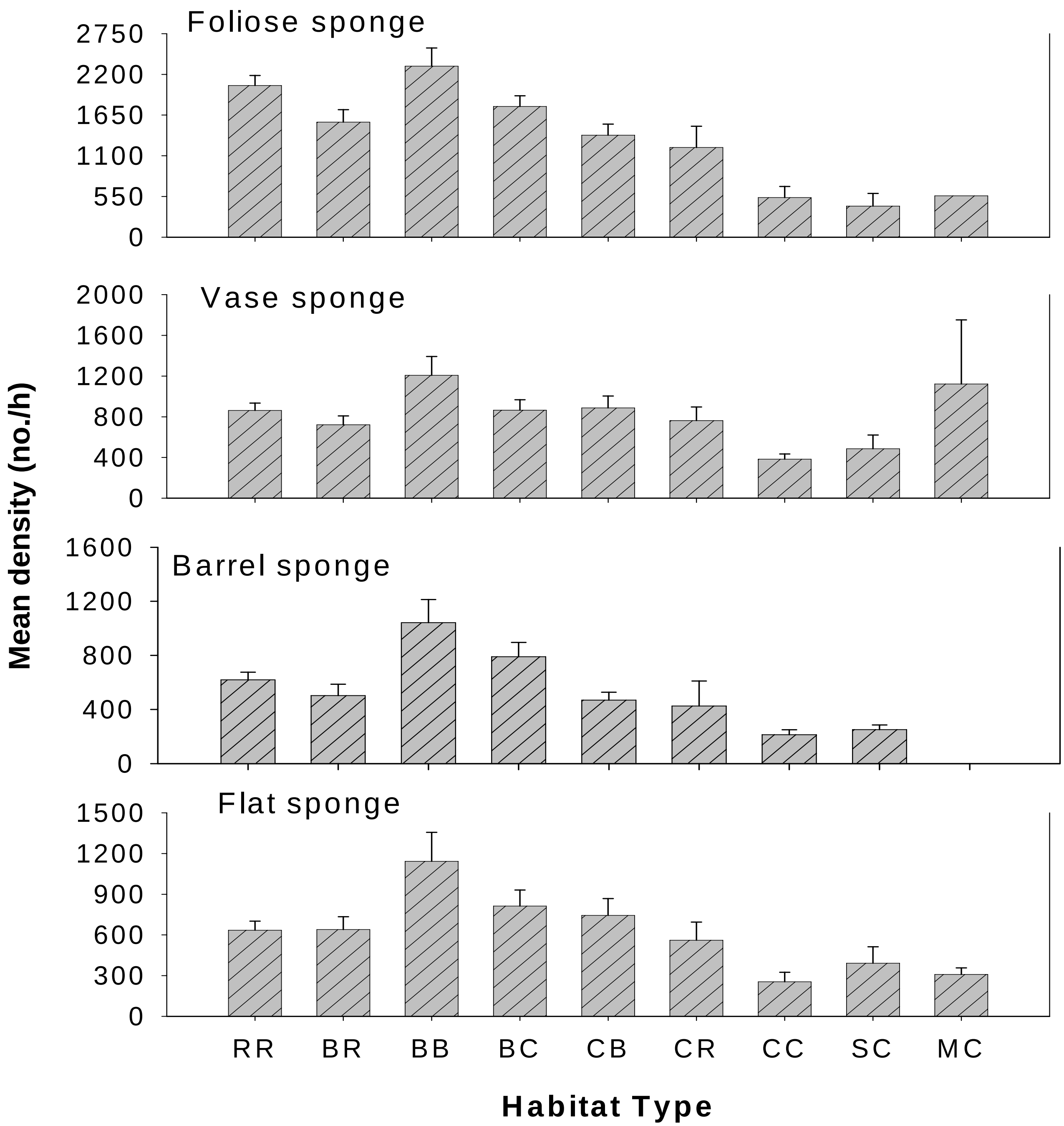

Figure 8. Invertebrate density (#/h) with standard error by substrate type for foliose, vase, barrel and flat sponges.

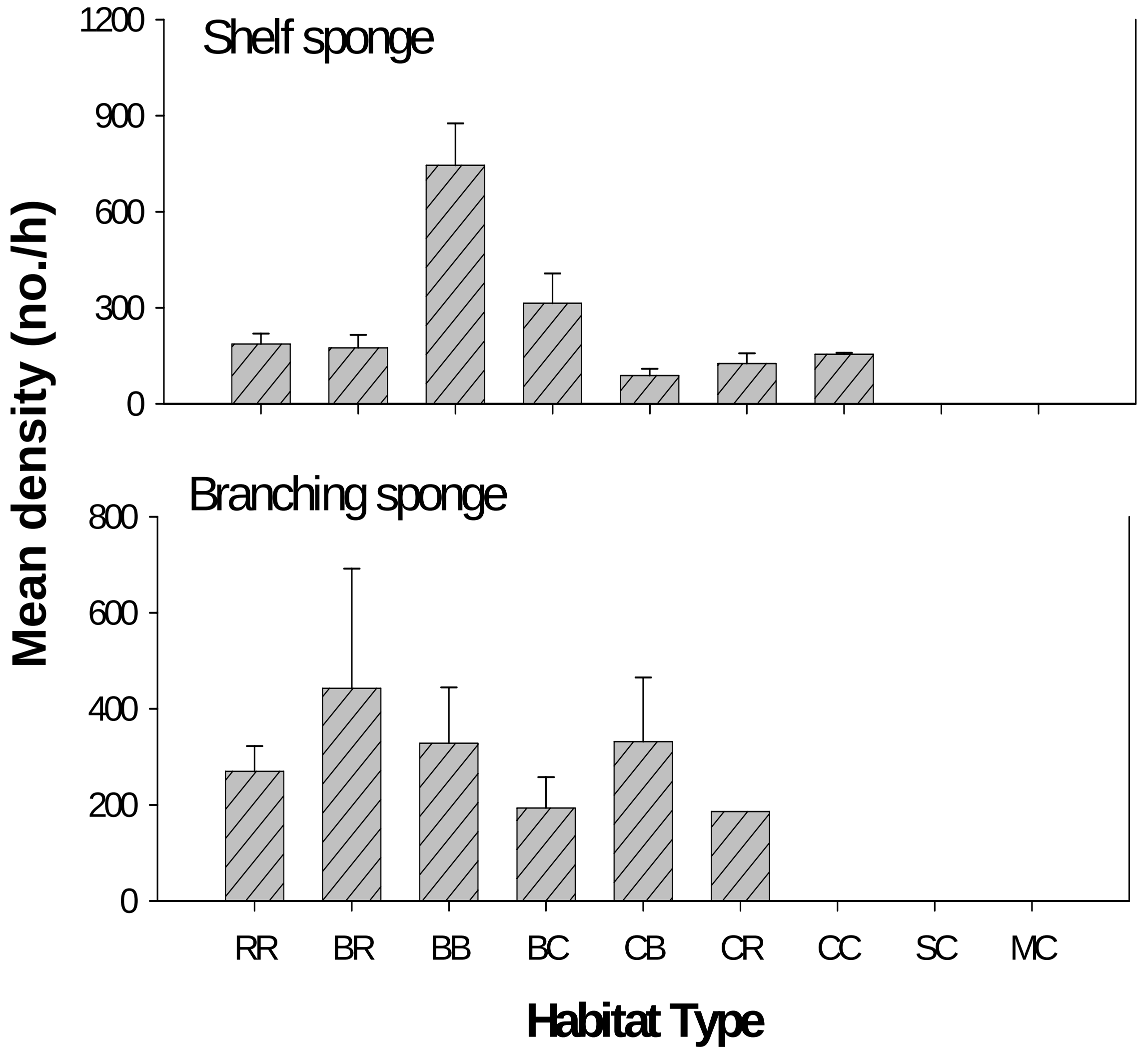

Figure 9. Invertebrate density (#/h) with standard error by substrate type for shelf and branching sponges.

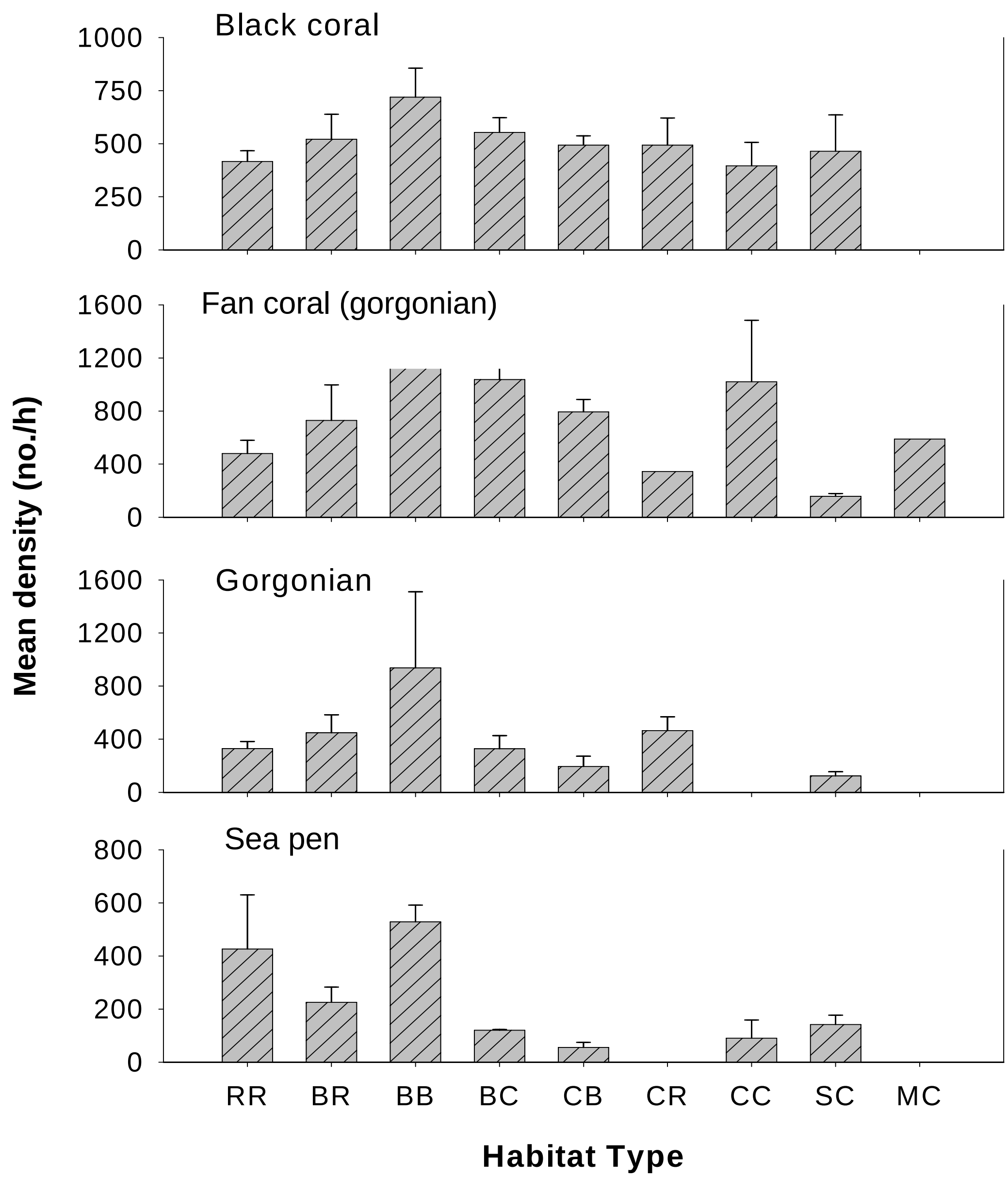

Figure 10: Invertebrate density (#/h) with standard error by substrate type for black coral, fan coral (gorgonian), gorgonian and sea pen.

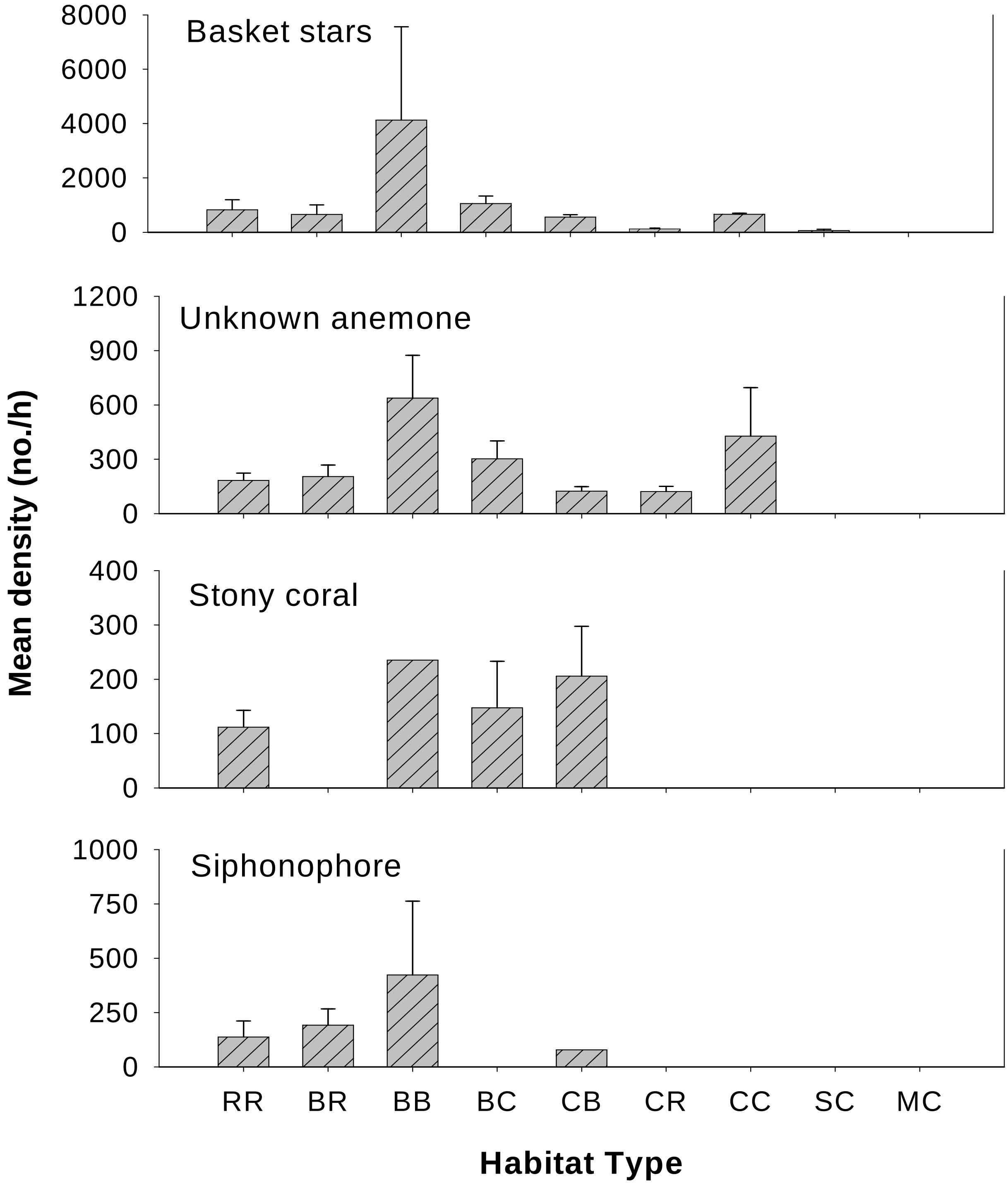

Figure 11: Invertebrate density (#/h) with standard error by substrate type for basket star, anemone, stony coral and siphonophore.

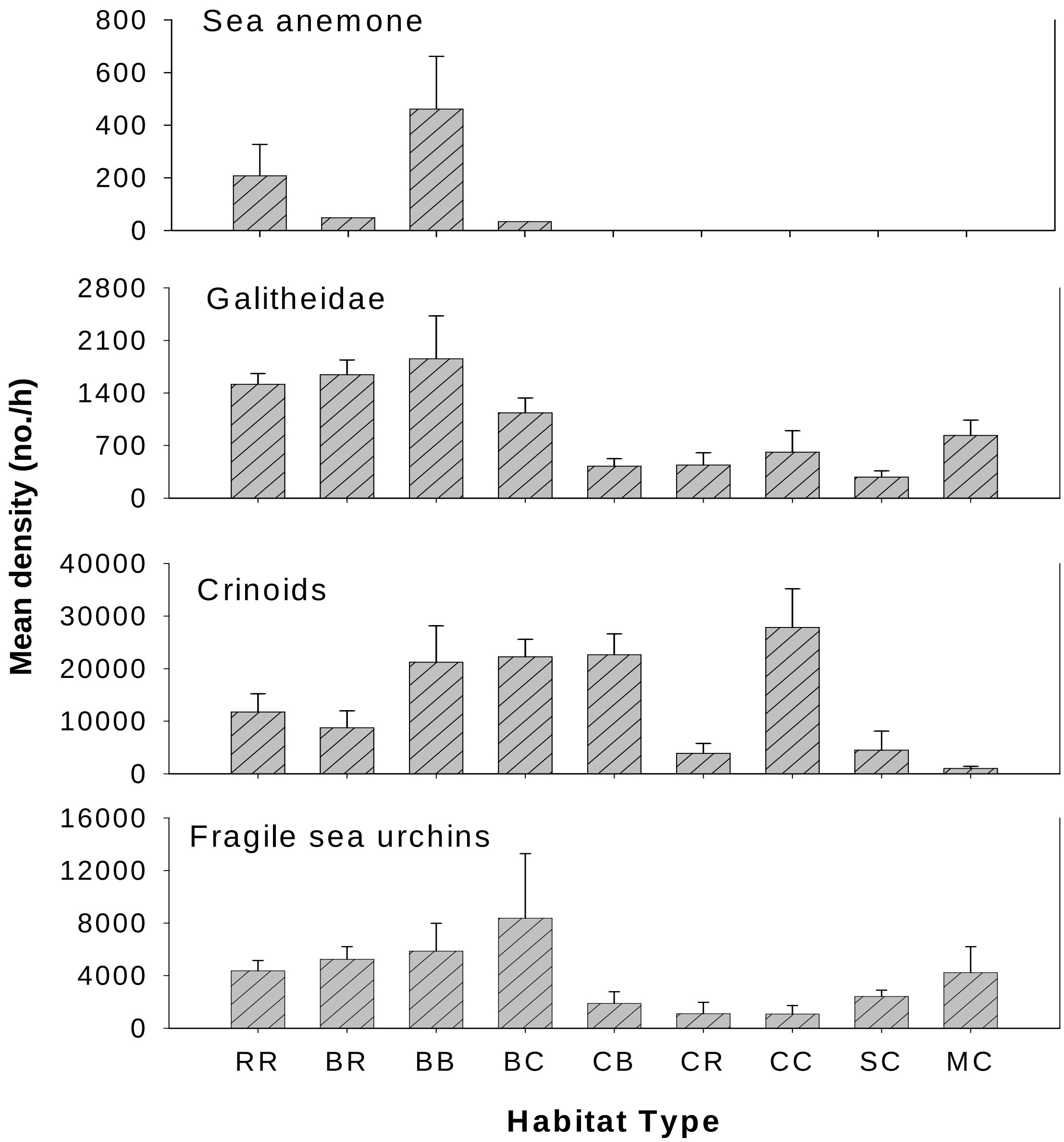

Figure 12: Invertebrate density (#/h) with standard error by substrate type for sea anemone, galatheid crab, crinoid and fragile sea urchin.

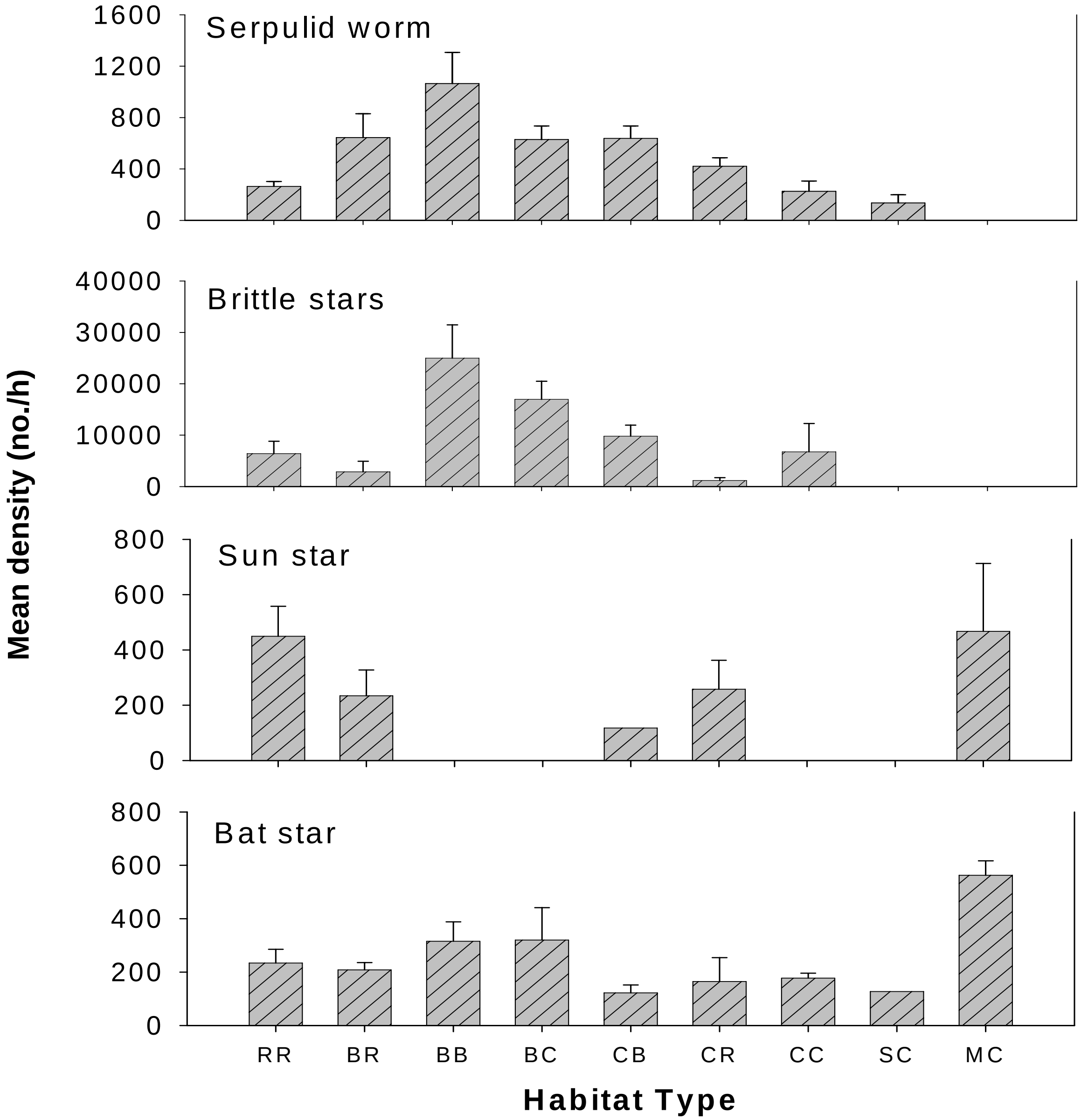

Figure 13: Invertebrate density (#/h) with standard error by substrate type for serpulid worm, brittle star, sun star and bat star.

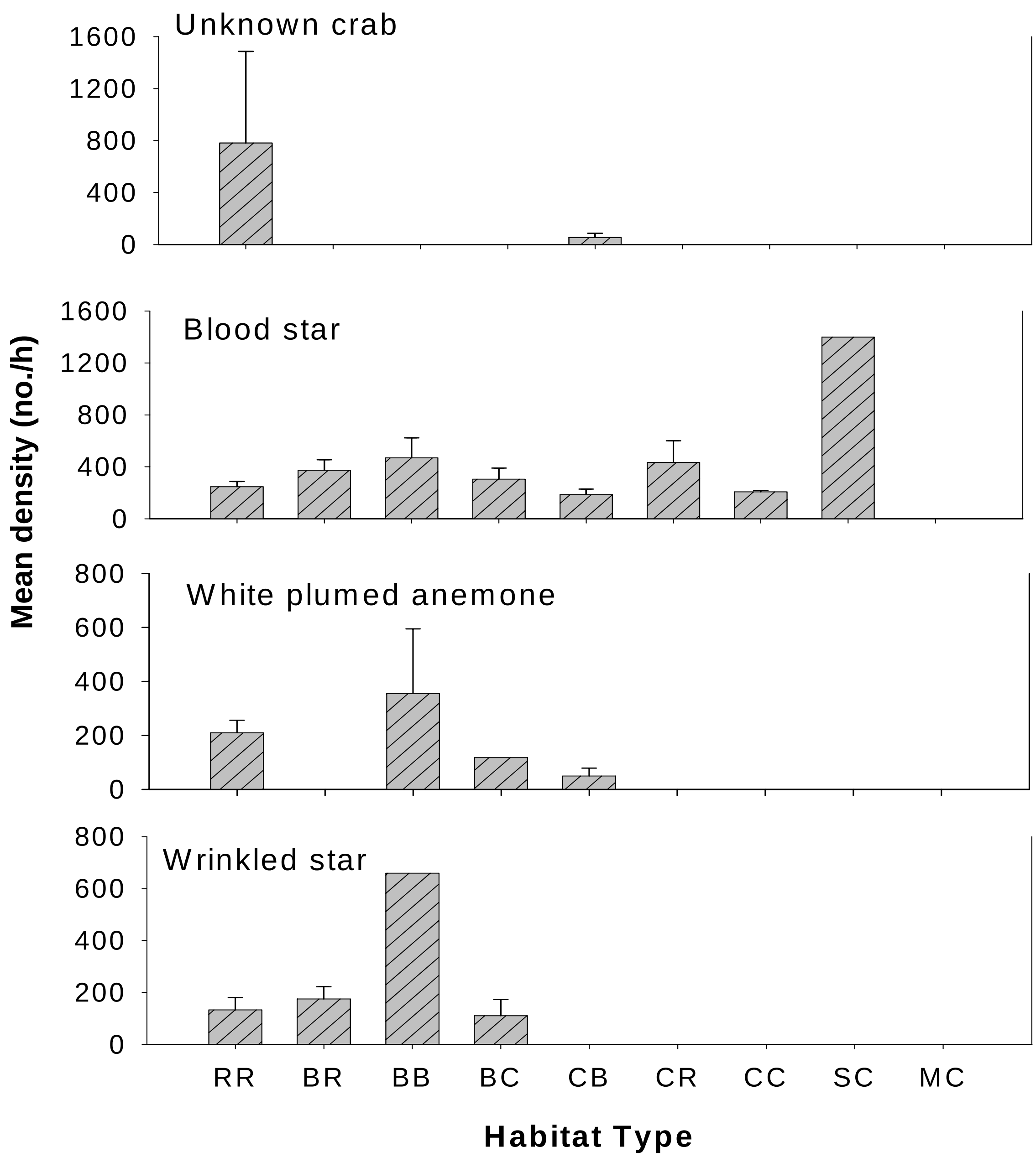

Figure 14: Invertebrate density (#/h) with standard error by substrate type for unknown crab, blood star, white plumed anemone and wrinkled star.

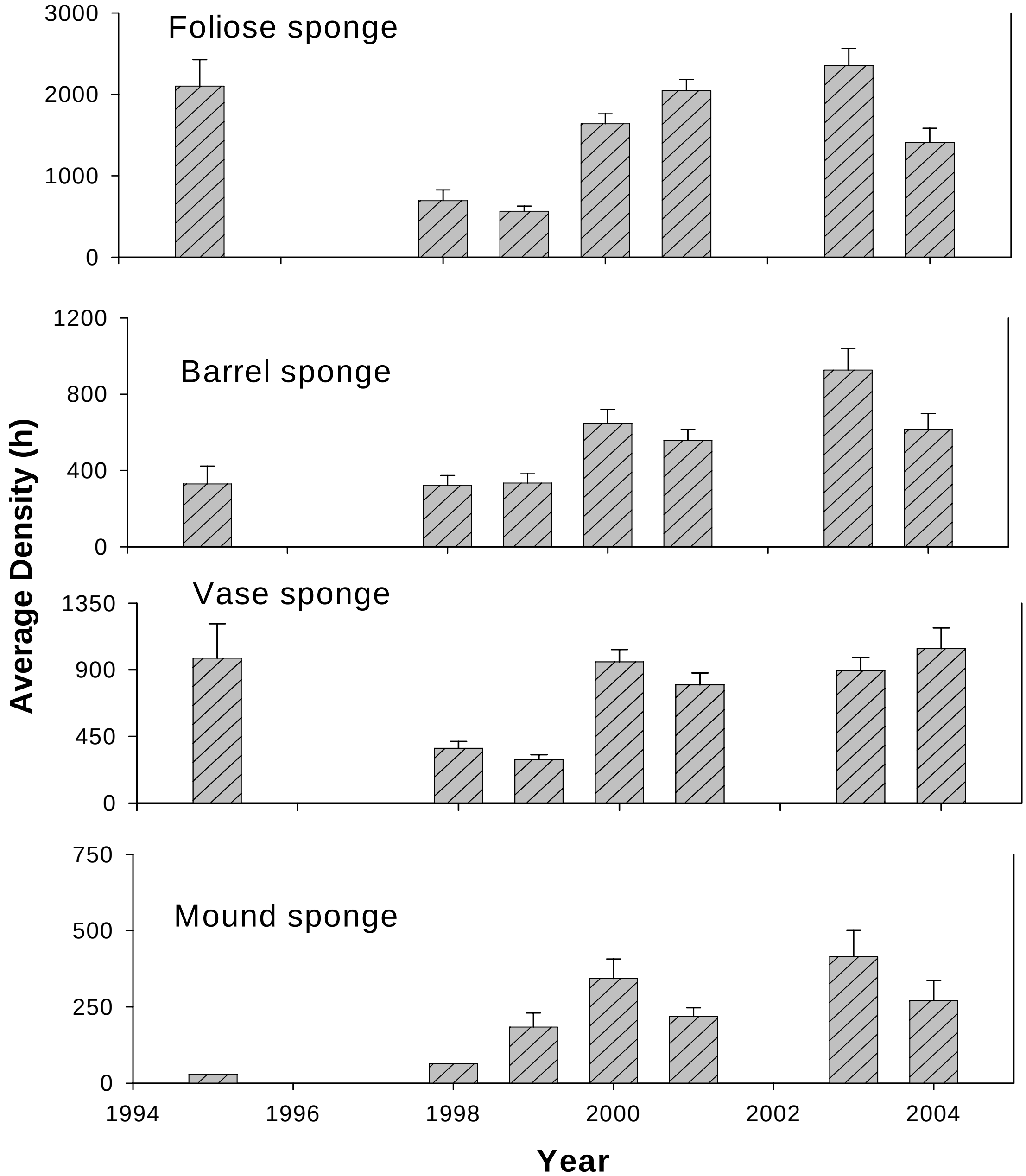

Figure 15: Invertebrate density (h) patterns between 1995 – 2004 for foliose, barrel, vase and mound sponges.

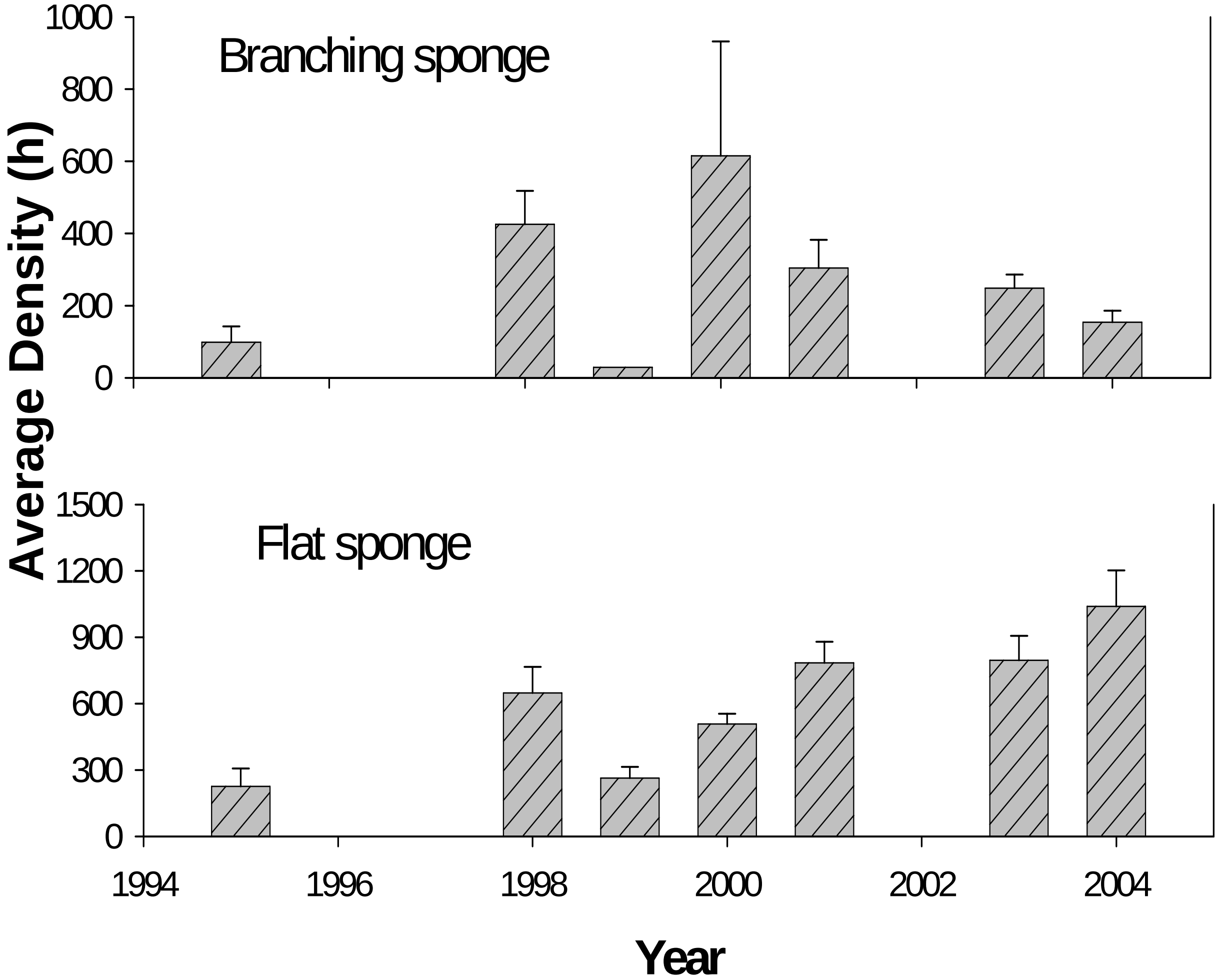

Figure 16: Invertebrate density (h) patterns between 1995 – 2004 for branching and flat sponges.

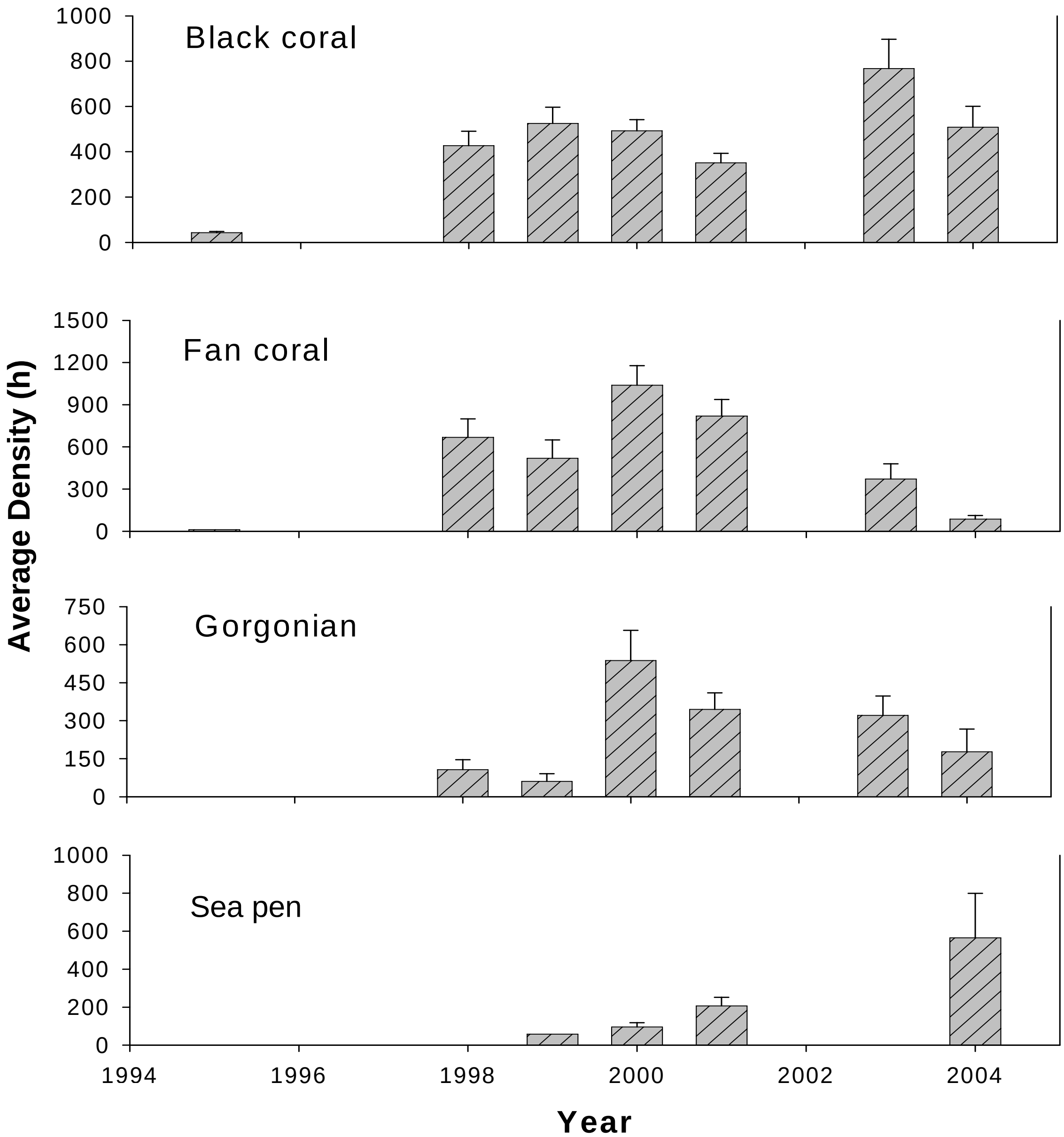

Figure 17: Invertebrate density (h) patterns between 1995 – 2004 for black coral, fan coral (gorgonian), gorgonian and sea pen.

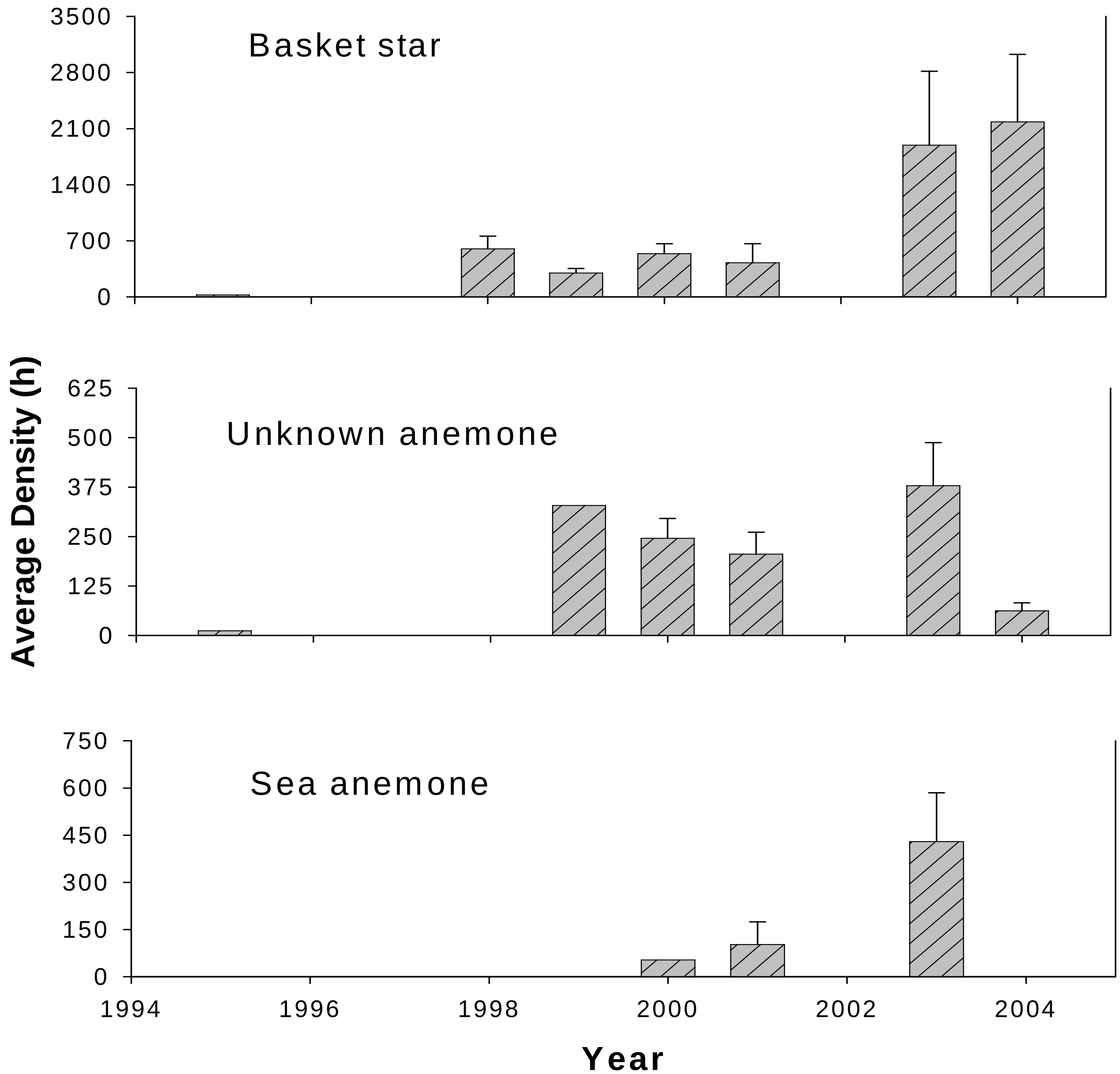

Figure 18: Invertebrate density (h) patterns between 1995 – 2004 for basket star, unknown anemone and sea anemone.

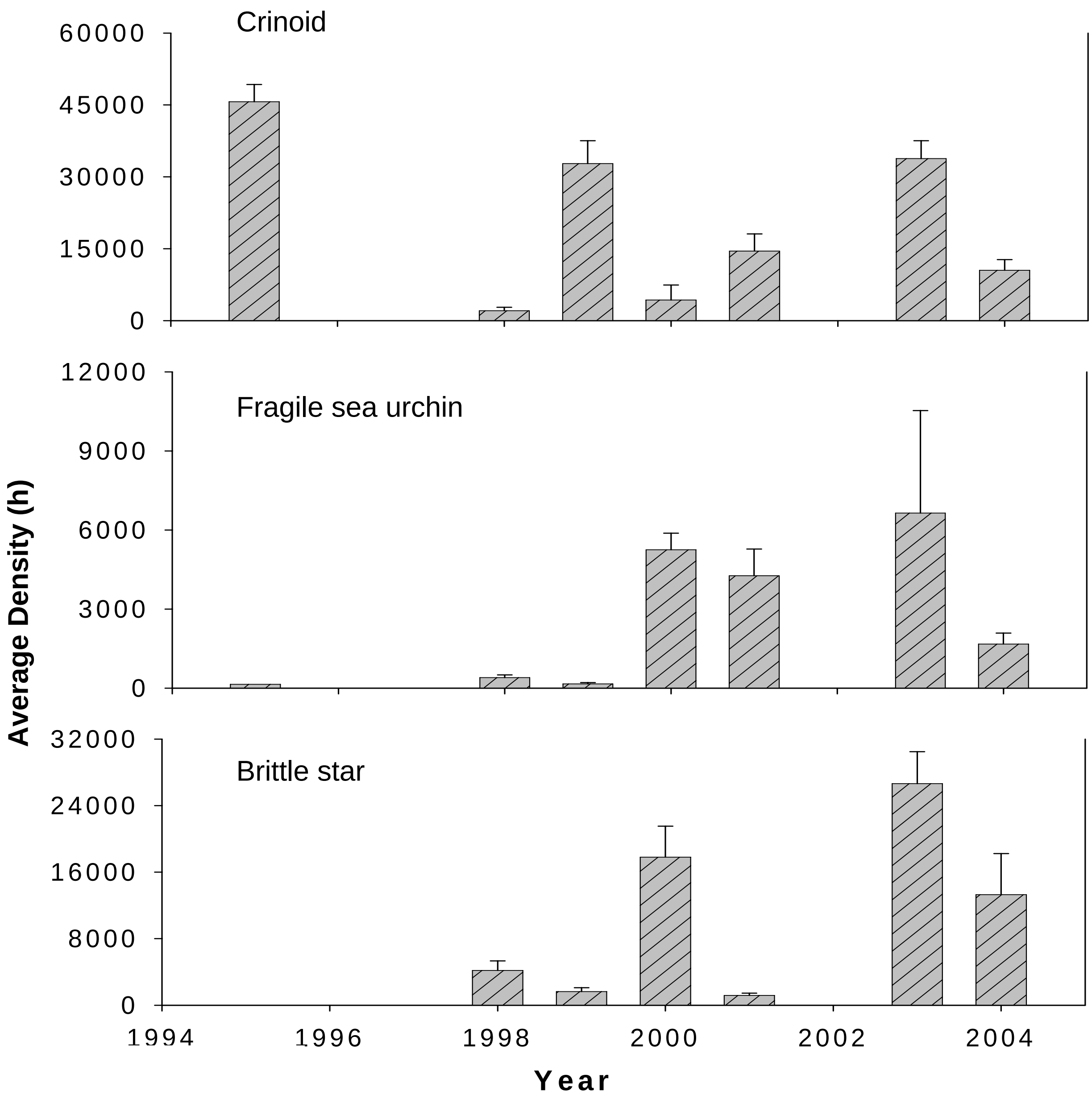

Figure 19: Invertebrate density (h) patterns between 1995 – 2004 for crinoid, fragile sea urchin, and brittle star.

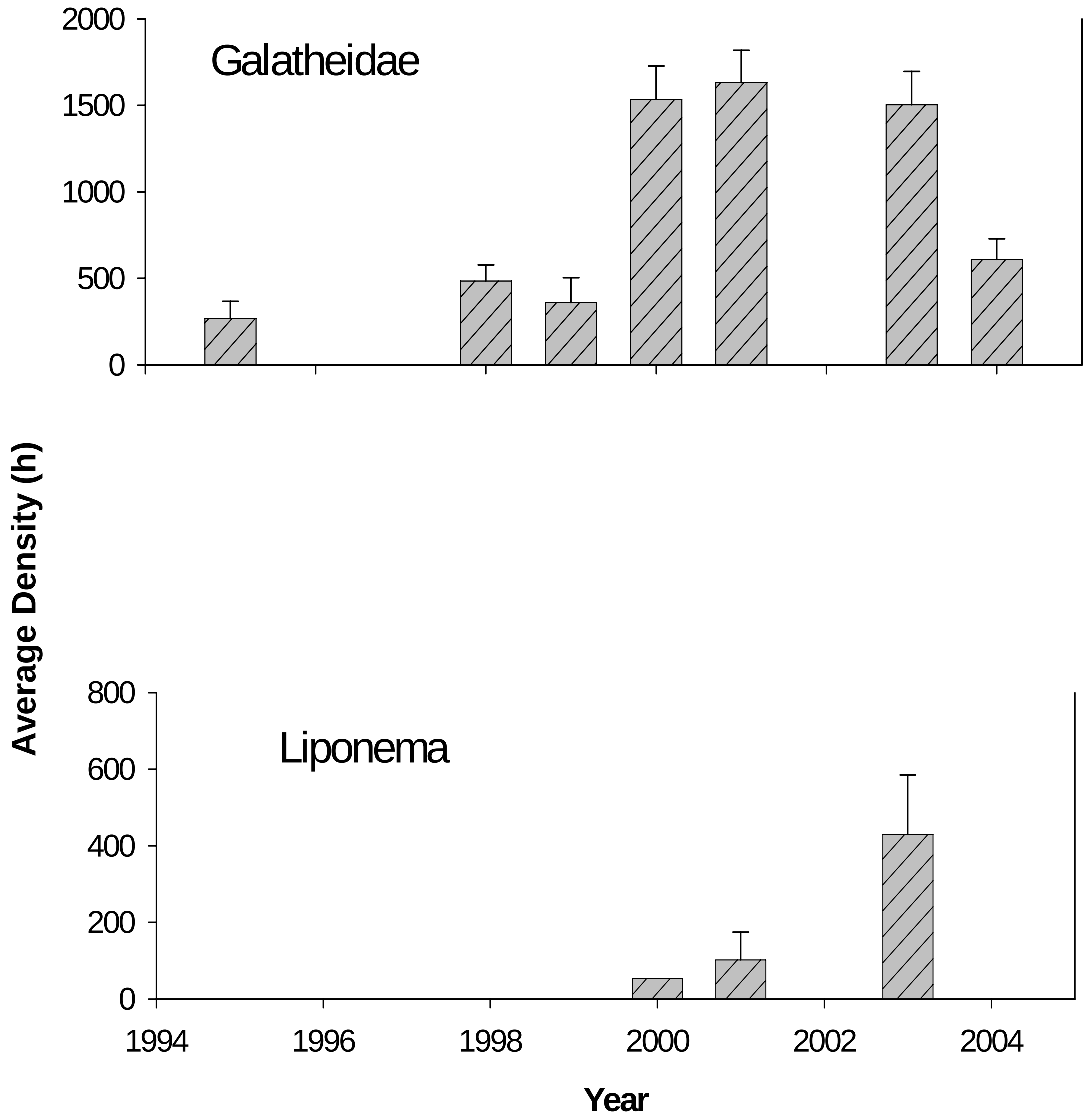

Figure 20: Invertebrate density (h) patterns between 1995 – 2004 for galitheidae and liponema.

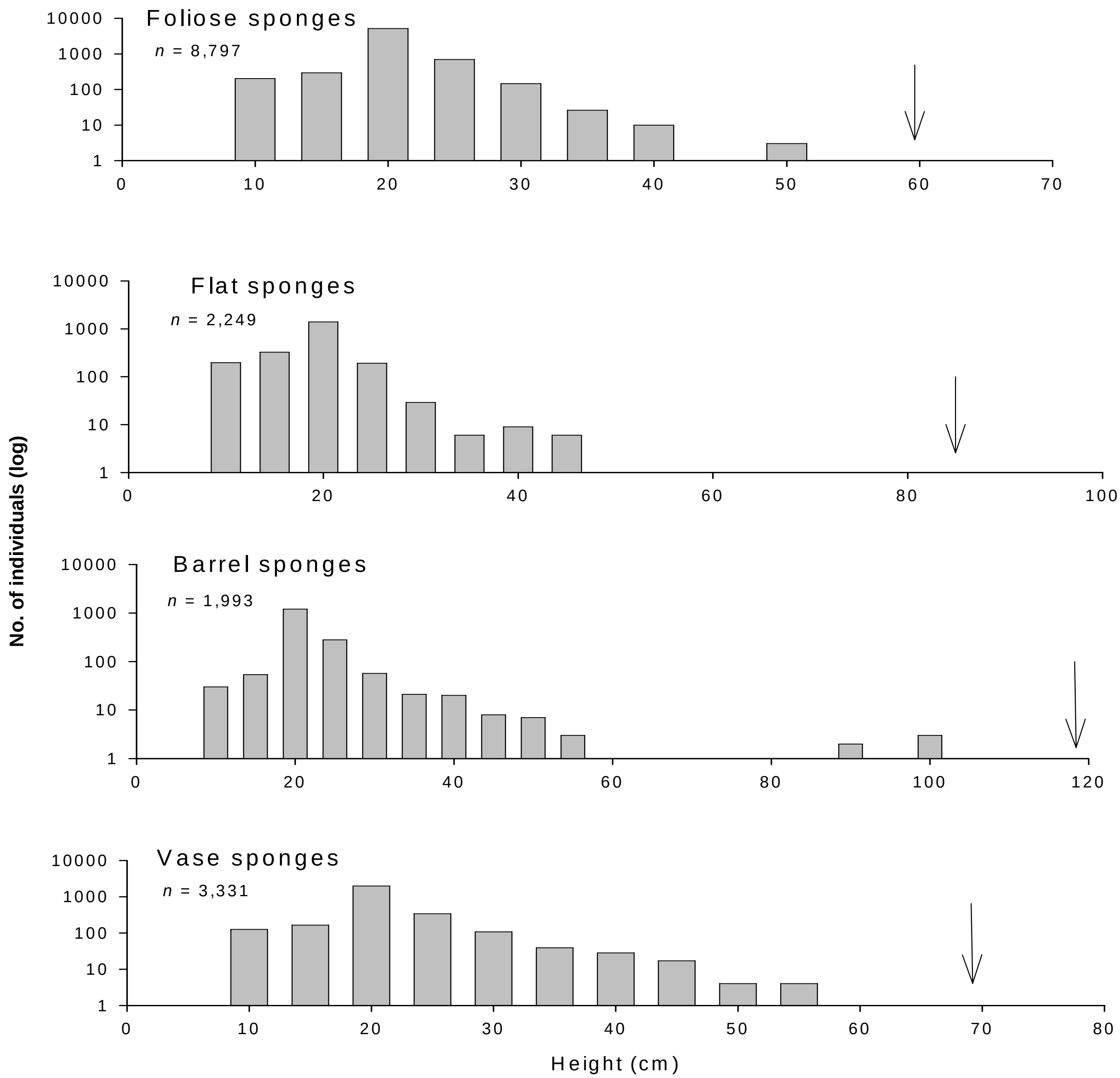

Figure 21: Number of individual invertebrates listed by size for foliose, flat, barrel and vase sponges. Arrows indicate largest size observed for each invertebrate.

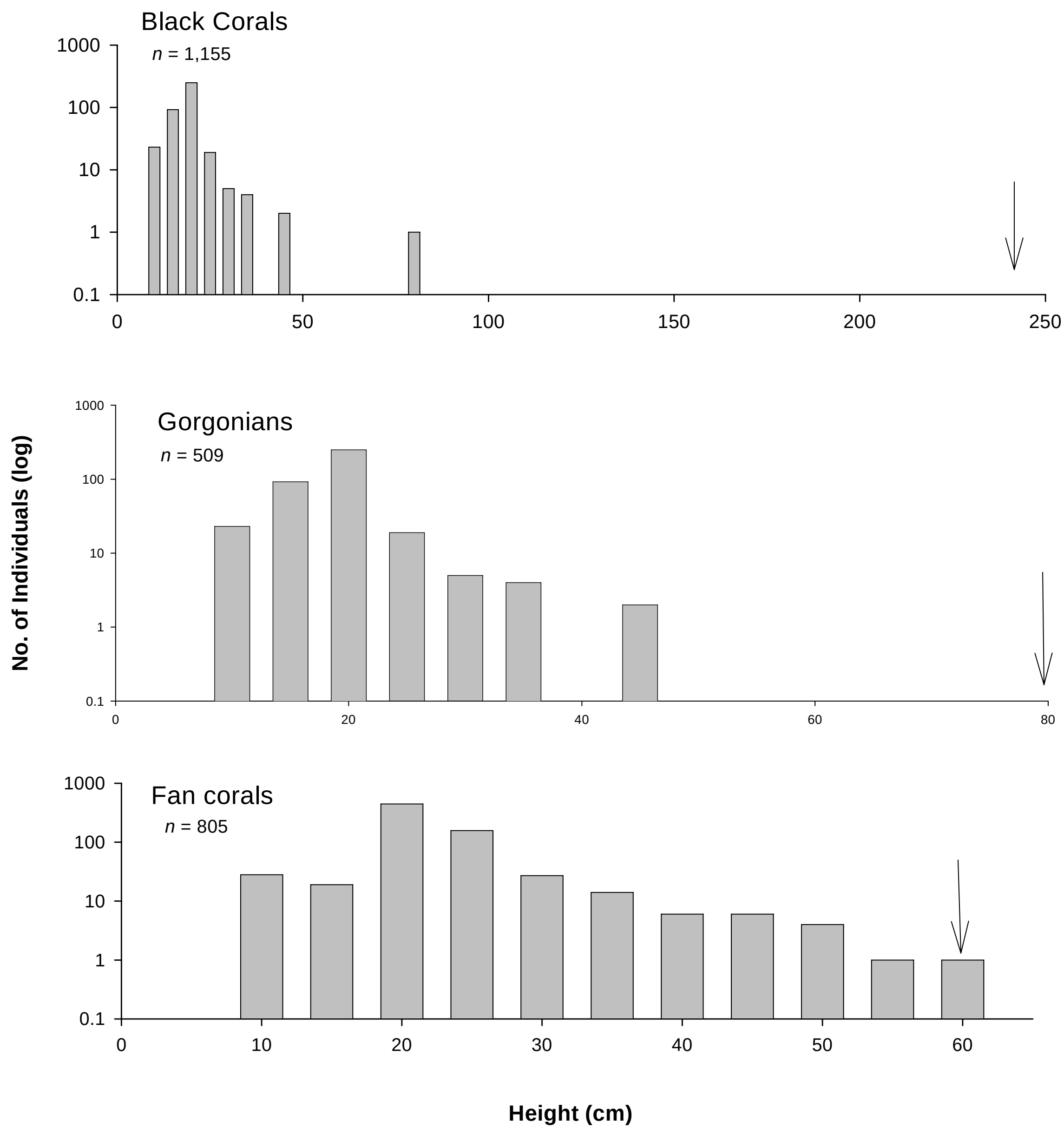

Figure 21: (Cont.) Number of individual invertebrates listed by size for black corals, gorgonians and fan corals (gorgonians). Arrows indicate largest size observed for each invertebrate.

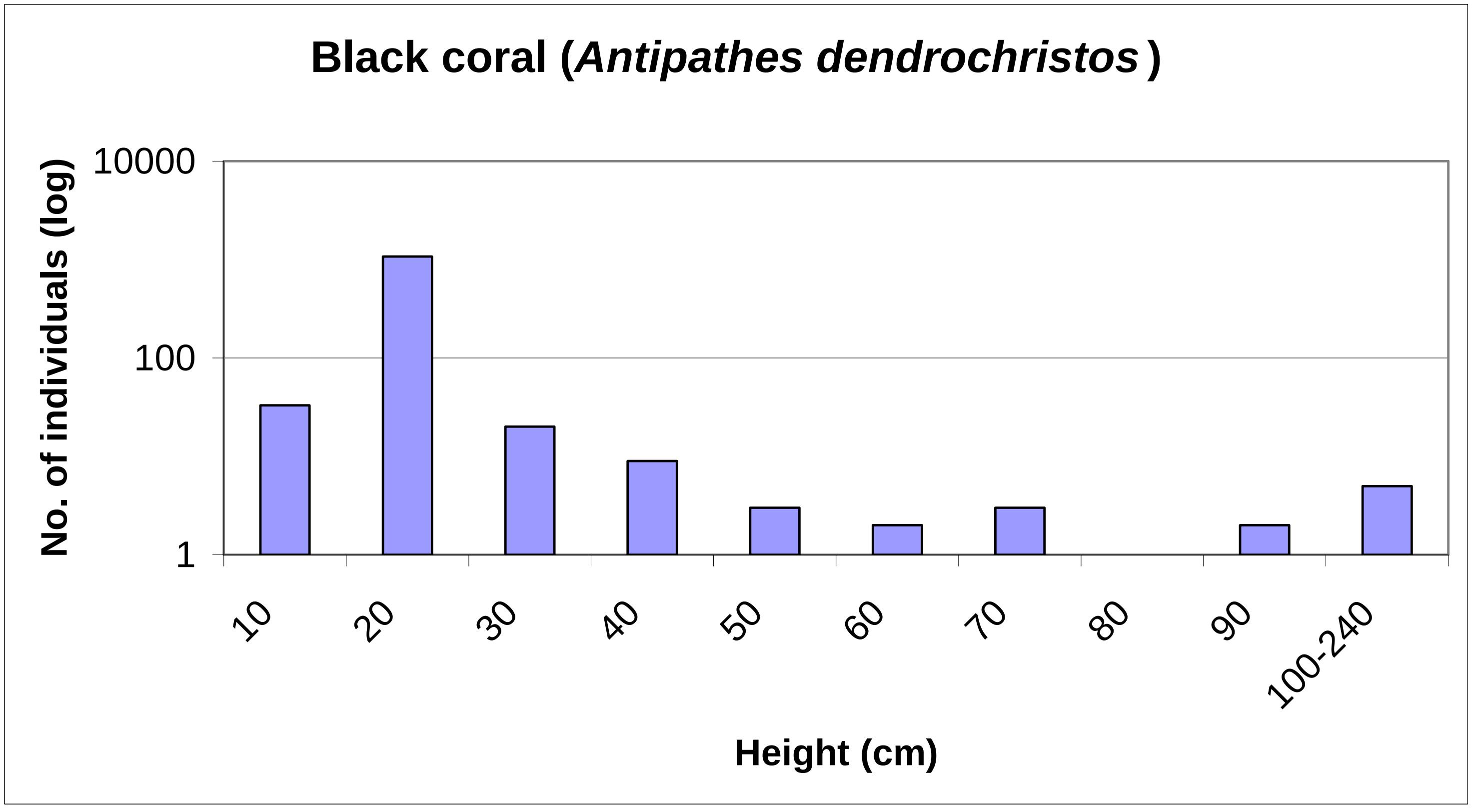

Figure 22. Size distributions for black corals (*Antipathes dendrochristos*) at the Footprint.

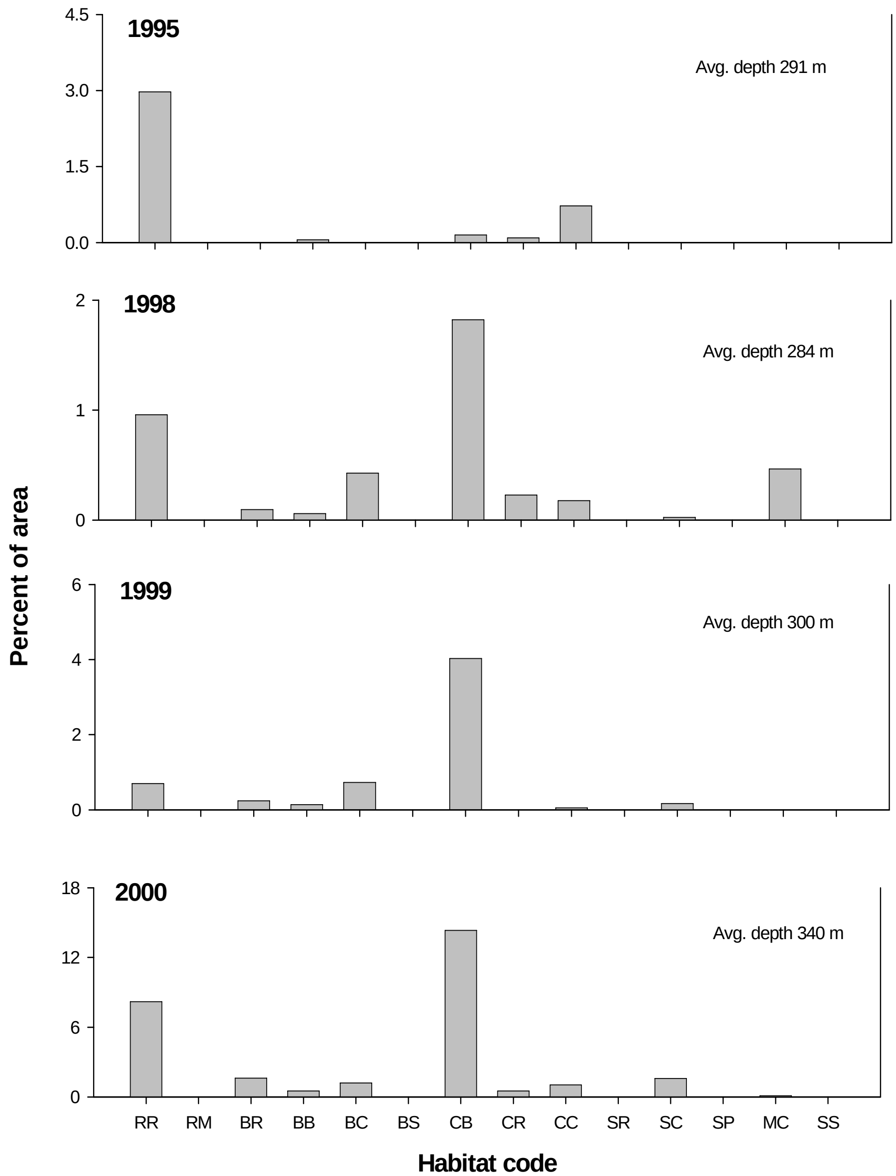

Figure 23: The percent of area, habitat type and average depth for 1995, 1998, 1999, and 2000 at the Footprint.

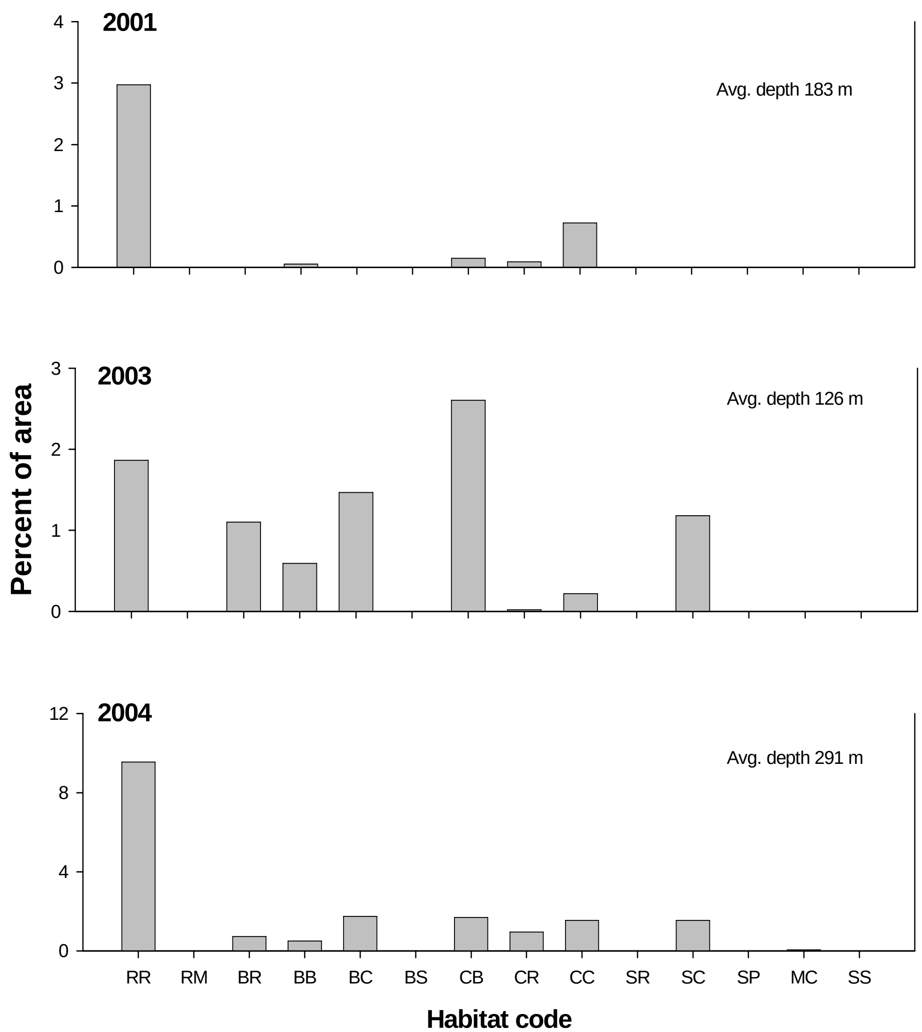

Figure 23: (Cont.) The percent of area, habitat type and average depth for 2001, 2003 and 2004 at the Footprint.