BY AMY R. BACO

Exploration for Deep-Sea Corals on North Pacific Seamounts and Islands

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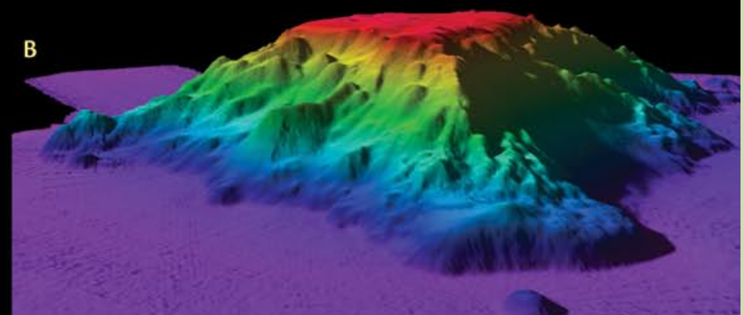

Figure 1. Seamounts resemble mountains on the seafloor. (A) Bathymetry of northern chain of seamounts in the Gulf of Alaska, explored in 2004. *Image credit: Peter Etnoyer, Aquanautix.* (B) Welker Seamount bathymetry. *Image Credit: Chaytor et al 2007.* (C) Ely (left) and Giacomini (right) bathymetry from the northern chain of the Gulf of Alaska seamounts. *Image Credit: Chaytor et al 2007*

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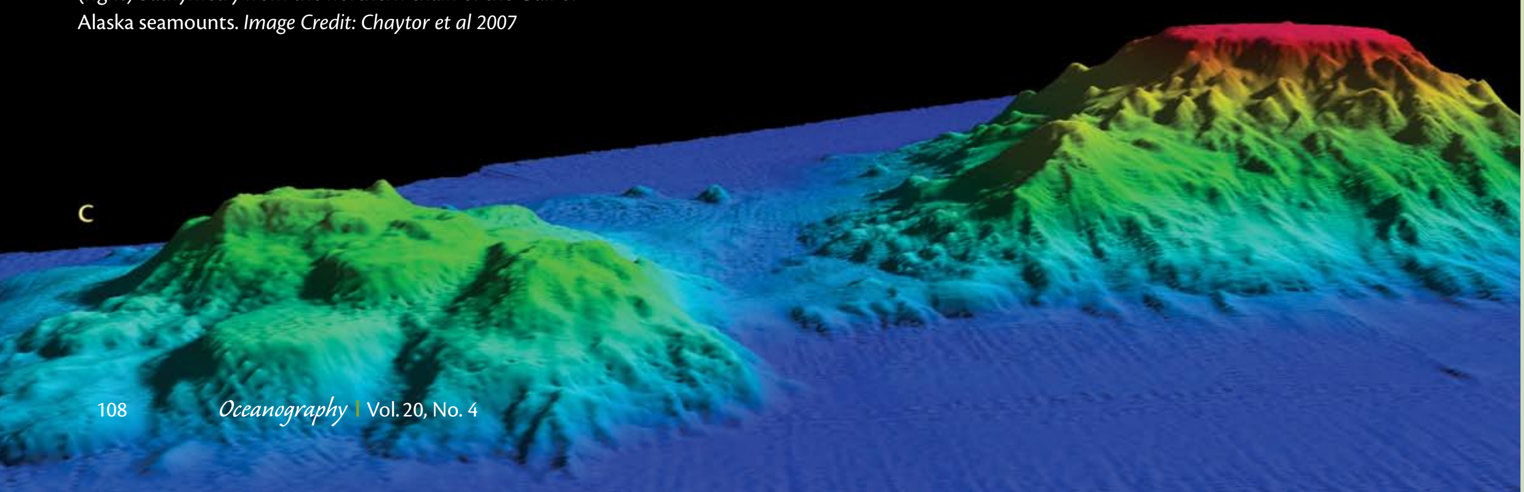

SEAMOUNTS ARE mountains that rise from the seafloor. The technical geological definition of a seamount is a steep-sided feature with greater than 1000 m of relief compared to the surrounding sea bottom (Figure 1) (reviewed in Kitchingman and Lai, 2004). Seamounts go by a variety of names, including tablemounts, guyots, and banks, depending on their specific morphology. Although they are not considered seamounts, oceanic islands and atolls are essentially seamounts that breach the sea surface. At least 50,000 seamounts are distributed throughout the world's ocean (reviewed in Kitchingman and Lai, 2004), with more than half of these occurring in international waters.

Seamounts and oceanic islands provide benthic habitat in otherwise pelagic realms. For larvae of a benthic organism spawned on a seamount, the next closest benthic habitat could be hundreds of kilometers distant. In addition to the physical isolation of distance, some seamounts have specialized currents over or around them called Taylor columns or Taylor caps, which are thought to retain larvae over the seamount (reviewed in Rogers, 1994). Life-history strategies may also play a role in isolating seamount fauna. For example, on Cobb Seamount in the North Pacific, studies show a higher proportion of organisms with limited larval dispersal abilities than on shelf and slope habitats at the same latitude (Parker and Tunnicliffe, 1994).

For these reasons, seamounts are thought to be highly isolated habitats and are hypothesized to be locations of high levels of speciation in the deep sea. This is supported by discoveries of high levels of species endemism on several groups of seamounts (e.g., Parin et al., 1997; De Forges et al., 2000; Koslow et al., 2001). The isolation of seamounts makes them of interest to scientists studying speciation, evolution, biogeography, population connectivity, and ecology in the marine environment in the same way oceanic islands are of interest to terrestrial biologists interested in these processes on land.

The hard-bottom habitats of seamounts often harbor a diverse array of invertebrate fauna (e.g., Parin et al., 1997; De Forges et al., 2000; Stocks, 2004), dominated by suspension feeders, particularly deep-sea corals and sponges. In fact, deep-sea corals (see Box 1) are the most diverse invertebrate group on seamounts (Stocks, 2004). They dominate in both abundance (Genin et al., 1992; Rogers, 1994) and biomass (Probert et al., 1997). Corals are also important habitats for invertebrates and potentially fishes (e.g., Jensen and Frederiksen, 1992; Krieger and Wing, 2002).

During breeding, spawning, and feeding periods, some fishes (e.g., orange roughy and pelagic armourhead) are known to congregate around seamounts (e.g., Clark, 2001). Fisheries for these species utilize large trawl nets dragged across the seamount surfaces. An estimated 2.25 million tons of fishes have been removed from worldwide seamounts since these fisheries began in the 1970s (Clark et al., 2007). Not only do these fisheries impact the target fish species, but they are also highly destructive to benthic habitats of seamounts, scraping away all the benthic fauna, including entire deep coral and invertebrate communities. Given the high levels of endemicity found in seamount fauna, and the fact that very few have been explored, trawling may have resulted in the permanent loss of high numbers of undocumented species from the world's ocean (e.g., Koslow et al., 2001).

Concerns about the destructive nature of trawling and associated potential loss of biodiversity (e.g., Koslow et al., 2001) along with an international interest in deep-sea coral ecosystems have led to a recent surge of research on and exploration of poorly studied seamount environments. A portion of this work focuses on the relatively pristine seamounts of the North Pacific.

EXPLORATION OF SEAMOUNTS AND ISLANDS OF THE HAWAIIAN ARCHIPELAGO

The Hawaiian Archipelago is of hotspot origin and includes many islands, banks, ridges, and seamounts, extending 1500 km from the Big Island to the Emperor seamount chain. Most people think of scleractinian reef-forming corals when they think of Hawaii. However, most of the major deep-sea coral groups are known to exist in the Hawaiian Archipelago, and the group known as octocorals are, in fact, far more diverse in Hawaii than are shallow, warm-water scleractinians.

Within the Hawaiian Archipelago, there are three species of precious corals: two octocorals (*Corallium secundum*, *Corallium lauuense*) and an undescribed zoanthidean in the genus *Gerardia* (Figure 2). These three species occur at depths of 350–575 m throughout the Hawaiian Archipelago and into the Emperor seamount chain. These corals are termed precious corals because they have been commercially harvested and their skeletons are used to make jewelry and curios. Species in these same genera are also harvested in the western Pacific and Mediterranean (reviewed in Grigg, 1993). Research on precious corals in Hawaii began in the 1960s when they were actively harvested (Grigg, 1993). This work also led to the discovery and documentation of over 100 species of deep-sea corals in Hawaii, primarily gorgonian octocorals (Grigg and Bayer, 1976). The coral fisheries in Hawaii ended in 1978 because of high operating costs. Research on Hawaiian deep-sea corals then tapered off with the end of the fishery.

In 1998, the availability of one-person submersibles led to speculation about the feasibility of profitable selective harvest of precious corals in Hawaii. This, along with a budding international interest in deep-sea corals and seamounts, brought about the resurgence of research on deep-sea corals in the Hawaiian Archipelago. Scientific interest initially focused on several topics: (1) use of precious corals as model organisms to test the theories of isolation of seamounts as well as to define the stock structure of the harvested species to help manage the fishery (Baco and Shank, 2005; Baco et al., 2006), (2) the role of corals as habitat for fishes and the endangered Hawaiian monk seal (Parrish et al., 2002), and (3) determination of recovery from previous harvests (reviewed in Grigg, 2002). These studies targeted the main Hawaiian Islands (east to west, Hawaii Island to Kauai), Cross Seamount, and the northwestern Hawaiian Islands (NWHI) as far as Brooks Banks. All studies were conducted at precious-coral depths.

In 2003, the National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean Exploration (OE) funded the first major deep-sea submersible and remotely operated vehicle (ROV) expedition to the far NWHI. The goals of the second leg of this cruise were to explore for new locations of precious corals to expand the genetic connectivity studies begun in the main Hawaiian Islands (Baco and Shank, 2005; Baco et al., 2006), to collect specimens to study the reproductive biology of precious corals (Waller and Baco, 2007), and to explore for corals below precious-coral depths on three newly mapped seamounts (Smith et al., 2004; Baco et al., 2005).

None of the sites visited on this cruise had been previously observed or sampled in situ. Not surprisingly, the explorations revealed many species of corals new to science, including eight new species of octocorals, two new genera and several new species of antipatharians (Dennis Opresko, Oak Ridge National Observatory, *pers. comm.*, October 10, 2004), three new stylasterid

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BOX 1. CATEGORIES OF CORALS

Most people think of warm, tropical coral reefs when they think of corals. However, "coral" is actually a common term for a diverse array of Cnidarian taxa (see summary below). Corals occur from the Arctic to the Antarctic and down to depths of at least 6000 m (Keller, 1976). The corals that form coral reefs fall into the Scleractinia. Ironically, scleractinians are actually more diverse in deep and cold water than they are in the tropics. In the North Pacific, octocorals and antipatharians are more abundant and diverse on seamounts and islands in deep water than are the scleractinians.

"Coral" is a general term used to describe several different groups of animals in the Phylum Cnidaria. These animals have "the presence of skeletal material that is embedded in the living tissue or encloses the animal altogether" (NOAA's CoRIS glossary http://www.coris.noaa.gov/glossary/glossary_a_k.html#c). The following is a summary of current Cnidarian taxonomy, showing the primary groups containing animals referred to as "corals."

This taxonomic summary is based on the Tree of Life Web site (http://tolweb.org/tree?group=Cnidaria&contgroup=Animals) and the Octocorals Homepage Web site (http://www.calacademy.org/research/izg/OCTOHT.htm).

Phylum Cnidaria

Classes Cubozoa, Scyphozoa – do not contain corals

Class Anthozoa – corals, sea anemones, sea pens
- Subclass Alcyonaria (Octocorallia) – octocorals
  - Order Helioporacea – blue corals
  - Order Pennatulacea – sea pens
  - Order Alcyonacea – soft corals, sea fans, sea whips[1]
- Subclass Zoantharia (Hexacorallia) – sea anemones, stony corals
  - Order Scleractinia – stony corals or hard corals
  - Order Zoanthidea – zoanthids
- (Subclass Ceriantipatharia)
  - Order Antipatharia – black corals[2]

Class Hydrozoa – hydroids and hydromedusae
- Order Anthoathecatae
  - Family Stylasteridae – stylasterine hydrocorals
  - Family Milleporidae – fire corals

[1] Note: Sea fans and sea whips used to be placed in the order Gorgonacea and are often referred to as "gorgonians." This order has been combined with Alcyonacea.

[2] Note: Antipatharians are sometimes included in Zoantharia.

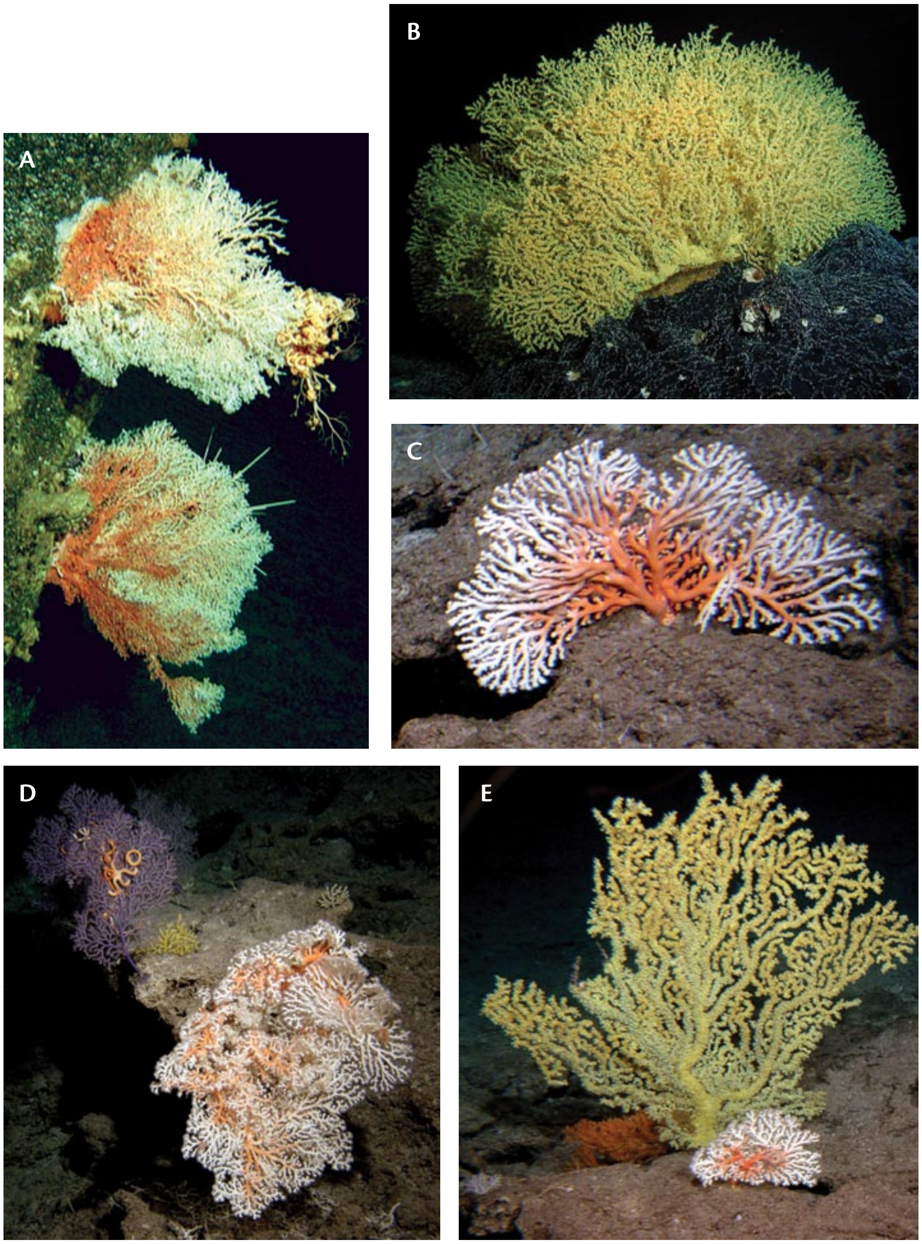

Figure 2. Three species of commercially harvested corals, called "precious corals," occur at depths of 350–600 m throughout the Hawaiian Archipelago: (A) the "red coral" *Corallium lauuense,* (B) the "gold coral" *Gerardia* sp., and (C) the "pink coral" *Corallium secundum.* (D) A particularly large colony of *C. secundum* (foreground) with an unidentified octocoral (purple coral in background, likely in the family Paramuriceidae) and a small acanthogorgiid octocoral (goldish coral in midview). (E) *Gerardia* sp. can also grow in a planar form, shown here with a small *C. secundum* and a small antipatharian. *Photos by A. Baco, T. Kerby, and M. Kremer, HURL and NOAA OE*

species (Cairns, 2005), one new zoanthid species, and several new records of Scleractinia (Cairns, 2006). Five new precious coral locations were also documented. Explorations of the deeper seamounts revealed that diverse communities of octocorals and antipatharians extended far below precious-coral depths.

A further exploratory cruise was conducted in 2004 to the main Hawaiian Islands and Cross Seamount (Figure 3). The focus of this study was to examine the habitat associations of invertebrates with octocorals and antipatharians within the precious-coral beds. Although these submersible dives were conducted in what are probably the most studied deep-sea coral beds in the world, at least three new species of octocorals and two new species of antipatharians (Opresko, 2005) were discovered. Specimens also provided range extensions (Stephen Cairns, Smithsonian Institution, *pers. comm.*, August 12, 2004) for several genera and species of corals that were not previously known from Hawaii. In fact, one of the new Hawaiian records, that of the genus *Paracalyptrophora*, is one of the dominant nonprecious corals at the Makappuu bed, a site which has seen in excess of 15 scientific deep-sea coral submersible dives, numerous ROV dives, and countless harvesting dives.

Therefore, although an extensive species list exists for the Hawaiian Archipelago, the high rate of discovery of new species and new records implies the archipelago is largely undersampled for deep-sea corals. Other invertebrate taxa associated with the corals and deep-sea sponges that are also abundant within these same habitats remain virtually untouched taxonomically.

EMERGING PATTERNS OF DISTRIBUTION OF HAWAIIAN DEEP-SEA CORAL COMMUNITIES

As discussed above, until 2003, the majority of studies in Hawaii were from sparse trawl data or had concentrated on the harvested black, gold, and pink corals; thus, much of our knowledge of deep-sea coral distribution is limited to these depths and species. However, with the 2003 and 2004 explorations, new patterns are beginning to emerge.

The Hawaiian Archipelago appears to be a diversity hotspot for deep-sea corals (Rogers et al., 2007). Published records of these corals include over 137 species

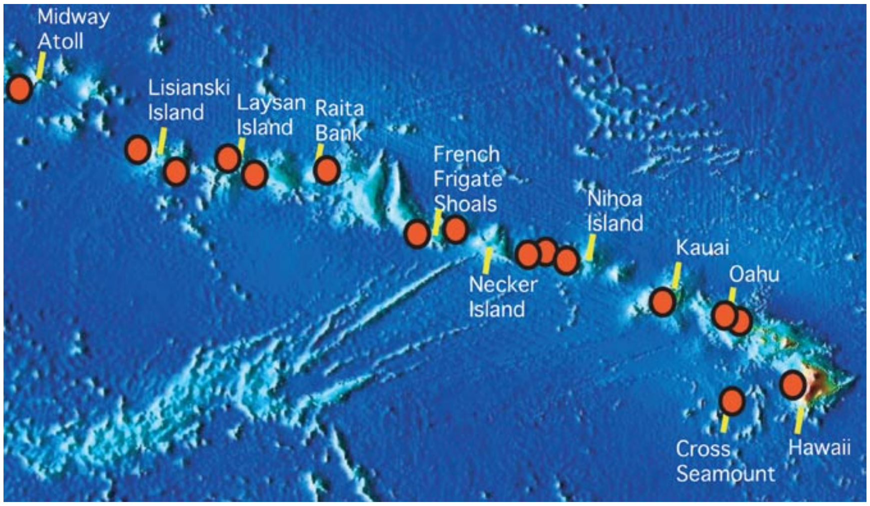

Figure 3. Map of the Hawaiian Archipelago with red dots indicating sites sampled for deep-sea corals. Three additional sites have also been sampled past the western edge of the map. The dot west of French Frigate Shoals marks Brooks Banks. The Emperor seamount chain extends from west of Midway Island nearly to the Russian Kamchatka Peninsula. *Base map courtesy of John Smith, HURL*

of gorgonian octocorals and 63 species of azooxanthellate scleractinians (complete species list reviewed in Parrish and Baco, 2007). Most abundant are octocorals in the families Coralliidae, Isididae, Primnoidae, Paramuriceidae, Chrysogorgiidae, and Acanthogorgiidae. Abundant Antipatharian taxa include *Antipathes*, *Cirripathes*, *Stichopathes*, *Stauropathes*, *Bathypathes*, *Myriopathes ulex*, *Trissopathes, Umbellopathes, Dendropathes*, and *Leiopathes*. A review of the structure-forming coral species and a more in-depth discussion of corals by taxon can be found in Cairns (2006) and Parrish and Baco (in press).

In general, the deep corals in Hawaii do not form the extensive reef structures observed in the Atlantic and South Pacific. Instead, corals grow attached directly to hard substrates, with octocorals and antipatharians often found in high densities at numerous sites, particularly on summit areas of seamounts or other topographic highs where they can form extensive coral "gardens," "forests," or "beds" with abundant associated invertebrates. In rare instances, the density of corals and sponges is so high that the underlying substrate cannot be seen. Coral beds occur at all depths so far studied (to 1800 m), with species zonation patterns slowly emerging from recent observations.

Between shallow scleractinian reef depths and the precious coral beds, in at least two locations—the Au'au channel between Maui and Lanai, and off the southern end of the Big Island—are beds of black corals at depths of 30–110 m. The dominant species found in these locations are *Antipathes cf. curvata* (95% of the population) followed by *Antipathes grandis.* These species also sustain a small fishery (based on scuba), but are currently threatened by an invasive octocoral, *Carijoa riisei* (reviewed in Parrish and Baco, 2007). The depth zone between the black coral beds and the precious coral beds has been studied even less, though corals have been observed in this zone. For example, an abundance of octocorals occur at the Makapu`u coral bed on the Island of Oahu, shallower than the precious corals, but they have not been sufficiently sampled to comment on diversity or species composition.

Probably the most abundant of Hawaii's known deep corals are the precious corals (Figure 2), including the octocorals *Corallium laauense* (red coral) and *Corallium secundum* (pink coral), and the zoanthid *Gerardia* sp (gold coral). These species are known to occur in beds in at least 16 locations in the Hawaiian Archipelago at depths of 350–600 m (reviewed in Parrish and Baco, 2007) and into the Emperor seamount chain (Bayer, 1956). Within a given coral bed, the two primary genera (*Corallium* and *Gerardia*) are usually found, but the ratio of abundance can vary greatly (Parrish, in press). Most precious coral sites also have a number of other noncommercial taxa (Figure 4); the author has observed these to include various octocorals (e.g., *Callogorgia*, *Paracalyptrophora*, *Acanthogorgia*, *Lepidisis*, *Keratoisis*, *Isidella*, *Kereoides*, and *Paragorgia,* and various paramuriceids) and antipatharians (e.g., *Leiopathes, Trissopathes,* and *Bathypathes*).

Of the known coral beds, the Makapu'u coral bed is the best studied and most diverse. It occurs between 375 m and 450 m depth in the channel between the islands of Oahu and Molokai. The bed comprises an area of about 3.6 km^2, with the most abundant coral, *C. secundum*, at a mean density of 0.22 colonies per square meter between 365 and 400 m (Grigg, 1988). Other abundant corals found at Makapuu include bamboo corals (*Lepidisis olapa* and *Acanella* spp.), gold coral (*Gerardia* sp.), and three genera of gorgonians (*Narella* sp., *Psuedothesea* sp., and *Callorgorgia gilberti*), a sea pen (*Stylatula* sp.), and black coral (*Leiopathes n. sp.*) (reviewed in Parrish and Baco, 2007). Many coral taxa of no commercial interest are also present in or adjacent to the bed, including *Enallopsammia rostrata, Thouarella hilgendorfi*, acanthogorgiids, *Paragorgia* sp., various species of Paramuriceidae, *Trissopathes pseudotristicha* (antipatharian), and a number of undescribed octocorals.

Only a few sites have been explored below precious-coral depths: Pioneer Ridge, the small seamount southeast of Laysan Island, an unnamed seamount east of Necker Island, Cross Seamount, and Keahole Point. At these greater depths in high-current areas, such as ridges and pinnacles, there appears to be a fair amount of overlap in species composition of both corals and sponges between sites. Although the number of observations is very limited, there appears to be a transition in species below about 600–700 m, from *Corallium*- and *Gerardia*-dominated communities, to a different suite of species (Figure 5). The author has observed that many species of chrysogorgiids, primnoids, isidids, coralliids, and antipatharians begin to appear around this depth; among the more common octocoral genera observed are *Chrysogorgia*, *Metallogorgia*, *Iridigorgia*, *Narella*, *Calyptrophora*, *Candidella*, *Keratoisis*, *Isidella*, *Acanella*, *Corallium*, and *Paragorgia*, as well as the antipatharian genus *Bathypathes* The depth distribution of many of these species appears to continue through 1800 m. Explorations below 1800 m have not occurred to date.

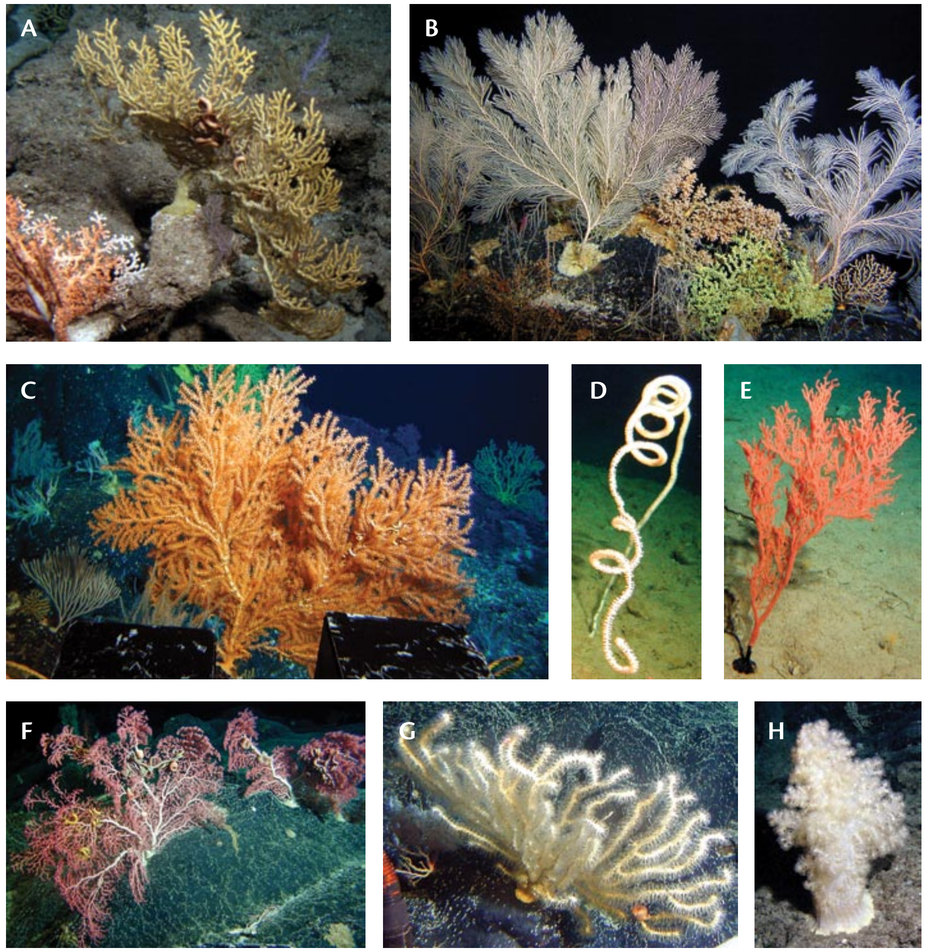

Figure 4. Many other species of octocorals and antipatharians occur in the precious coral beds. (A) *C. secundum* and two unidentified octocorals, possibly *Keroeides* or *Paracis* and a paramuricied. (B) Primnoids, zoanthids, and *Gerardia* cover a small pinnacle near the summit of Cross Seamount. (C) An isidid coral, likely *Isidella trichotoma*, with a field of *Gerardia* visible in the background. (D) The isidid *Lepidisis olapa* from the Makapu`u coral bed on Oahu. (E) An antipatharian, likely a new species of *Leiopathes*, from the Makapu`u coral bed on Oahu. (F) Large *Paragorgia* sp. near the summit of Cross Seamount. (G) A second species of *Paragorgia* near the summit of Cross Seamount. (H) A soft coral, *Siphonogorgia* sp. from the northwestern Hawaiian Islands. *Photos by A. Baco, T. Kerby, and M. Kremer, HURL and NOAA OE*

Many or most of the corals observed have associated commensal invertebrates (Figure 6). The species change by depth and with coral species, but the most common of the commensal invertebrates on these corals include chyrostylid crabs, barnacles, sponges, anemones, zoanthids, polychaetes, crinoids, ophiuroids, and basket stars. Preliminary observations suggest some of these commensals may be specific to their hosts, whereas others are more generalized. One of the more notable commensal relationships is the association of polynoid polychaetes with species in the genus *Corallium*. Each *Corallium* species appears to have its own species of polynoid polychaete, which can reach high densities within individual colonies. A more generalized commensal is the unbranched basket star, *Asteroschema* sp., which has been observed on a number of different species of octocorals at each site. Dead coral skeletons also appear to provide good recruitment habitat for many invertebrate species, with many types of sessile, attached fauna observed as well as numerous young corals (Baco and Shirley, 2005a).

GULF OF ALASKA SEAMOUNT EXPLORATIONS AND CORAL DISTRIBUTION PATTERNS

Within the Gulf of Alaska, three seamount chains of hotspot origin run parallel to the Hawaiian Archipelago. Although cold- and deep-water corals were well documented along the shelf and slope of Alaska and into the Aleutian Islands (reviewed in Cairns, 1994, and Stone and Shotwell, in press), until 2002 they had not been studied on the Gulf of Alaska seamounts. Exploration of the central chain of seamounts in 2002 provided a first glimpse of a diverse seamount octocoral and antipatharian community, with apparently little species overlap with Alaskan slope corals at the same depths.

This first glimpse provided motivation for a second cruise in the Gulf of Alaska in 2004. Five seamounts in the northern seamount chain were surveyed for deep-sea corals using the submersible *Alvin*. The goal of that study was to document the corals present on these seamounts and to compare species composition, abundance, and diversity among seamounts.

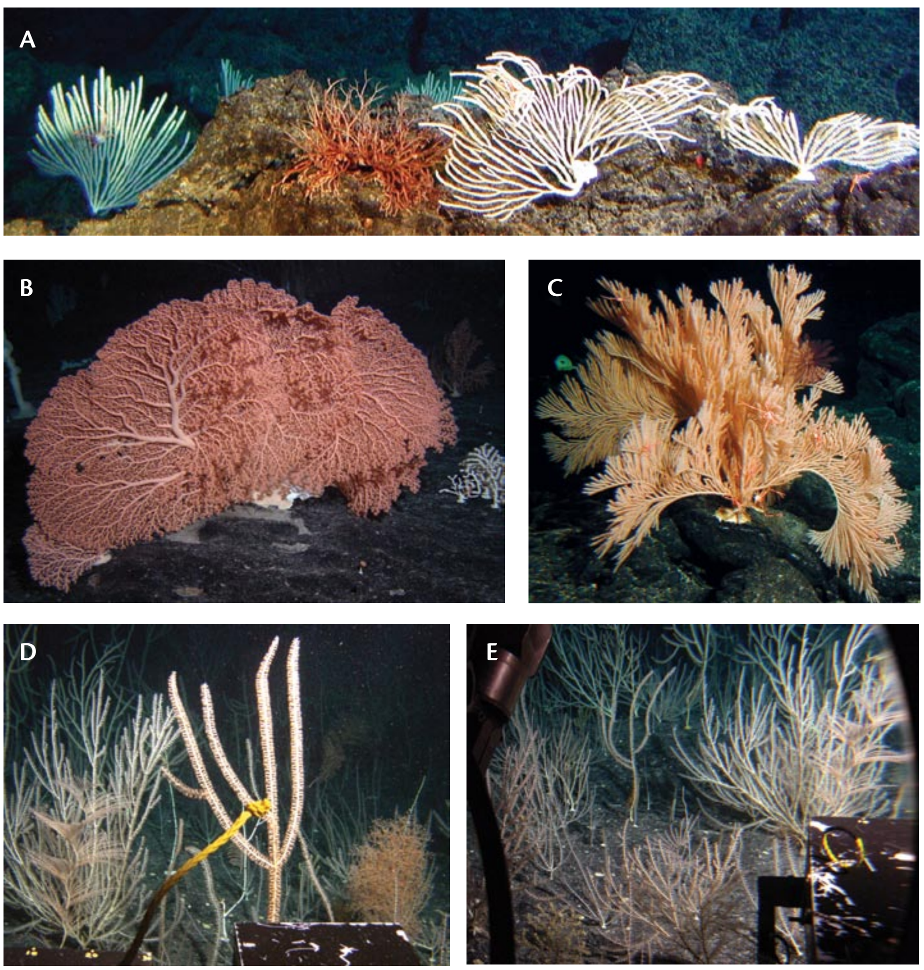

Figure 5. Corals are also abundant below precious-coral depths off the Hawaiian Islands. A different suite of species dominates at water depths of 600–1800 m. (A) Several colonies of the primnoid *Narella* lie on a small ridge just downslope from the Keahole precious coral bed, with a basket star also visible. (B) A large colony of a new species of *Corallium*, from the northwestern Hawaiian Islands. (C) A primnoid coral in the genus *Calyptrophora.* (D and E) Images through a submersible window show a dense isidid and chrysogorgiid coral bed in the northwestern Hawaiian Islands. *Photos by A. Baco, T. Kerby, and M. Kremer, HURL and NOAA OE*

Like the Hawaiian Archipelago, the seamounts of the Gulf of Alaska are dominated by octocoral and antipatharian communities, with few scleractinians. In fact, scleractinian corals were only observed on one Gulf of Alaska seamount in 2002 and one in 2004; the primnoid, paragorgiid, paramuriceid, and isidid octocorals, as well as antipatharians, were the most abundant taxa. At least 43 species of corals are present on these seamounts. The coralliids and *Gerardia* that are so abundant in Hawaii were only represented by a few individuals (likely of different species) in the 2002 and 2004 observations.

Although much less sampling has been done in the Gulf of Alaska compared to Hawaii, a transition in coral community composition was also observed with depth. Corals were most abundant on the shallowest depths of each seamount, with paragorgiids and isidids being the dominant families at 700 m. The 1700-m-depth zone had the fewest corals and lowest diversity, with antipatharians and primnoids dominating. This depth range fell within the oxygen-minimum zone for these seamounts. Along the 2700-m transects, primnoids were the dominant family (Baco and Shirley, 2005b). Near the summits of seamounts and on topographic highs, the octocorals and antipatharians formed coral beds similar to those observed in Hawaii, but overall the coral densities were lower than those observed in the Hawaiian coral beds, particularly in the two deeper zones in Alaska. This may be in part due to the difference in sampling depth range between the two locations.

Similar to observations in Hawaii,

the corals harbored abundant associated invertebrates. At least 12 phyla were present, with the highest abundances of invertebrate assemblages at the shallower depths. The most abundant commensal taxa were unbranched basket stars and other ophiuroids, asteroids, polynoid polychaetes, shrimp, and chyrostylid crabs. Some invertebrates were associated only with particular coral taxa, and most were suspension feeders (Shirley and Baco, 2005)

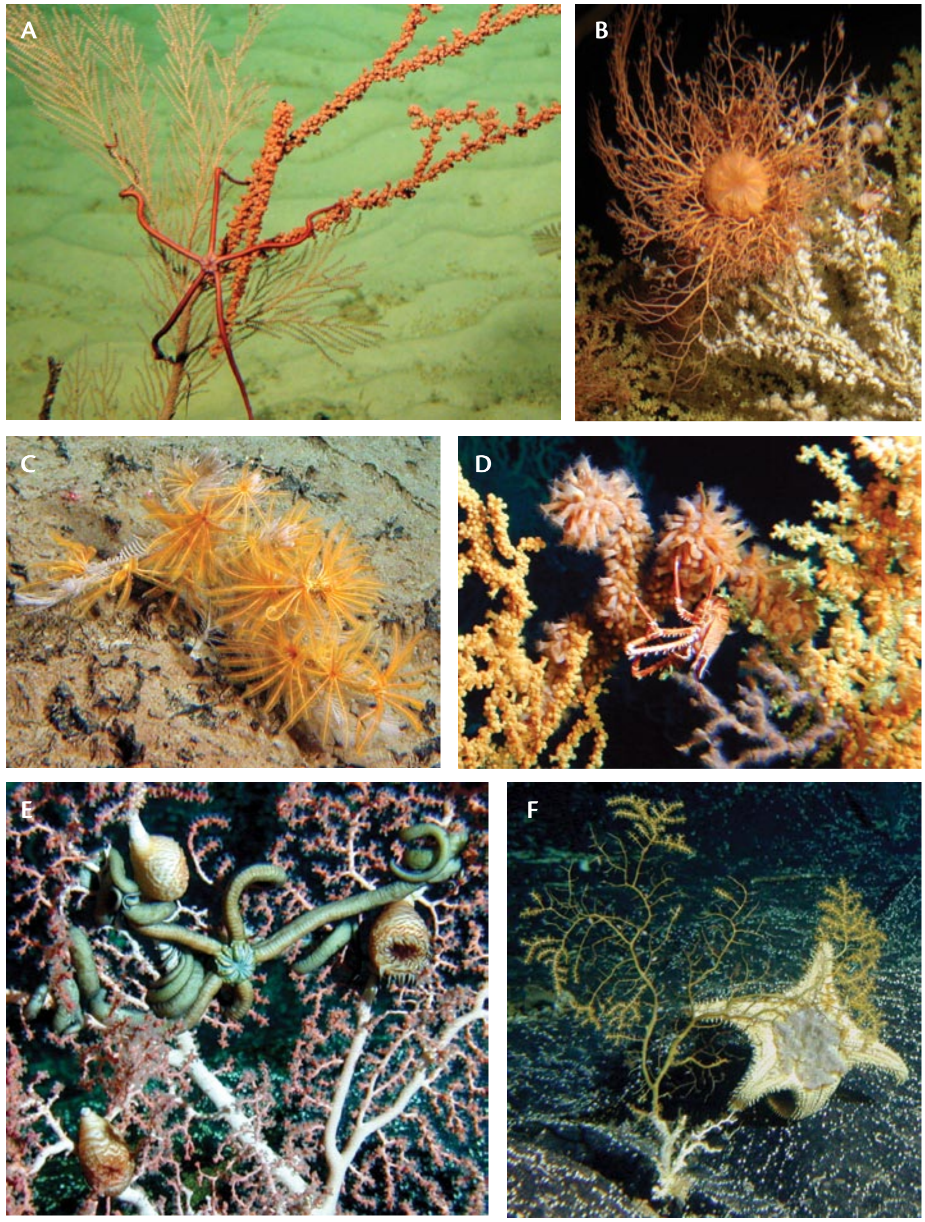

Figure 6. Octocorals and antipatharians harbor a suite of commensal invertebrate organisms. Some of the more common taxa are shown. (A) Zoanthids and an unbranched basket star on a primnoid. (B) Basket star on *Gerardia.* (C) A primnoid is barely visible under a layer of crinoids. (D) A large chyrostylid crab and zoanthids on *Gerardia.* (E) Unbranched basket stars and anemones on *Paragoriga* sp. (F) Not all invertebrates on the corals are friendly; here, a seastar with an everted gut consumes the tissue of an acanthogorgiid octocoral. *Photos by A. Baco, T. Shirley, T. Kerby, and M. Kremer, HURL and NOAA OE*

DERICKSON SEAMOUNT CORALS

Although it is known that deep-sea corals occur to depths of 6328 m (Keller, 1976), most seamount coral studies have focused above 2000 m. A unique opportunity to study a deep seamount occurred in 2004 at Derickson Seamount, off Alaska's Aleutian island chain. Using the ROV *Jason 2*, one vertical transect was conducted on the eastern slope of the seamount from near its base at about 5200-m depth to the summit at about 2766 m. A second transect was conducted on the northern side of the seamount from 4800 m to 4000 m. This was the first survey of this seamount and the deepest in situ survey of deep-water corals that has been undertaken.

The minimum depth of the seamount was below the maximum known depth for many deep-sea octocoral families. However, octocorals and antipatharians were distributed across the full depth of the seamount on hard substrates. Not surprisingly, most of the corals collected from the seamount were new to science, extending the known depth range for their genus by up to 1000 m. Many corals also significantly extended the northern geographic range for their genus or family (Cairns and Baco, 2007). At least five species of antipatharians and 17 species of octocorals in the families Primnoidae, Isididae, Chrysogorgiidae, and Paragorgiidae were present. Of these, at least 10 are new to science (Cairns and Baco, 2007). Soft-sedimented areas of the seamount exhibited an abundance of solitary scleractinians in the family Fungiacyathidae. Preliminary data do not indicate a change in species composition with depth, but there was a clear difference in species abundance between the two transects (Baco and Cairns, 2005).

SUMMARY AND CONCLUSIONS

Unlike much of the rest of the world where scleractinians are the dominant deep-sea coral group and the focus of intense research (Rogers et al., 2007), octocorals and antipatharian communities dominate seamounts and oceanic island slopes in the North Pacific, with little difference in communities between island and seamount slopes at the same depth. Octocoral and antipatharian diversity and abundance are high in the North Pacific on both Hawaiian and Alaskan seamounts, with Hawaii being a biodiversity hotspot for deep-sea corals (Rogers et al., 2007). It is unclear why scleractinians are not as abundant on North Pacific seamounts, but it may have to do with a variety of environmental factors (e.g., discussed by Guinotte et al., 2006; Clark et al., 2006).

Coral community composition changes with depth and is likely related to environmental factors such as oxygen, temperature, or food availability. The dominant coral taxa at intermediate depths in Hawaii, Coralliidae and *Gerardia*, are rare or absent on seamounts in Alaska (although most Alaskan seamounts peak and/or were sampled below precious coral-depths). At higher taxonomic levels, similar groups of invertebrates are often associated with corals in the North Pacific across depth zones and regions, including chyrostylid crabs, basket stars and other ophiuroids, polynoid polychaetes, and shrimp.

FUTURE DIRECTIONS

Much of the international research on deep-sea corals has focused on *Lophelia* and other scleractinians because they form extensive reef structures. However, octocorals and antipatharians clearly also play a role as habitat for a diverse invertebrate community, particularly in the North Pacific where they form extensive coral beds or forests. These corals should also be considered in management and protection plans for seamounts.

Despite the intensive exploratory efforts in the North Pacific over the last decade, the high rate of discovery of species new to science, new records, and geographic and depth range extensions all suggest that deep-sea corals remain vastly understudied in the North Pacific. Recent reviews of seamount fauna, deep-sea corals, and deep-sea corals on seamounts all cite a "global deficiency of scientific expertise in [morphological] taxonomy" (Rogers et al., 2007) as a significant impediment to our understanding of deep-sea coral diversity, coral biogeography, and seamount ecology (Clark et al., 2006; Parrish and Baco, 2007; Rogers et al., 2007). A dedicated effort is needed to improve the taxonomy and systematics of deep-sea corals and to increase the number of people trained to identify these corals.

We have also barely scratched the surface for understanding other seamount taxa, particularly sponges and the invertebrates associated with corals and sponges. These groups promise a plethora of discoveries over the next decades as well.

Bathymetrically, although all depths clearly need further study, the least-studied depth zones for seamounts and deep-sea corals are those below 1500 m. Based on observations on Derickson Seamount and the deeper portions of the Alaskan and Hawaiian seamounts, deep-sea corals are clearly abundant at greater depth and need further study. Geographically, the Emperor seamount chain represents an enticing enigma in the North Pacific. It extends a thin connection from the Aleutian chain and continental slopes of the North Pacific down to the seamount-dense region of the central and western Pacific, which may provide a stepping stone for past and present dispersal of deep-sea fauna.

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