# Deep-sea Coral Ecosystems of the United States

Feature Article 3

S. ELIZABETH LUMSDEN
THOMAS F. HOURIGAN
ANDREW W. BRUCKNER

NMFS Office of Habitat Conservation

Silver Spring
Maryland

## INTRODUCTION

Coral reefs are among the most spectacular ecosystems on the planet, supporting such rich biodiversity and high density of marine life that they have been referred to as the rainforests of the sea. The coral reefs that most people think of are found in warm shallow waters, generally within recreational diving depths (30 m or less). However, other coral ecosystems thrive on continental shelves, slopes, canyons, ocean ridges, and seamounts around the world, sometimes thousands of meters below the ocean's surface. These communities are structured by deep-sea corals, also referred to as cold-water corals, and are distributed across a wide range of depths and latitudes, in both temperate and tropical oceans.

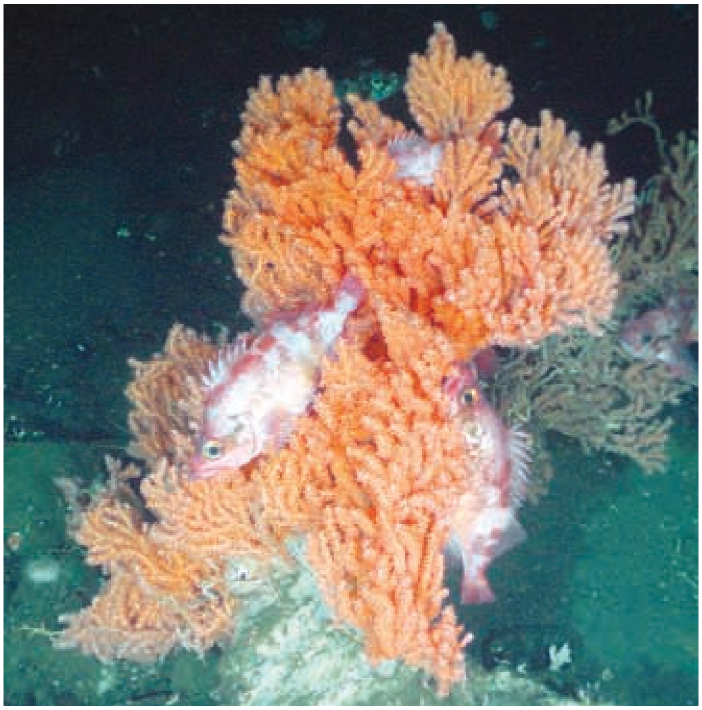
Research over the last decade has revolutionized our understanding of these deep-sea coral ecosystems and spurred calls for their protection. In 2006, the U.S. Congress included provisions for research and conservation of deep-sea corals in the reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act, our Nation's primary fisheries law, and the United Nations General Assembly passed major resolutions designed to help protect deep-sea corals and other vulnerable marine ecosystems on the high seas. In 2007, the National Oceanic and Atmospheric Administration (NOAA) published *The State of Deep Coral Ecosystems of the United States* (Lumsden et al., 2007), the first major peer-reviewed assessment of deep-sea coral ecosystems in U.S. waters and the source for this chapter.

### Major Groups of Structure-Forming Deep-Sea Corals

Corals are a taxonomically and morphologically diverse collection of animals in the Phylum Cnidaria with rigid skeletal structures composed of calcium carbonate or a horn-like proteinaceous substance. Deep-sea corals lack symbiotic algae (zooxanthellae) characteristic of most reef-building shallow-water tropical corals (Table 1). Deep-sea corals occur in cold oceanic waters worldwide from near the surface to 6,000 meters in depth; however, most are found between 50 and 2,000 meters.[1] Unlike their shallow-water relatives, which rely heavily on photosynthesis by their symbionts to produce food, deep-sea corals assimilate plankton and organic matter for much of their energy needs. They generally grow much more slowly than their shallow-water counterparts.

Deep-sea corals include both reef-building and non-reef-building corals. While more than 90% of shallow-water stony corals (Order Scleractinia) are colonial structure-forming species (many contributing to coral reefs), there are at most 14 species of azooxanthellate deep-water scleractinians in the world that can be considered structure-forming species, 13 of which occur in U.S. waters (Cairns, 2001, 2007). These structure-forming species can occur as individual small colonies or they may form aggregations that can create vast reef complexes tens

[1]The term "deep-sea" usually refers to depths greater than 200 m; however, structure-forming corals that lack symbiotic zooxanthellae occur over a broader range of depths.




Rockfish among primnoid corals in Olympic Coast National Marine Sanctuary.

of kilometers across and tens of meters in height over time (Freiwald et al., 2004). *Lophelia pertusa* and *Oculina varicosa* are the most important stony corals that form reef-like structures in U.S. waters. Other species of deep-sea corals, including black corals (Order Antipatharia), gold corals, *Gerardia* species, octocorals (gorgonians, true-soft corals, and sea pens), and lace corals (Family Stylasteridae, Class Hydrozoa) do not form reefs, but often have branching tree-like forms and either occur singly or form thickets of many colonies.

## Importance of Deep-sea Coral Communities

As our understanding of deep-sea coral ecosystems has increased, so has our appreciation of their value. Deep-sea coral communities can be hot spots of biodiversity in the deeper ocean, making them of particular conservation interest. Stony coral reefs, as well as thickets of sea fans or black corals and aggregations of lace corals, often have large assemblages of associated fauna. This high biodiversity is intrinsically valuable and may provide significant opportunities for chemical and biological research on marine organisms. For example, deep-sea bamboo corals are being investigated for their medical potential in bone grafts and other biomedical applications (Ehrlich et al., 2006).

Strong associations have been observed between certain commercially important fishes and structure-forming deep-sea coral habitats. In Alaska, commercially valuable species of rockfish, shrimp, and crabs are associated with coral habitat, appar-

**Table 1**
Comparison of tropical shallow-water and deep-water structure-forming stony corals (modified from Freiwald et al., 2004; Hourigan et al., 2007).

| Parameter | Tropical shallow-water stony corals | Deep-water stony corals |
|---|---|---|
| Depth range | 0–100 m | 39–2,000 m |
| Temperature | 18–31° C | 4–13° C |
| Distribution | Tropical and subtropical seas from 30° N to 30° S latitude. | Tropical to subpolar, at least from 71°N to 56° S latitude. |
| Symbiotic algae | Yes | No (however, several species of *Oculina* and *Madracis* have a facultative relationship with zooxanthellae in shallow populations) |
| Growth rates | 1–10 mm per year for massive slow-growing corals<br>50–150 mm per year for faster-growing branching corals | 1–20 mm per year for three branching species; growth rates for other species are unknown |
| Number of reef-building species | Approximately 650 | Approximately 6–14 |
| Nutrition | Photosynthesis, zooplankton, and suspended organic matter | Zooplankton and possibly suspended organic matter |
| Primary threats | Overfishing & destructive fishing<br>Pollution & siltation<br>Coastal development<br>Over-harvest of corals<br>Recreational misuse<br>Diseases<br>Climate change (coral bleaching, ocean acidification, and storm intensity) | Bottom-tending fishing gear<br>Oil and gas exploration and production<br>Pipelines and cables<br>Climate change (ocean acidification and possible changes in currents and temperatures) |

ently using it for protection from predators and as a feeding area (Krieger and Wing, 2002; Stone, 2006). In the Gulf of Mexico, a number of fish species are closely associated with *Lophelia* reefs (Sulak et al., 2008). Koenig (2001) found a relationship between the abundance of economically valuable fish (e.g. grouper, snapper, sea bass, and amberjack) and the condition of *Oculina* coral. These *Oculina* coral reefs off Florida have been identified as essential fish habitat for Federally managed species, as have gorgonian-dominated deep-sea coral communities in Alaska and along the West Coast. In other cases, however, the linkages between commercial fisheries species and deep-sea corals remain unclear (Auster, 2005) and may be indirect.

Deep-sea gorgonian and stony coral species have proven useful in reconstructing historical global climate and oceanographic conditions (Risk et al., 2002; Williams et al., 2006). Skeletons of living deep-sea corals have been dated at more than 1,000 years old, and dead corals forming deep banks have been radiocarbon-dated at more than 40,000 years old. Stable isotopes and trace elements incorporated in the skeletons of deep-sea corals can provide a record of past temperatures, and analyses of deep-sea coral skeletal microchemistry allow researchers to reconstruct past oceanic conditions.

## MAJOR DEEP-SEA CORAL COMMUNITIES IN U.S. WATERS

The U.S. Exclusive Economic Zone (EEZ) extends 200 n.mi. (370 km) offshore, covering 11.7 million square kilometers in the Pacific, Atlantic, and Arctic Oceans. This broad geographic range includes a wide variety of deep-water ecosystems, most of which have not been explored. Despite growing knowledge of the distribution of deep-sea coral communities and regional differences in the types of corals that structure these communities and associated organisms, the majority of the U.S. EEZ has not been surveyed, mapped, or characterized.

Important deep-sea coral communities have been identified in every U.S. region. Most deep-sea coral groups, with the exception of sea pens, occur primarily on hard substrata, especially near the Continental Shelf break, along the Continental Slope, and on oceanic islands and seamounts.

Currently, it is impossible to ascertain the overall extent of deep-sea coral communities, much less their condition or conservation status, since so many of the deeper areas that these communities inhabit have been insufficiently explored or have not been explored at all. There is also very limited information on the species composition and condition of some Continental Shelf habitats prior to the inception of trawl fisheries. Therefore, the following discussion on trends in distribution should be viewed with caution.

### Pacific

**Alaska:** The U.S. EEZ around Alaska includes the Gulf of Alaska, Aleutian Islands, and Eastern Bering Sea in the Pacific, and the Chukchi and Beaufort Seas in the Arctic. Deep-sea corals appear to be rare in the Arctic, but they are an important structural component of other Alaska marine ecosystems (Stone and Shotwell, 2007). Gorgonian deep-sea corals reach their highest diversity in the United States in the Aleutian Islands, often forming structurally complex “coral gardens” with lace corals, sponges, and other sedentary taxa. Gorgonians are also the most important structure-forming corals in the Gulf of Alaska, with species of the genus *Primnoa* reaching 5–7 m in size, while the Bering Sea has dense aggregations of soft corals and sea pens on the Continental shelf and slope, respectively. The region is relatively depauperate in stony corals; those that do occur appear as solitary cups and do not form true coral reefs.

**U.S. West Coast:** The deep-sea coral communities off the Washington, Oregon, and California coasts share many similarities with those farther north along the Pacific coasts of British Columbia and Alaska (Hourigan et al., 2007). Understanding of the spatial distribution of these communities has benefited from relatively extensive NOAA trawl survey catch records, supplemented by museum collections and underwater vehicle exploration (Whitmire and Clarke, 2007). Gorgonians are the most abundant and diverse structure-forming deep-sea corals along the West Coast (Whitmire and Clarke, 2007). There appear to be biogeographic differences in the distributions of certain deep-sea coral groups within the region. Gorgonians appear to be most abundant south of Point Conception

S. W. Ross, K. Sulak, M. Nizinski

Deep-water *Lophelia* coral reef community in the southeast United States.

and north of Cape Mendocino. Black corals appear abundant between Cape Mendocino and Canada, and are less common in Alaska.

**U.S. Pacific Islands:** The U.S. Pacific Islands represent diverse oceanic archipelagos scattered across wide areas of the Pacific and encompassing several different biogeographic regions. They do not have continental shelves or slopes, but represent emergent and non-emergent seamounts—many highly isolated from other areas. Aside from the Hawaiian Archipelago, almost nothing is known of the deep-sea coral resources in the U.S. Pacific Islands. The first submersible explorations of American Samoa and the U.S. Line Islands were begun in 2005, and surveys of additional areas in the U.S. Pacific are needed. Octocorals and black corals are the principal structure-forming species on deep Hawaiian slopes and seamounts (Parrish and Baco, 2007). While the Hawaiian Archipelago shares some species with Alaska and the West Coast, it likely has a relatively high number of endemic species. Understanding of the unique deep-sea coral assemblages in Hawaii has benefited from information gathered in association with commercial harvests of deep-sea corals—including gold (*Gerardia* species) and pink (*Corallium* species) precious corals and the shallower black corals (*Antipathes* species). Monitoring in support of management has provided perhaps the most extensive studies of growth and recruitment rates for any deep-sea coral taxa.

### Atlantic

**Northeast United States:** This region has among the longest histories of both deep-sea scientific research and extensive trawl fisheries. Gorgonians represent the predominant structure-forming deep-sea coral taxa in this region, and they appear to be most numerous on hard substrates associated with canyons along the shelf and Georges Bank slopes, and on the New England Seamount chain (Packer et al., 2007). Though *L. pertusa* has been reported occasionally, no major reef-like formations have been recorded from U.S. waters in this region.

**Southeast United States:** Within U.S. waters, deep-water scleractinian coral reefs probably reach their greatest abundance and development in the Atlantic south of Cape Hatteras (Ross and Nizinski, 2007). The deep reef-forming coral *L. pertusa* is the major structural component of reefs on the Continental Slope and Blake Plateau from North Carolina to Florida. These reefs provide habitat at depths from 370 to at least 800 m for a well developed faunal community that appears to differ from the surrounding non-reef habitats (Ross and Nizinski, 2007). The world's only known *Oculina varicosa* reefs are found in 70–100 m depths off east-central Florida. Because of their shallow depth and occurrence on the Continental Shelf, *Oculina* banks may be atypical of deeper coral communities. However, their accessibility has facilitated a more comprehensive understanding of the ecology of the corals, the role of the reefs as essential fish habitat, and the impacts of trawl fishing on these resources (Koenig, 2001; Reed et al., 2007; Ross and Nizinski, 2007). Gorgonians are common in the region, but relative to the northeast and West Coast much less is known (or at least less information has been systematically collated) concerning the region's octocoral and black coral resources.

**Northern Gulf of Mexico:** The northern Gulf of Mexico is home to significant *L. pertusa* reefs, though their structure appears to differ from that observed in the southeast United States (Brooke and Schroeder, 2007; Sulak et al., 2008), growing primarily on carbonate and clay substrates rather than mounds of dead coral. Despite extensive environmental studies associated with oil and gas development in the Gulf, knowledge of the distribution of deep-sea coral reefs is limited to a handful of sites where targeted studies have been conducted. Each area, from Pourtales Terrace in the Florida Straits to sites in the northwestern Gulf of Mexico, represents unique habitat types. As in the southeast, limited information is available concerning the distribution of the gorgonian and black coral resources that occur in this region. Recent remotely operated vehicle (ROV) surveys focused on the reefs and banks of the northwestern Gulf of Mexico at depths of 50–150 m have resulted in expanded knowledge of the distribution of deep-water biological communities, including black corals, gorgonians, and sponges. The communities are more widespread and densely populated than reported thus far. These studies are ongoing, and are being led by NOAA's Flower Garden Banks National Marine Sanctuary.

**U.S. Caribbean:** The U.S. Caribbean includes the waters surrounding Puerto Rico, the U.S. Virgin Islands, and Navassa Island, and represents a small part of the larger Caribbean ecosystem. It has not been well studied with respect to deep-sea corals (Lutz and Ginsburg, 2007) and the primary information comes from scientific collections—most from other areas of the wider Caribbean. In U.S. waters, limited ROV and submersible studies have been conducted off Navassa Island and Puerto Rico, revealing scleractinian, black, and gorgonian corals, but distributions have not been rigorously documented.

## CONSERVING U.S. DEEP-SEA CORAL ECOSYSTEMS

### Threats to Deep-sea Coral Communities

Deep-sea corals are generally slow-growing and fragile, making them and their associated communities vulnerable to human-induced impacts, particularly physical disturbance. The level and types of threats affecting these ecosystems differ regionally (Table 2), as do the management actions that have been adopted to address impacts from fisheries.

Disturbances to deep-sea coral communities from bottom-tending fishing gear, especially bottom trawl gear, are the best documented (Freiwald et al., 2004; Stone, 2006; Reed et al., 2007) and are considered the major threat to deep-sea corals in most U.S. regions where such fishing is allowed (Hourigan et al., 2007; Table 2). With the exception of a few areas (e.g. the Oculina Banks), the full extent of habitat degradation resulting from these threats is largely unknown. In such complex habitats as deep sea-coral communities, recovery rates could be extremely slow (decades to centuries), if at all.

| | Regions | | | | | | |
|---|---|---|---|---|---|---|---|
| Threats | Alaska | West Coast | Pacific Islands | Northeast | Southeast | Gulf of Mexico | Caribbean |
| Bottom trawl fishing impacts | High | High | NA | High | High | Low-Medium | NA |
| Other bottom fishing impacts | Low-Medium | Low | Low | Low-Medium | Low | Low | Low |
| Deep-sea coral harvest | NA | NA | Medium | NA | NA | NA | NA |
| Oil and gas development | Low | Low | NA | NA | NA | Medium | NA |
| Cable deployment | Low | Low | Unknown | Low | Low | Low | Unknown |
| Sand and gravel mining | Low | NA | NA | Low | Low | Low | NA |
| Invasive species | Unknown | Unknown | Medium | Unknown | Unknown | Unknown | Unknown |
| Climate change | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |

**Table 2**

Summary of perceived levels of current threats to deep coral communities for U.S. regions. NA = Not Applicable (i.e. this threat is prohibited or does not occur anywhere within that region). Source: Hourigan et al. (2007). Note that these threat levels are derived from expert opinions and reflect only the occurrence of these stressors in a region, and their potential, if unmitigated, to damage deep coral communities they might encounter. The threat levels do not indicate the actual impacts of each stressor, which will likely vary widely within and among regions.

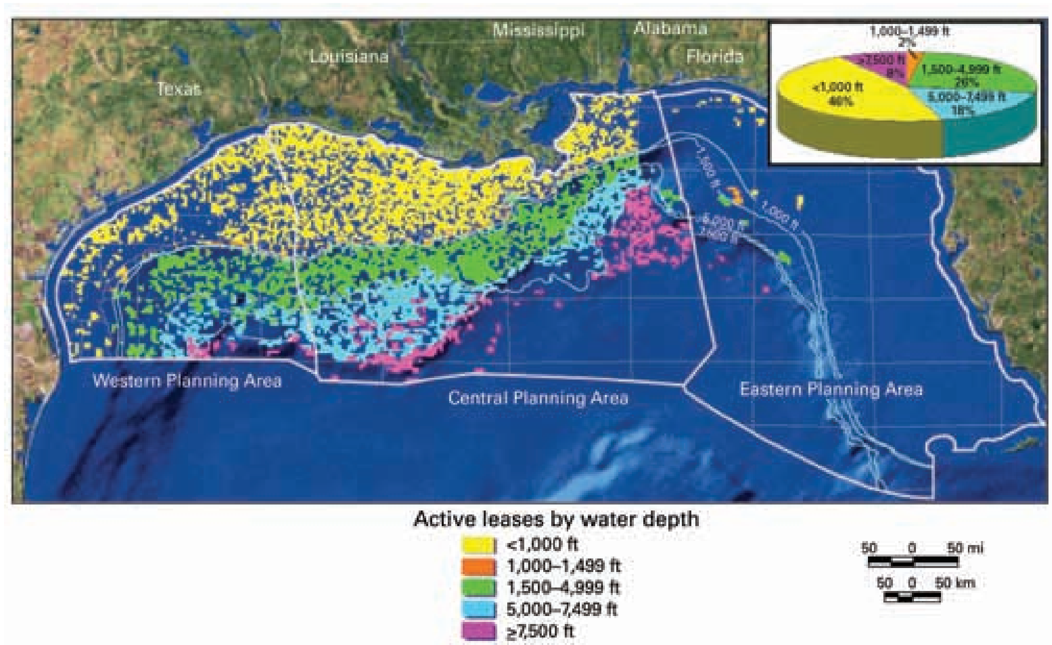



**Figure 1**
Map of the Gulf of Mexico showing active leases by water depth in 2007. Courtesy of the Minerals Management Service.

Other activities that can directly impact deep-sea coral communities include coral harvesting; oil, gas, and mineral exploration and extraction; and submarine cable/pipeline deployment (Freiwald et al., 2004; Hourigan et al., 2007). Hawaii is the only jurisdiction where precious coral harvests are allowed. It is also the only place where an invasive species, the snowflake coral, has been identified as a current threat, having overgrown and killed over 50% of commercial black coral colonies in one location. Oil and gas exploration and development in the Gulf of Mexico, where approximately 98% of all active U.S. oil and gas leases are located, is increasingly conducted in deeper waters and has been identified as a moderate threat to deep-sea coral communities in that region (Figure 1). Climate change and ocean acidification represent potentially serious threats that have not been adequately studied.

### Managing Impacts to U.S. Deep-sea Coral Communities

Most deep-sea corals in U.S. waters occur in the EEZ, beyond the jurisdiction of individual states. Fisheries in the EEZ are managed by the National Marine Fisheries Service (NMFS) under fishery management plans prepared by eight regional Fishery Management Councils (FMC's) in accordance with the Magnuson-Stevens Fishery Management and Conservation Act.[2] In 2006, the Act was reauthorized, directing NOAA to establish a Deep-sea Coral Research and Technology Program and authorizing the designation of zones to protect deep-sea corals from damage caused by fishing gear under fishery management plan discretionary provisions.

NMFS and the FMC's have been active in protecting deep-sea coral habitat, relying on tools such as closed areas and gear modifications to address fishing impacts. In 1983, the Western Pacific FMC recommended and NMFS implemented a prohibition on the use of trawl gear, bottom-set longlines, and bottom-set gill nets—all identified as threats to deep-sea corals—within all 3.9 million $km^2$ of seafloor habitat waters in the EEZ surrounding the U.S. Pacific Islands. The following year, the South Atlantic FMC recommended establishment of the world's first area to protect deep-sea corals (the Oculina Bank Habitat Area of Particular Concern off Florida). Despite these steps, incomplete protection and lack of sufficient enforcement resulted in continued destruction of much of the *Oculina* habitat by 2001 (Reed et al., 2007), with dam-

[2] 16 U.S.C. 1801 et seq.

age attributed to bottom trawling. Expansion of the protected area, requirements for use of vessel monitoring systems, and enhanced enforcement since 2001 provide hope for the remaining reefs.

Recent research has begun to reveal the extent and ecological importance of deep-sea coral communities, as well as the threats they face, greatly accelerating conservation action. In 2005, the New England and Mid-Atlantic FMC's recommended and NMFS approved closures of Oceanographer and Lydonia Canyons (approximately 400 $km^2$), on the southern flank of Georges Bank, to bottom trawling and gillnetting for monkfish. In 2006, NMFS approved FMC recommendations to protect almost 1.5 million $km^2$ of vulnerable benthic habitats in the Pacific. In 2008, additional habitat conservation efforts were underway through the North Pacific, New England, and South Atlantic FMC's.

In addition to the FMC's, NOAA's National Marine Sanctuary Program has responsibilities for protection and management of natural resources within the boundaries of National Marine Sanctuaries, eight of which are known to contain deep-sea corals. The goals of the National Marine Sanctuaries Act[3] include maintaining the natural biological communities in the National Marine Sanctuaries, and protecting—and where appropriate—restoring and enhancing natural habitats, populations, and ecological processes. New oil and gas development is currently prohibited in all National Marine Sanctuaries, although leases in place before sanctuary designation are allowed to continue. Deep-sea coral communities also occur in the Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands and are likely to occur in certain National Parks and National Wildlife Refuges, especially in Alaska and the Pacific Remote Island Areas.

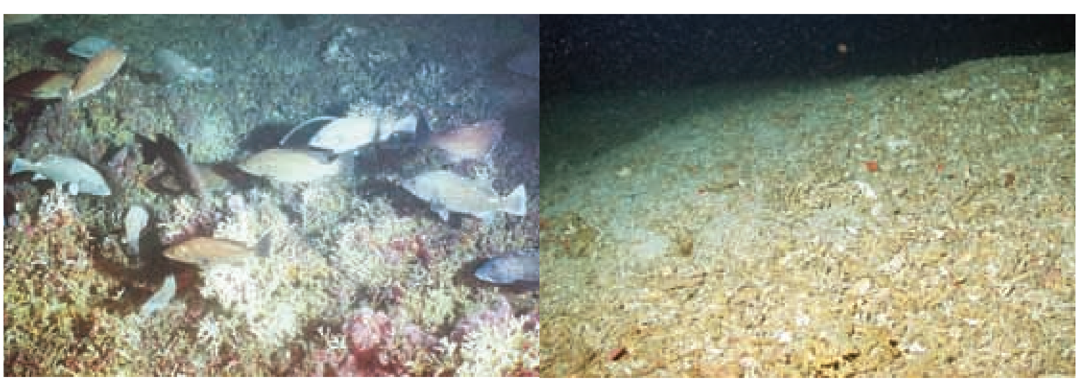
Mineral resource exploration and extraction activities, including oil and gas exploration in Federal waters, are managed by the Minerals Management Service (MMS) in the U.S. Department of the Interior. The MMS regulates the impact of mineral resource activities on the environment through an Environmental Studies Program and an Environmental Assessment Program. These programs provide scientific and technical information to support decisions and monitor environmental impacts of exploration, development, and production of mineral resources.

## DEEP-SEA CORAL RESEARCH PRIORITIES

Over the past few years, NOAA has increased activities to locate, study, and protect deep-sea corals. The following research priorities common to most or all U.S. regions have been identified as having the potential of contributing to better understanding and improved management of deep-sea coral ecosystems. This is not a comprehensive list of scientific research needs and is not in order of importance.

**Habitat Mapping and Characterization:** The highest priority in every region is to locate, map, characterize, and conduct a baseline assessment of deep-sea coral habitats. The locations of deep-sea coral habitats are not well known, making it difficult, if not impossible, to adequately manage associated resources.

[3]16 U.S.C. 1431 et seq.



Left: Grant Gilmore, Dynamac Corp.; right: Lance Horn, NURC/UNCW

Left: Commercial groupers on healthy *Oculina* deep-sea coral habitat off the East Coast of Florida. Right: Trawled *Oculina* habitat.

Victoria O'Connel, Alaska Department of Fish and Game

Juvenile rockfish in Alaskan red tree coral (*Primnoa* species).

**Modeling the Distribution of Deep-sea Coral Habitats:** Modeling the distribution of deep-sea coral habitats will facilitate the geographic targeting of future research efforts and the identification of areas that should be managed with greater precaution, in the absence of expensive ground-truthed data.

**Data Mining and Data Management:** Because of the high cost of new exploratory surveys, there is a priority on mining data from museum collections or past submersible surveys focused on other subjects (e.g. geology or fish) to yield distributional data for corals at a low cost. These may also provide qualitative baselines for assessing change. There is also a need to better manage existing information to enhance research collaboration and access to data for management purposes.

**Monitoring**: Monitoring is key to understanding the state of resources and gaining clues to processes that may affect change and recovery from damage. However, in contrast to shallow reefs, the costs associated with observing deep-sea coral communities are much higher. As a result, most deep-sea coral communities have likely not yet been discovered, much less have baselines developed or repeated surveys begun. To date, monitoring of deep-sea corals in U.S. waters has been limited to the relatively shallow Oculina Banks off Florida, and black and precious corals in selected locations off Hawaii. These studies have yielded valuable life-history and ecological information on those coral species.

**Understanding the Biology and Ecology of Deep-sea Coral Species**: The basic taxonomy of deep-sea coral taxa, their biogeography, and the processes that may contribute to distributions and endemism are poorly known. Needs include: genetic studies to understand recruitment dynamics and resilience to disturbance; the study of factors influencing reproduction, recruitment, and recolonization rates; and study of patterns and processes of growth and mortality for key coral species.

**Biodiversity and Ecology of Deep-sea Coral Communities:** Structure-forming deep-sea corals have been shown to provide important ecosystem functions in the deep sea environment, especially as habitat for numerous other species. In addition to conducting species inventories and quantifying the associations between corals, other invertebrates, and fish, this may include characterizing trophic dynamics within deep-sea coral communities, and studies on the life history of associated species. Understanding the ecological function of these communities and their importance for Federally managed species is a management priority.

**Understanding Effects of Climate Change and Ocean Acidification:** Deep-sea corals may provide windows into past environmental conditions in the deep ocean, as well as clues for prospective analyses of future changes that may result from climate change. Deep-sea coral communities may also be uniquely vulnerable to ocean acidification (changes in ocean chemistry associated with increased atmospheric $CO_2$ from the combustion of fossil fuels).

**Fishery Impacts:** Since fishing impacts are currently the major threat to these communities in U.S. waters and around the world, it is especially important to gain a comprehensive understanding of fishing effort and distribution with respect to the location of deep-sea coral habitat. Coral bycatch in trawl surveys and commercial fisheries has proven valuable in mapping coral resources and interactions with fisheries.

**Other Anthropogenic Stressors:** Many other human activities are also expanding into deeper waters. Documenting their effects on seafloor habitats provides a foundation for developing sound policy and making wise management decisions. Additionally, there is a need for basic research to understand recently recognized threats to these ecosystems, such as invasive species.

## CONCLUSIONS

Although this article has highlighted regional variability and the many gaps in our knowledge of deep-sea corals and the communities they structure, there has been tremendous progress in our understanding of these ecosystems over the last decade. Though a comprehensive inventory of deep-sea coral habitats is not possible at the present time, these communities appear to be more widespread in deeper waters of the U.S. EEZ than previously thought. Impacts from fishing gear, especially bottom trawl gear, are currently the greatest threat to deep-sea coral habitat, and we may never know the true extent of past fishing-related impacts on Continental Shelf ecosystems. However, deeper coral habitats (>500 m) appear to be relatively undisturbed, and increased appreciation of these coral communities by Federal management agencies, regional fishery management councils, and the public has resulted in major conservation actions on a geographic scale that was previously unprecedented. Continued progress in conservation will require sustained mapping and research efforts, as well as application of scientific and management lessons learned across the Nation's varied regions.

It is clear that other biogenic habitats in deep water also deserve study. In particular, sponges may contribute to habitat complexity in much the same way as do deep-sea corals. We know even less about the biology and ecology of deep sponges and their habitats. As NOAA moves forward with partners to better understand deep-sea coral communities, these other types of deep-sea communities also deserve attention.

Understanding and conserving habitats of high biological diversity, such as deep-sea coral habitats, is taking on increasing importance as NOAA moves towards an ecosystem approach to managing the Nation's living marine resources. Deep-sea coral habitats were highlighted for special attention in the 2006 reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act. In a similar vein, conservation of these vulnerable

Andy Bruckner

Pink coral (*Corallium*) jewelry for sale in Japan. Pink and red precious corals have been valued for jewelry and art objects for over 5,000 years.

marine ecosystems on the high seas has become a major subject of international negotiations.

For more in-depth information on the state of our knowledge of deep-sea coral communities, please see *The State of Deep Coral Ecosystems of the United States* (Lumsden et al., 2007).

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