Ecosystem-based management as a tool for protecting deep-sea corals in the USA

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Abstract

In the USA, deep-sea coral habitat protection occurs as a secondary issue to traditional commercial fishery management. Ecosystem-based management (EBM) would better serve the goals of fishery management and deep-sea coral protection for three reasons. First, EBM preserves all parts of the ecosystem regardless of commercial value and prevents collateral damage of fishing activities on sensitive habitats including coral areas. Second, EBM addresses ecosystem stressors, holistically providing a framework to evaluate and manage the combined impacts of fishing and non-fishing threats to deep-sea corals. Third, EBM bases adaptive management on the precautionary principle, allowing emerging science to guide management actions.

The Pew Oceans Commission (2003) and the US Commission on Ocean Policy (2004) recommended stricter protection of vulnerable coral habitats. The President's 2004 Ocean Action Plan also emphasized deep-sea coral conservation and called for further identification and protection of deep-sea coral areas. To date, the recommendations by these panels are moving slowly and to a great degree have not been initiated by the federal government, though fishery management councils have made some strides in protecting deep-sea corals under essential fish habitat designations.

While there is great diversity among deep-sea coral species, the most pressing issue they face is their vulnerability to destructive human activities that contact the seafloor or alter the deep ocean environment (Freiwald et al., 2004; Roberts and Hirschfield, 2004; Kahng and Grigg, 2005; Guinotte et al., 2006; Morgan et al., 2006; Roberts et al., 2006). These activities include both direct and indirect human impacts that are occurring over large spatial and temporal scales. These impacts interact synergistically to the detriment of deep-sea coral health.

Fishing gears that contact the seafloor inevitably disturb the seabed and pose the gravest direct threat to deep-sea corals and sponges. In recent years, several reports have documented the impacts of fishing methods to seafloor habitats including two large symposium volumes (Benaka, 1999; Barnes and Thomas, 2005) as well as the National Research Council's review of fishing impacts (National Research Council, 2002). Fishing gears that impact the seafloor include bottom trawls, bottom longlines, bottom gillnets, dredges, and pots/traps (Chuenpagdee et al., 2003; Morgan and Chuenpagdee, 2003). Among these, bottom trawling is considered by scientists, managers and fishing professionals to be the most ecologically destructive fishing method (Chuenpagdee et al., 2003; Morgan and Chuenpagdee, 2003). Bottom trawling, which targets fish living on or just above the seafloor, destroys deep-sea coral ecosystems that took centuries to millennia to form (Fosså et al., 2002; Hall-Spencer et al., 2002; Puglise et al., 2005). Large bottom trawl gear can weigh several tons (Merrett and Haedrich, 1997) and the footrope

George, R. Y. and S. D. Cairns, eds. 2007. Conservation and adaptive management of seamount and deep-sea coral ecosystems. Rosenstiel School of Marine and Atmospheric Science, University of Miami.

is further weighted to keep the net in close contact with the seafloor. The footrope can be a chain or cable and is sometimes modified with large, heavy discs that are designed to ride over obstructions and keep the net from snagging and tearing on the seafloor. The benthic impacts of bottom trawling have been compared to the clear-cutting of old-growth forests (Watling and Norse, 1998), except that ancient corals are usually not collected and/or used, and are discarded overboard as bycatch.

Bottom trawling is widespread throughout the world's oceans and there are many international examples of coral damage caused by this fishing method. In Norway, 30%–50% of pre-existing *Lophelia pertusa* (Linnaeus, 1758) reefs have been destroyed by trawling (Fosså et al., 2002) and significant trawl damage to *L. pertusa* reefs has been documented in Irish waters (Hall-Spencer et al., 2002). Bottom trawling in the Canadian Atlantic dislodges deep-sea corals, which inevitably end up in fishing nets (Mortensen et al., 2005). Recent reports state that Canadian fishermen are observing a decrease in the size and abundance of corals in their nets (Gass and Willison, 2005). Koslow and colleagues (2000) reported that trawling reduced coral cover on a Tasmanian seamount from 90% to 5%, and Anderson and Clark (2003) reported that 1 hr of trawling for orange roughy (*Hoplostethus atlanticus* Collett, 1889) removed 1.6 t of corals in the New Zealand fishery.

Fisheries are managed in US waters by eight regional fishery management councils. The use of trawl gear is widespread in the New England and Mid-Atlantic council regions. In 1996 it was estimated that an area equivalent to three to four times the size of the entire Georges Bank area was being trawled annually (Auster et al., 1996). Although deep-sea corals have been recorded in these regions since 1874, scientists suspect that the current distribution of deep-sea corals has been altered by bottom fishing, and that many of the corals in historical records have since been destroyed by fishing (Watling and Auster, 2005). Shrimp trawling has destroyed the vast majority of *Oculina* reefs in the South Atlantic region (Koenig et al., 2005). Bottom trawling affects the largest area and leaves the largest ecological footprint in the waters off the US west coast (Morgan et al., 2005). West coast trawling activity occurs in areas with significant deep-sea coral habitats and the same is true in Alaskan waters. Between 1997 and 2001, an average of 81.5 t of coral was uprooted every year by commercial fishing in the North Pacific council region; 97% of this was attributed to bottom trawls (North Pacific Fishery Management Council, 2003; National Marine Fisheries Service (NMFS), 2004). At present, bottom trawling does not occur in the Caribbean and Western Pacific council regions.

Current management authorities for deep-sea corals in the USA.—Deep-sea corals occur throughout US waters (Fig. 1). The US federal agencies with deep-sea coral management authority include National Marine Fisheries Service (NMFS) (with advice from the eight regional fishery management councils), NOAA's National Marine Sanctuary Program, and the Minerals Management Service (MMS) in the Department of Interior. NMFS and the regional fishery management councils may protect corals by adopting regulations that restrict fishing in certain areas, but they are not mandated to do so. National Marine Sanctuaries are designed to manage multiple uses compatible with protection, but management of fisheries is left to fishery management councils and NMFS. Consequently, bottom trawling is allowed in most US marine "sanctuaries" (Chandler and Gillelan, 2004). MMS oversees mineral, oil/gas exploration, and extraction in federal waters and is responsible for assessing the environmental impacts of these activities to natural resources, including deep-sea corals. Oil and gas development in

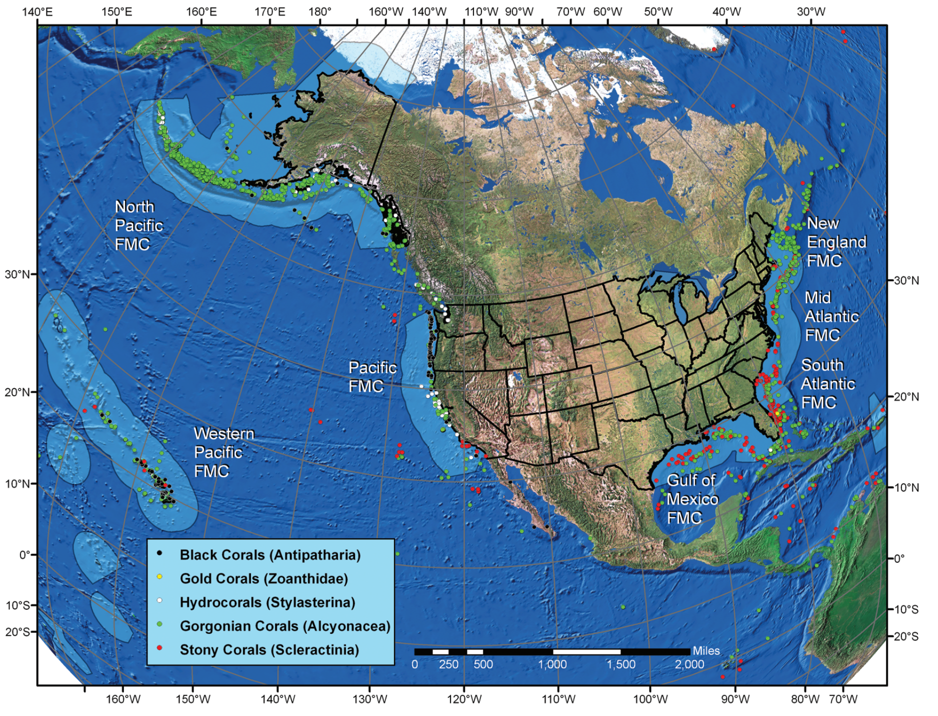

Figure 1. Overview of selected deep-sea corals in US waters with fisheries management council (FMC) regions (adapted from Morgan et al., 2006).

the Gulf of Mexico, the world's most active region for deep-water drilling (Glover and Smith, 2003; Avent, 2004), represents a threat to deep-sea corals because drilling, pipelines, and platform construction activities are occurring at depths and in areas where deep-sea corals are found (e.g., Viosca Knoll Lease Blocks 826 and 862 support diverse and abundant coral communities, S. Brooke, pers. comm.). These activities can crush corals or leak pollutants that may impact corals. Other activities which alter the seabed, including cable laying, are regulated by the Army Corps of Engineers.

Management of deep-sea corals as essential fish habitat.—Because fishing is the greatest current threat to deep-sea corals and most legal protections for them have been adopted in accordance with the nation's fishery management act, we focus the remaining discussion on management activities undertaken by NMFS. The authority to manage US fisheries comes from the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act, or MSA). Under the MSA, NMFS and the eight regional fishery management councils are required to identify and minimize impacts on essential fish habitat (EFH) of all species managed by federal fishery management plans. The MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The purpose of EFH is to identify areas required to support a sustainable fishery and ecosystem throughout the life cycle of the managed species. Within an EFH, the council can further designate Habitat Areas of Particular Concern (HAPCs). However, the MSA does not require protective regulations to be established for EFH and HAPC, and the HAPC designation only signifies that the habitat is a higher priority than the rest of EFH for conservation (Pautzke, 2005). National

Standard 9 of the Magnuson Stevens Act further requires the NMFS to adopt measures to minimize bycatch, including the bycatch of deep-sea corals, but this has not been used to limit fishing in coral areas.

Protection of deep-sea corals by regional fishery management councils under the EFH provisions are inconsistent and highly variable. This is a direct result of the non-binding language contained in the MSA. Some fishery management councils identify corals as a type of EFH for managed fish species, while others consider deep-sea corals themselves to be managed species. Thus some councils designate EFH specifically for deep-sea corals, while others only include deep-sea corals as EFH if a federally managed species can be shown to have a strong relationship with the coral. Often deep-sea corals are not considered in EFH designations because councils have insufficient data on the location of corals in their managed regions, or do not have sufficient information on the nature of the relationship of deep-sea corals and managed fish species.

Additionally the MSA was reauthorized in 2006, requiring NOAA to initiate a coordinated deep-sea corals research program to identify and map deep-sea coral ecosystems; it also affirms the authority of the regional fishery management councils to protect areas of the seafloor from any type of fishing gear that damages deep-sea coral habitat. The law gives the councils the unmistakable authority to move ahead with deep-sea coral protection efforts irrespective of whether coral areas have been deemed essential fish habitat. This is an important step for deep-sea coral protection, but it has not yet been acted upon by the fishery management councils.

Limitations to EFH designations.—The nature of single-species management or multi-species management—the current paradigm of fishery management—limits comprehensive protection for habitats and ecosystems. Many management actions, including EFH designations, are implemented through species-specific fisheries management plans, and are neither comprehensive nor primarily focused on deep-sea corals. To fully protect deep-sea corals, EFH designations must be accompanied by management actions to close areas to destructive fishing impacts. Instead, management actions are often limited by season restrictions, fishing gear, or fish species. In many cases the lack of clearly demonstrated fish—coral associations prevents EFH designation. Inconsistencies exist between fishery management councils definitions of EFH as well as their management actions. The following EFH actions highlight these inconsistencies.

Research has demonstrated the importance of deep-sea corals as fish habitat in Alaska, and managers have taken steps to protect some corals in this region. Deep-sea corals in Alaska have been described as keystone structures (Heifetz et al., 2005), and fish associations with corals are well documented (Stone, 2006). Stone (2006) reports that 85% of economically important fish and crabs, and 97% of juvenile rockfishes observed along submersible transects in the Aleutian Islands were associated with deep-sea corals or other emergent epifauna. Heifetz (2002) found Atka mackerel (*Pleurogrammus monopterygius* Pallas, 1810) and rockfish (*Sebastes* spp.) commonly associated with corals. In a study in waters of southeast Alaska, 85% of large adult rockfish were observed in and around *Primnoa* colonies (Krieger and Wing, 2002). These findings led the North Pacific Fishery Management Council to close some deep-sea coral areas to commercial fishing. In 2005 additional EFH regulations to prohibit bottom trawling in the Aleutian Islands Habitat Conservation Areas (AIHCA) (277,100 nmi^2) were adopted to address concerns about impacts on benthic habitat, particularly deep-sea corals, although much of the closure is deeper than trawlers operate at present. Additional protections for deep-sea corals exist for Bowers Ridge HAPC, where mobile bottom gear is prohibited, and in six small Coral Garden Marine Reserves (a total of 110 nmi^2) currently closed to all bottom gears. These actions serve to protect some small areas and prevent the expansion of trawling, but other gears (e.g., crab pots, bottom longlines) which can crush or entangle coral are still permitted in most areas (NMFS, 2005).

Similarly, *Oculina* reefs off Florida were important breeding sites for commercially important snapper (*Lutjanus* spp.) and grouper (Serranidae) (Reed et al., 2005a). Gag grouper (*Mycteroperca microlepis* Goode and Bean, 1879) and dense spawning populations of scamp grouper (*Mycteroperca phenax* Jordan and Swain, 1884) were observed above the corals in the 70s and 80s (Koenig et al., 2005; Reed et al., 2005a). *Oculina* also provides shelter for juvenile speckled hind (*Epinephelus drummondhayi* Goode and Bean, 1878), suggesting use of the habitat as a nursery (Gilmore and Jones, 1992; Koenig et al., 2005). Reed and colleagues (2005b) examined fish on and surrounding the deep reefs of Pourtales Terrace and Miami Terrace (south Florida) and found several important commercial fishes, including blueline tilefish (*Caulolatilus microps* Goode and Bean, 1878), seabasses and groupers (serranids), red porgy (*Pagrus pagrus* Linnaeus, 1758), blackbar drum (*Pareques iwamotoi* Miller and Woods, 1988), blackbelly rosefish (*Helicolenus dactylopterus* Delaroche, 1809), scorpionfish (scorpaenids), greater amberjack (*Seriola dumerili* Risso, 1810), phycid hakes (*Urophycis* spp.), and sharks (carcharinids). In the South Atlantic region, the 300 nmi^2 *Oculina* Banks HAPC off Florida now prohibits bottom trawling, and four deep-sea coral areas have been proposed as EFH/HAPCs in the South Atlantic Fishery Management Council region.

In other regions, however, the precise nature of the association between fish and deep-sea coral habitats is less clear, even though commercial fisheries occur in deep-sea coral areas. The designation of fish habitat as essential is problematic and varies from region to region. In many cases, fish appear to prefer three-dimensional structures, but do not differentiate between corals and other living or non-living structures (Auster, 2005; Tissot et al., 2006). Other factors, including research techniques and size-, age- or species-specific fish behavior, may also influence the observed relationship. Scientists do know that habitat changes resulting from coral removal have likely influenced the behavior of fish and their population distribution (Sainsbury et al., 1997). Hence, just because we do not see fish associating with corals in the present day does not mean that they would not have associated with corals in the pre-trawling past.

In the Gulf of Maine, fish density does not seem to be influenced by the presence or absence of corals. The only fish species known to demonstrate a preference for coral areas over other structures for shelter and feeding is the oreo *Neocyttus helgae* (Holt and Byrne, 1908) (Auster, 2005; Auster et al., 2005). However, destructive fishing methods have altered coral distributions and abundance throughout the Gulf of Maine (Watling and Auster, 2005) and it is probable that the association/correlation between fish behavior and coral habitat has also been altered. EFH designation prohibits trawling for monkfish (*Lophius americanus* Valenciennes, 1837) in two submarine canyons in New England (Oceanographer and Lydonia Canyons) that are identified as HAPC for the purpose of protecting deep-sea corals. However, other bottom-tending gears not targeting monkfish still can be used to catch other fish species, and these methods negatively impact deep-sea coral ecosystems.

In the Pacific region, scientists observed large invertebrates and fishes among newly-discovered Christmas tree coral (*Antipathes dendrochristos,* Opresko, 2005) colonies off southern California, but the abundance of these invertebrates and fishes was low

(Tissot et al., 2006). Only eight of the 106 observed fish species showed a higher concentration inside the coral area as opposed to outside. A possible explanation for the lack of a demonstrable fish-coral association is that the relatively small size of most of the Christmas tree corals observed (< 50 cm) prevents them from serving as key shelter and refuge (Tissot et al., 2006). An EFH designation proposed by the fishery management council in 2005 and approved by NMFS in 2006 closed some banks to bottom trawling and all waters west of the 700 fathom depth contour to bottom trawling to protect depleted groundfish stocks. This action is intended to prevent further expansion of trawling into deeper waters, but it is unknown whether it will protect deep-sea corals since there are few known deep-sea coral records (Etnoyer and Morgan, 2005) in the region. Large closures created by "freezing the trawl footprint" may also not contain the most important deep-sea coral habitats.

Current coral management under fishery management plans has limitations; they focus on activities related specifically to certain economically valuable species, regional councils interpret fishery regulations differently, and council regulations are not law and can be rescinded. Finally, despite a dramatic increase in deep-sea coral science in recent years, the burden of proof is to demonstrate impact, rather than demonstrating no impact. This has been partially reversed with management actions that freeze the historic footprint of trawling activities, but remains a large obstacle to coral protection.

The burden of proof to determine the functional relationships between fish and corals prior to EFH designation or deep-sea coral protection is squarely at odds with the advice of the MSA to managers. MSA suggests that managers manage in a precautionary manner, but EFH designation requires that functional relationships be proven before protection is granted. This is a catch-22 situation and represents a substantial threat to deep-sea corals.

Areas with complete gear closures designated for deep-sea corals are quite small, and typically created after significant gear impacts have occurred (e.g., Aleutian Islands), and experience shows that enforcement can be a significant obstacle (e.g., illegal trawling in the *Oculina* HAPC off Florida, Reed et al., 2005a).

The need for ecosystem-based management.—Ecosystem-based management (EBM) will markedly improve the management of deep-sea corals and reduce current limitations on deep-sea coral conservation for three reasons. First, EBM addresses more than commercially valuable species and seeks to maintain habitats and ecosystem functions (Pikitch et al., 2004; Murawski, 2005; George et al., 2007). In EBM, deep-sea corals do not have to be proven as essential for commercial fishes before receiving protection. The habitat complexity that deep-sea corals contribute to the benthic environment is enjoyed by commercial and non-commercial fishes alike, and EBM lends itself to protecting all parts of the ecosystem regardless of their commercial value. EBM departs from the single-species approach to fisheries management, and should prevent collateral damage of fishing to the ecosystem. Deep-sea corals will gain comprehensive protection as opposed to the case-by-case/gear-by-gear management actions that have taken place to date. Access to remote locations is difficult and expensive, and using traditional coastal resource management based on individual fisheries assessments is logistically intractable. Also, with single-species management methods, a new fishery could develop and wipe out a habitat before protective measures could be enacted. Protecting an entire ecosystem allows management to be pro-active rather than reactive.

Second, EBM integrates the management of not only fishing activities but also other human impacts on the ecosystem (Rosenberg and McLeod, 2005; George et al., 2007). It provides the framework for assessing the consequences of hydrocarbon development, waste dumping, cable laying, climate change, etc., on deep-sea corals. More importantly, it allows us to evaluate and manage the synergistic impacts of all these threats combined. EBM is suitable for examining human impacts holistically and bringing together multiple government agencies with different authorities to address conservation issues.

Third, EBM bases adaptive management on the precautionary principle. EBM places the burden of proof on those whose activities affect the ecosystem (Pikitch et al., 2004; Murawski, 2005). In an EBM scenario, the fishing industry would be required to prove that fishing does not result in detrimental effects on the habitat of a particular area before fishing is allowed there. As scientific understanding progresses and ecosystem functions are better understood, management can adapt and regulate activities that are compatible (or not compatible) with specific habitats and ecosystem functions. Given that new locations/species of deep-sea coral are discovered every year and deep-sea coral research is growing at a fast pace, adaptive management would be a suitable approach for integrating new research findings into protection measures.

In recent years, management of commercial fisheries in the USA has been slowly evolving and a greater recognition of the interconnectedness of exploited species and their supporting ecosystems has taken on added importance. NMFS appears to be committed to viewing fishery management as more than the sum of multiple fishery stock assessments (Murawski, 2005). This is very good news to those concerned with biodiversity conservation, but current laws continue to provide a disservice to marine organisms that are not "proven" contributors to commercial fisheries. Deep-sea corals are not protected under the Endangered Species Act or similar legislation. EBM would also benefit sponges, echinoderms, and other cnidarians such as sea anemones, which all play important roles in benthic environments.

In summary, deep-sea corals in the USA are largely unprotected and the few seafloor habitat areas that are protected obtain a reprieve from destructive fishing methods only because they are thought to be important to a managed fishery or occur in areas where fishermen do not want to fish (e.g., rocky canyons, very deep water). Coral protection via fisheries management plans has proven to be insufficient for coral ecosystem health and a new approach is warranted. Ocean management should focus on ecosystem resilience and the maintenance of biodiversity rather than the health of commercially important fisheries alone. Fisheries and catch levels should be developed in accordance with protecting benthic habitats such as deep-sea corals and other components of seafloor ecosystems. An ecosystem-based management approach is the method by which deep-sea corals will truly receive protection from destructive fishing methods.

Acknowledgments

We are grateful for the support of Richard and Rhoda Goldman Fund, Bullitt Foundation, National Fish and Wildlife Foundation, Curtis and Edith Munson Foundation, J. M. Kaplan Fund, and Oak Foundation for our efforts to study and conserve deep-sea corals. E. Norse, W. Chandler, H. Goldstein, and J. Palmer all provided important contributions to this paper. ESRI generously donated software. We appreciate the encouragement of R. George, and the efforts of S. Cairns to produce this volume. NOAA provided access to lots of information and data that was very helpful. We also thank the following scientists for help in accessing information and data, P. Etnoyer, P. Auster, R. Stone, L. Watling, S. Cairns, M. Stiles, J. Warrenchuk, and M. Hirshfield. Lastly, we thank the participants of the Third Symposium on Deep-Sea Corals for their infectious enthusiasm for these animals.

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