

Can the last deep-sea *Oculina* coral reefs be saved?:
A management analysis of the *Oculina*
Habitat Area of Particular Concern

by

Kelly Roth

Date: _____

Approved:

Dr. Larry Crowder, Advisor

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ABSTRACT

The ivory tree coral, *Oculina varicosa*, is known to form reefs only in deep water (80-100 meters) off the central Atlantic coast of Florida. These unique reefs support high levels of biodiversity, and provide important spawning habitat for commercially important fish species such as snappers and groupers. The fragile, slow-growing *Oculina* reefs are easily destroyed by bottom trawls, and other types of bottom fishing gear. In 1984 the South Atlantic Fishery Management Council established the *Oculina* Habitat Area of Particular Concern (HAPC), banning all bottom trawling in a portion of the reef system. The protected area was expanded in 1994 to include most of the *Oculina* reefs. However, recent surveys showed that about 90% of the reefs have been destroyed, mainly by bottom trawling for rock shrimp. This project is an analysis of why the *Oculina* reefs are almost gone despite many years of protection, and what could be done to improve enforcement and protection of the *Oculina* HAPC.

Information was collected from literature research, and conversations with several stakeholders and experts on issues relevant to the *Oculina* HAPC. Four main policy problems emerged: a historical lack of enforcement in the rock shrimp fishery, continuing lack of enforcement in the snapper grouper fishery, insufficient penalties for violations of the HAPC regulations, and a lack of funding for research, enforcement, education, and outreach. The pros and cons of six potential solutions to address these problems are discussed: (1) require VMS in the snapper grouper fishery; (2) establish acoustic monitoring systems in the OECA; (3) increase penalties for violations of the *Oculina* HAPC; (4) increase funding for research, enforcement, education, and outreach; (5) expand the *Oculina* HAPC; and (6) establish part or all of the *Oculina* HAPC as a National Marine Sanctuary. It is important to establish effective protections for the *Oculina* HAPC, not only to conserve the remaining *Oculina* reef ecosystems, but to learn how to prevent such widespread destruction of other deep-sea coral ecosystems.

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Introduction

Fifteen miles off the central eastern coast of Florida and 80 meters below the surface, white, bush-like thickets of coral several meters across sit atop limestone pinnacles up to 30 meters tall (Reed 2002a,b). These reefs, estimated to be over 1,500 years old, were built by the coral *Oculina varicosa*, and they extend for 167 miles along the continental shelf break (SAFMC 2006b). A diverse assemblage of fish and invertebrates thrives among the coral branches (Reed 2002b, Koenig et al. 2005). Brittle stars, tube worms, and sponges cover the stark white coral; rock shrimp and small crabs take refuge among the branches; and reef fish dart among the coral mounds. Commercially important reef fish, such as snappers and groupers, aggregate by the hundreds on these reefs to spawn (Koenig et al. 2005).

This is how the *Oculina* reefs looked perhaps 30 or 40 years ago. Today, the landscape looks much different. Decades of illegal bottom trawling for rock shrimp have transformed nearly all of the healthy *Oculina* reefs into swaths of coral rubble, largely devoid of life (Koenig et al. 2005, Reed et al. 2007). The diversity and abundance of fish and invertebrates has declined drastically (Koenig et al. 2005). Habitat destruction and overfishing have severely reduced spawning aggregations of snappers and groupers. Only two *Oculina* reefs remain in this area—these are the last known deep water *Oculina* reefs in the world (SAFMC 2006a).

The widespread destruction of the *Oculina* reefs has occurred despite protections that have been in place for over 20 years. The South Atlantic Fishery Management Council (the Council) designated a portion of the *Oculina* reefs as a Habitat Area of Particular Concern (HAPC) in 1984, banning bottom trawling, bottom long lines, and fish traps (SAFMC 2006b). In 1998 the Council expanded the *Oculina* HAPC to include all the deep-water reefs known at

that time (see Fig. 1). However, more than 90% of the reefs in *Oculina* HAPC have been destroyed, and snapper and grouper spawning aggregations have declined, and in some places disappeared.

In this paper I analyze the management of the *Oculina* HAPC to determine the policy problems that have led to the widespread destruction of this unique reef system, and to identify potential management solutions to improve protection of the reefs and the ecosystems they support. In part one, I describe recent research and current understanding of *Oculina* reef ecology. In part two, I discuss the human and political aspects of the issue. In this section, I summarize the management history of the *Oculina* HAPC, and describe the policy problems that have led to the destruction of the reefs. I then describe relevant legal mandates, and the human ecology of the issue, including the roles of stakeholders and administrative agencies. In part three, I discuss possible management solutions that could improve the protection of the *Oculina* reefs, and associated fish populations.

PART I. ECOLOGY OF DEEP-SEA *OCULINA* REEFS

Deep sea *Oculina varicosa* reefs

Oculina varicosa, the ivory tree coral, has a broad geographical distribution, but only forms reefs where it grows in deep water. *Oculina* occurs in the Caribbean and the Bahamas, along the Florida coast, and as far north as Bermuda (Reed 1980). Throughout most of its distribution, *Oculina* is found in shallow, tropical to sub-tropical waters and usually forms only small colonies less than 30 cm in diameter (Reed 2002a). *Oculina* only forms large thickets and reef structures at depths of 60 to 150 meters (Reed 2002a). A 167 km stretch near the shelf break off central eastern Florida is the only known place in the world where deep sea *Oculina* reefs occur.

Deep sea *Oculina* reefs have grown to impressive sizes over hundreds of years. Individual colonies range from 10 cm to 1.5 meters across, and sometimes grow together to form linear colonies 3 to 4 meters long. At a depth of 80 meters, *Oculina* grows an average of 16 mm per year (Reed 1981). At this rate, a colony 1.5 meters across could be almost 100 years old. The largest deep-sea *Oculina* reefs, reaching heights of 25 meters, are estimated to be at least 1,526 years old (Reed 2002a). Such reefs have grown together to form massive thickets on the slopes and crests of rocky pinnacles that can be several hundred meters in diameter and extend vertically as far as 35 meters above the sea floor (Reed 2002a, Reed 1980).

These pinnacles provide an optimal place for coral larvae to settle and build reefs. The reefs are believed to form when coral larvae initially settle on rock pavement or outcrops, and grow into a coral thicket, reproducing sexually or by branch fragmentation and re-growth (Brooke and Young 2003). As the coral mound grows, it traps sediment and coral debris,

eventually forming a large reef of unconsolidated coral debris and sediment capped with live coral (Squires 1964; Mullins et al. 1981). The *Oculina* pinnacles provide substrate that larvae need in order to settle and take hold. The pinnacles sit in the Florida Current, which carries plankton that the *Oculina* polyps capture for food. In fact, *Oculina* colonies are most dense on the southern sides of the pinnacles, which are more likely to be exposed to the Florida Current (Reed 2002a). Periodic cold-water upwelling may also be an important source of nutrients for the coral (Reed 2002b). This food source is important for deep-sea *Oculina* colonies because sufficient light for algal growth does not penetrate to these reefs. Unlike tropical shallow water corals that produce their own food via symbiotic zooxanthellae algae, deep-sea *Oculina* polyps lack zooxanthellae, hence their white color, and rely on food filtered from the water column (Reed 2002a).

Fish and invertebrate diversity on *Oculina* reefs

The *Oculina* reefs off Florida support a diverse array of fish and invertebrate species. The number of different taxa on these reefs is comparable to that of many shallow-water tropical reefs (Reed 2002a,b). *Oculina*'s rigid branches and bushy structure offer countless places for fish and invertebrates to take shelter, and to hide from predators. On just 42 small colonies from deep and shallow water, scientists found over 20,000 individual invertebrates (Reed 2002a). These included 230 mollusk species, 50 decapod species, 47 amphipod species, 21 echinoderm species, 15 pycnogonid species, and many other taxa (Reed et al. 1982; Reed & Hoskin 1987; Reed & Mikkelsen 1987; Child 1998).

In addition to high invertebrate diversity, healthy *Oculina* reefs also support dense fish

populations (Reed 2002a, Reed et al. 2005). The *Oculina* reefs off Florida provide important habitat and spawning grounds for many commercially important fish species (Gilmore and Jones 1992; Koenig et al. 2000). Greater amberjack, almaco jack, scamp, red snapper, snowy grouper, speckled hind, red porgy, gag grouper, and other snapper species are commonly found in aggregations on the reefs (Koenig et al. 2005). Furthermore, observations by Koenig et al. (2005) of juvenile speckled hind on Jeff's and Chapman's Reefs suggest that these reefs may serve as nurseries for commercially important fish species. Many commercially valuable fish species utilize *Oculina* reef habitat, including fish at reproductive and juvenile life history stages.

***Oculina* habitat decline**

The original *Oculina* HAPC was established in 1984, and was expanded in 1998. However, most of the corals in the *Oculina* HAPC have been destroyed. Koenig et al. (2005) estimate that 90% of the *Oculina* habitat in the HAPC has been severely degraded or destroyed, and recent analyses by Reed et al. (2007) that compare photographic transects from 1976 to 2001 show nearly 100% devastation of some of the northern reefs that were not protected in the original HAPC boundaries. Koenig et al. (2005) surveyed three high-relief sites in the *Oculina* HAPC—Jeff's Reef, Chapman's Reef, and Sebastian's Reef (see Fig. 2). In the 1970s, Jeff's Reef and Chapman's Reef were known to have extensive intact coral thickets, and Sebastian's Reef was known to have only extensive coral rubble. In 2001, less than 10% of the surveyed habitat contained intact coral colonies. Since 2001, few additional coral thickets have been found within the original HAPC (now called the *Oculina* Experimental Closed Area, or OECA) (Reed et al. 2005), but the areas that have been surveyed so far within the *Oculina* HAPC north of the OECA

appear to be mostly coral rubble. Scientists wanted to know what was causing the corals to disappear.

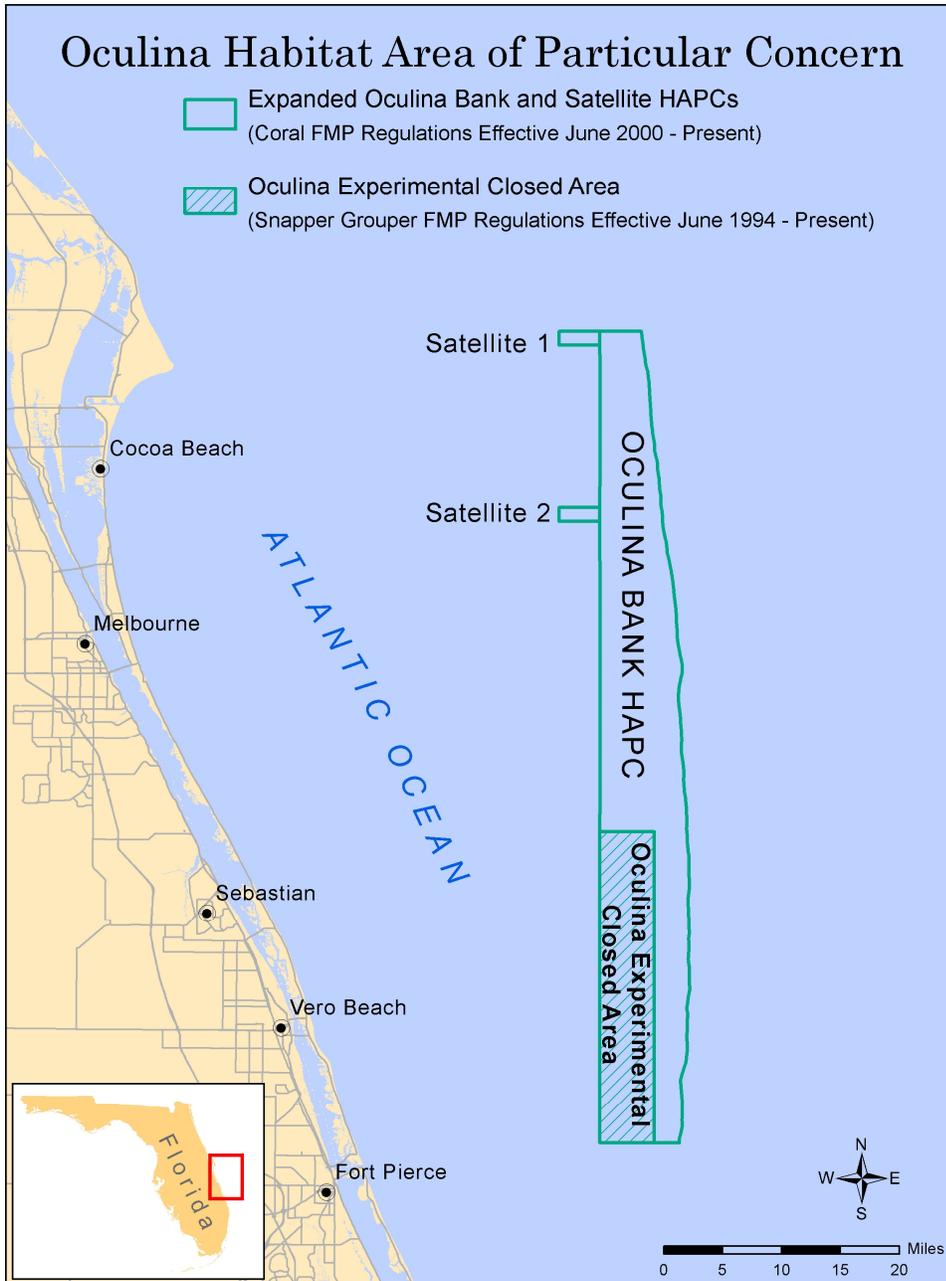


Figure 1. The *Oculina* Habitat Area of Particular Concern. The boundaries of the *Oculina* Experimental Closed Area encompassed the original *Oculina* HAPC of 1984. (SAFMC 2006b)

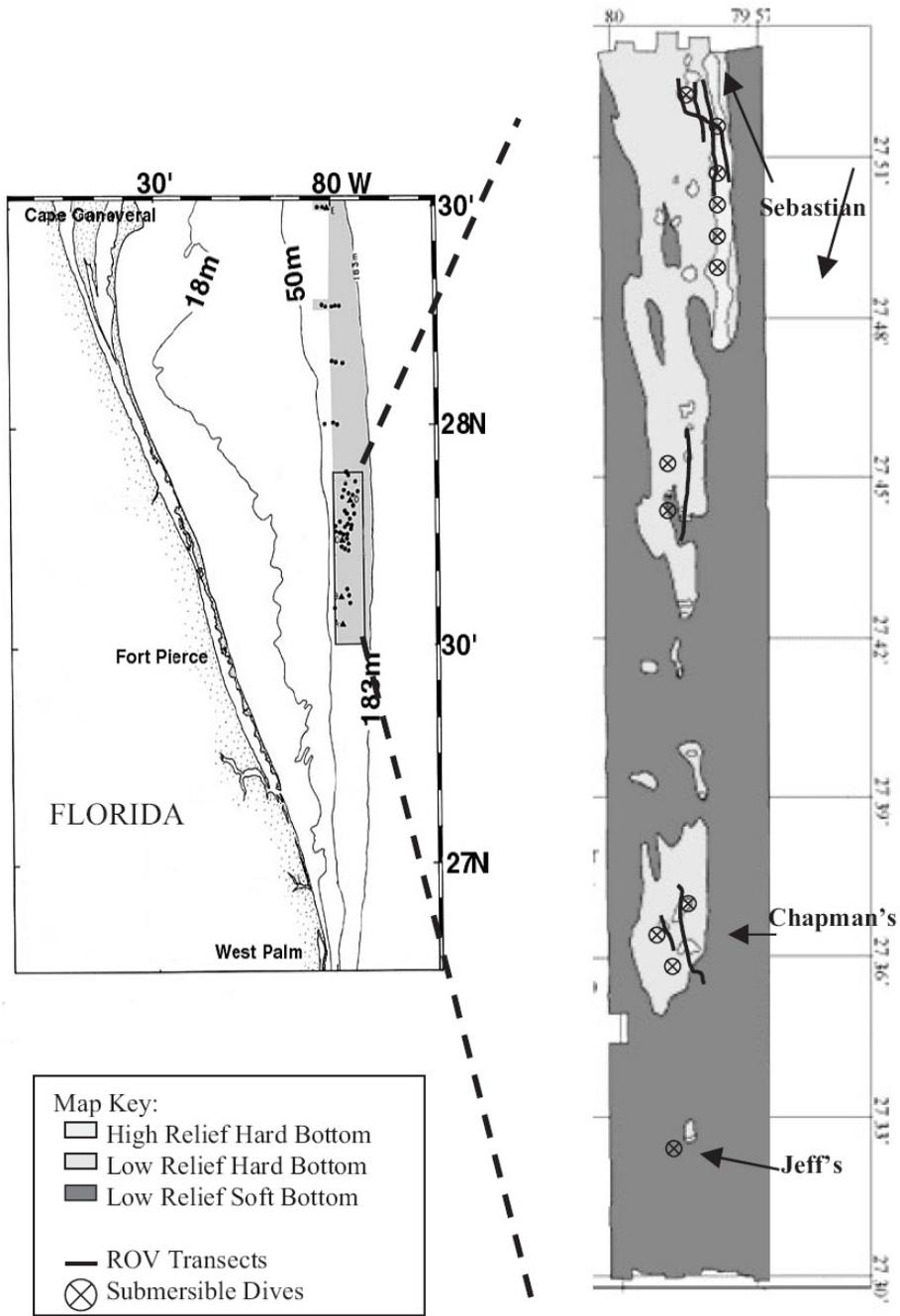


Figure 2. Study area from Koenig et al. 2005 showing the three reefs surveyed in the OECA and the three surveyed areas north of the OECA. The shaded area in the locator map at left is the Oculina HAPC. An enlarged view of the OECA is shown to the right. (Koenig et al. 2005)

While many environmental factors can damage corals, scientists do not believe these factors can account for the widespread destruction of the *Oculina* reefs. Corals can be damaged by extreme temperatures (Fitt et al. 2001), excessive nutrient input (Szmant 2002), strong currents (Lugo et al. 2000), and disease (Porter et al. 2001). However, *Oculina* appears to be relatively tolerant of changes in temperature, and changes in nutrient and sediment input that occur during upwelling events (Koenig et al. 2005). The effect of disease has not been studied on *Oculina* reefs, but scientists predict that virulent pathogens would cause extensive damage, rather than selective elimination of reefs, as is seen in the OECA (Koenig et al. 2005). Rather than changes in environmental conditions, scientists point to direct human impacts as the major threat to these reefs.

Mechanical destruction from fishing gear is the most probable explanation for the extensive reef damage. Several types of fishing gear are likely responsible for the damage to the fragile corals. Shrimp trawling is widely regarded as the largest threat to *Oculina* reefs (Koenig et al. 2005). Although it seems unlikely that trawl fishermen would operate among the high-relief pinnacles of the *Oculina* reef at the risk of losing gear, shrimp trawlers have been caught and fined for fishing in the *Oculina* HAPC (Reed 2002b). Roller trawl gear, which incorporates wheels along the bottom chain of the trawl net, is often used on rough bottom to prevent net hang-up (Reed 2002b). This type of gear would decimate fragile *Oculina* coral reefs. Anchors that are dropped or dragged through the reefs would also certainly destroy corals. Additionally, since the reefs are in the Florida Current, and are over 60 meters deep, fishermen fishing for snappers and groupers would have to use large fishing weights that would damage the reefs (Reed 2002b). If bottom traps are placed on reefs, they would also damage the fragile corals

(Reed 2002b).

Several commercial fisheries have utilized *Oculina* reef areas in recent decades. Within the last 30 years, three fisheries have operated in this area: a trawl fishery for rock shrimp, a trawl and dredge fishery for calico scallops, and a hook-and-line fishery for reef fish, such as groupers and snappers (Koenig et al. 2000). The rock shrimp and calico scallop fisheries began in the early 1970s. The scallop fishery collapsed in the late 1980s, but the rock shrimp fishery continues today (Stimpson 1989). Until 1998, when the *Oculina* HAPC was expanded, trawling was legal on the reefs north of the original HAPC, and many of the reefs were destroyed by trawlers during this time. Furthermore, both commercial and recreational hook-and-line bottom fishing increased in the OECA in the early 1980s, decimating the breeding aggregations of grouper and snapper by the late 1980s (Koenig et al. 2000).

Bottom trawling and dredging by both domestic and foreign fleets have occurred for decades off Florida's eastern coast. Foreign trawling ended in the late 1970s with the designation of the U.S. Exclusive Economic Zone (EEZ). How much domestic trawling occurs today in the *Oculina* reefs is unknown, but circumstantial evidence suggests that it does occur (Koenig et al. 2005). High-relief features where *Oculina* normally occurs show little evidence of coral recolonization, whereas dense thickets of coral cover untrawlable wrecks in the same areas. Until recently, the penalties for trawling in the *Oculina* HAPC were relatively light (i.e. confiscated catch and moderate fines), and were viewed by violators as a business expense (Koenig et al. 2005). Photographs of the reefs showing trawl scars cutting through coral rubble on the sea floor offer additional evidence of recent trawling activity in the *Oculina* HAPC (compare Fig. 3 a and b). Thus, there is a strong case that both legal and illegal fishing is

responsible for much of the reef destruction and overfishing in the *Oculina* HAPC and OECA.

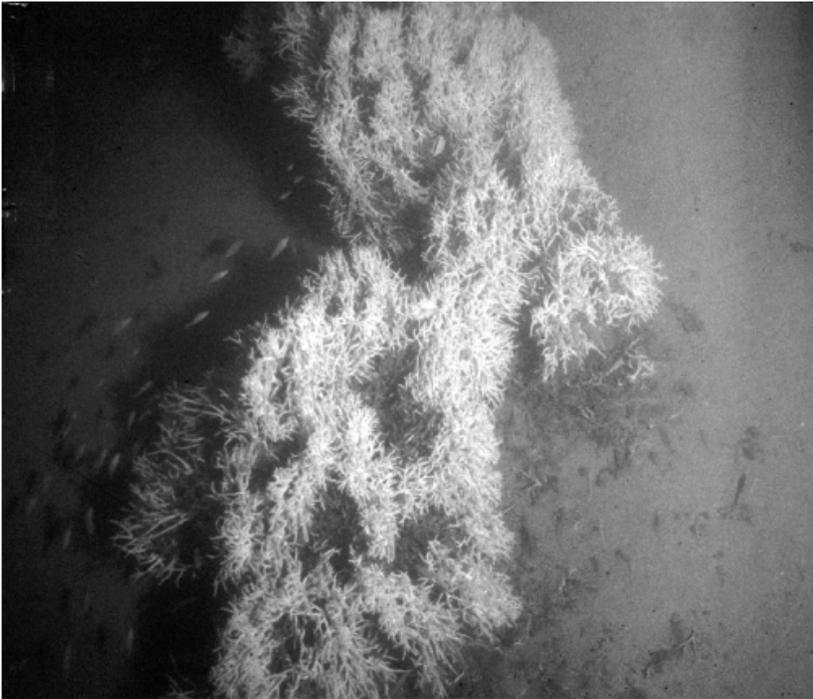


Figure 3(a). Intact *Oculina* reef at Cape Canveral pinnacle site in 1976. (From Reed et al. 2007)

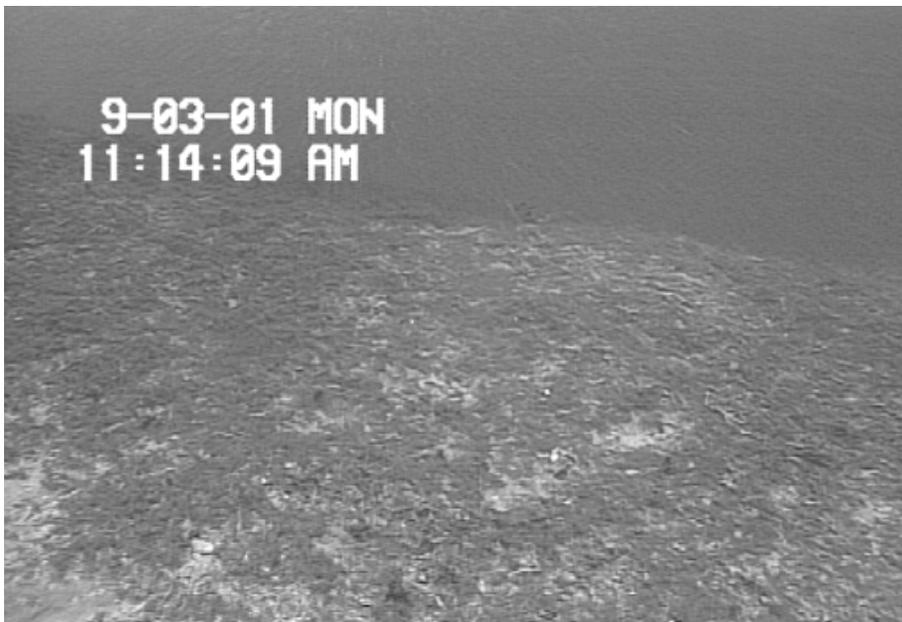


Figure 3(b). The same location in 2001. The reef has been reduced to coral rubble. (From Reed et al. 2007)

Fish populations

While healthy *Oculina* reefs support large populations of many fish species, habitat degradation has led to dramatic declines in fish populations in the *Oculina* HAPC. Koenig et al. (2005) compared videotapes of fish communities at Jeff's Reef in 1980 and 1995 which showed that dominance shifted from grouper species to small, non-fishery species, and that abundance of groupers declined. In 1980, Jeff's Reef supported a diverse assemblage of commercially important snapper and grouper species. The most abundant fish species was scamp, which accounted for 35.7% of all reef fish observed, and greater amberjack, which accounted for 30.2%. In 1980, nearly 70% of the dominant species were economically important species, mostly aggregating groupers (Koenig et al. 2005).

The 1995 video footage revealed distinct declines in the mean abundances and biomass of commercially important species. In these tapes, red barbier and roughtongue bass, neither of which are targeted by fishermen, accounted for 40.3% and 31.1% of fish sightings, respectively. Scamp accounted for just 4.4% of reef fish, and greater amberjack only 0.6% (Koenig et al. 2000). The loss and depletion of spawning aggregations likely caused these changes. Because fish migrate long distances to join these aggregations, the decreases probably signify region-wide population decreases (Koenig et al. 2000).

An analysis of the extent of reef damage during this time period suggests that habitat loss profoundly affects reef fish diversity. The destroyed habitats of Twin Peaks and Sebastian Pinnacles showed the lowest abundance of all the reefs, whereas intact reefs supported more fish (Koenig et al. 2000). These results reflect the notion that spatially complex habitats offer greater

opportunities for species to specialize in exploiting different resources than do spatially homogeneous habitats (Koenig et al. 2002). Thus, large areas of three-dimensional reef structures can support higher species diversity than expanses of fine coral rubble (Koenig et al. 2000).

Case study: Gag grouper

Decreasing gag populations have raised concerns about the effects of fishing on the health of the stocks. Studies conducted from the late 1970s to the mid-1990s showed significant declines in the proportion of males (Coleman et al. 1996; McGovern et al. 1998). In the late 1970s, males comprised 11% of the Atlantic gag population during the spawning aggregation period from December to March, but this percentage declined to 5% in the mid-1990s (Koenig et al. 2000).

While the mechanism by which gag change sex is poorly understood, it is likely that fishing on aggregations disrupts the process. Most fish in mid-transition from female to male were observed just after aggregation. This suggests that gag change sex near the time of aggregation, and that the cues for sex change probably occur at this time. The transition is mostly likely driven by social cues (Warner 1988). Over the same time period, gag populations have also decreased in size at maturity (McGovern 1998), decreased in mean size (Coleman et al. 1996), and experienced losses of spawning aggregations (Koenig et al. 1997). The low proportion of males may account for the inbreeding observed in the gag population (Chapman et al. 1999). Peak catches of gag occur during the spawning season (Koenig et al. 1996), however capture of males is highest on shelf-edge habitats, such as the *Oculina* reef, after the aggregation

period (Koenig et al. 2000).

Many economically and ecologically important reef fish species spawn on shelf-edge reefs. Some are affected by fishing similarly to gag, including scamp, red porgy, black grouper, jewfish, Nassau grouper, snowy grouper, Warsaw grouper, speckled hind, and yellowedge grouper (Koenig et al. 2000). Little is known about the reproductive ecology of these species, but the effects of fishing for gag in shelf-edge reef habitats suggests that shelf-edge marine reserves, like the *Oculina* HAPC, are necessary to sustain healthy fish populations (Koenig et al. 2000). The habitat destruction and declining fish stocks in the *Oculina* HAPC underscore the need for effective enforcement of reserves.

Reef restoration efforts

Researchers are testing concrete habitat modules to see if they could be effective tools in restoring fish habitat, and providing structure for coral recruitment (Koenig et al. 2005). In 2000, Koenig et al. (2005) placed artificial reef modules and reef balls (Reef Ball Foundation, www.reefball.org) in areas of the OECA where reefs had been destroyed. Reef balls are concrete domes 1 meter across and 0.7 meters high with several holes to allow fish to swim inside (see Fig. 4). They are meant to simulate the size and shape of *Oculina* colonies and to provide structure and hiding places for fish. They also provide substrate on which *Oculina* larvae may settle, and are used to transplant *Oculina* colonies in the hope of restoring thickets. When the reef balls were deployed, Koenig et al. (2005) attached living branches of *Oculina* to some of the reef balls (Fig. 5). However, Koenig et al. (2005) have not been able to return to the reef balls to assess their effectiveness for fish and coral recruitment. In a separate experiment, a 2003 survey

revealed *Oculina* coral settlement on some artificial reef structures that were deployed in 1997 (see Figs. 6 and 7; J. Reed, Harbor Branch Oceanographic Institute, pers. comm.).

Illegal trawling in the OECA continues to threaten restoration efforts. Poachers have been caught in the HAPC with trawl nets as recently as 2007 (J. Reed, pers. comm.). Recent submersible observations found some reef balls crushed, and other experiments were found littering the sea floor, suggesting a strong mechanical impact, such as from a trawl (Koenig et al. 2005). In addition, evidence of trawl tracks has been observed cutting through coral rubble on the pinnacle slopes (Reed et al. 2005). Even in areas not damaged by trawls, the researchers found limited evidence of coral re-colonization (Koenig et al. 2005). Since the coral grows slowly, it may be too soon to draw conclusions about whether or not the corals will be able to re-establish coral thickets and reefs. However, scientists believe that if the coral rubble remains intact, and recurrent trawling is prevented from disturbing the rubble, then the rubble will provide habitat for new coral recruits (J. Reed, pers. comm.). The geological development of these high-relief coral pinnacles provides evidence that *Oculina* coral can and does grow on rubble substrate.

Considering the short time that artificial reef experiments have been in place, the reef balls show promise for re-establishing fish populations. Koenig et al. (2005) found that all the grouper species that were observed on *Oculina* reefs in the 1980s, except warsaw grouper, were associated with the reef balls one year after they were deployed. Additionally, the presence of gag and scamp males, which are typical of spawning aggregation sites, suggests that the reef balls may eventually support spawning aggregations (Coleman et al. 1996, Koenig et al. 2005). Scamp also displayed presumed courtship behavior, suggesting that the reef balls may provide

appropriate spawning habitat (Koenig et al. 2005). So far, reef balls are proving to be highly successful at restoring populations of ecologically and economically important fish species.

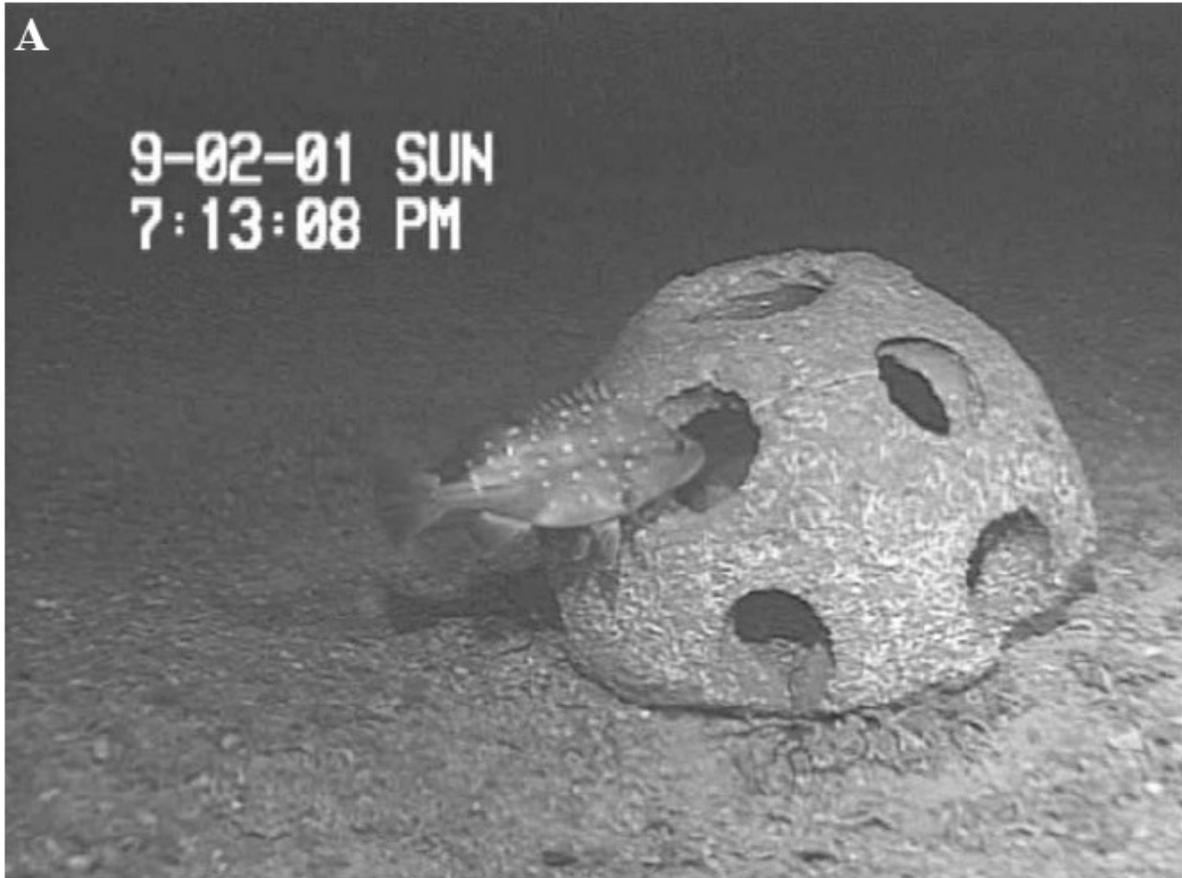


Figure 4. Reefball with snowy grouper deployed within Sebastian Pinnacles of the *Oculina* HAPC at 80 m depth (Reed et al. 2005).



Figure 5. *Oculina* coral fragment attached to reef ball prior to deployment (Koenig 2001).

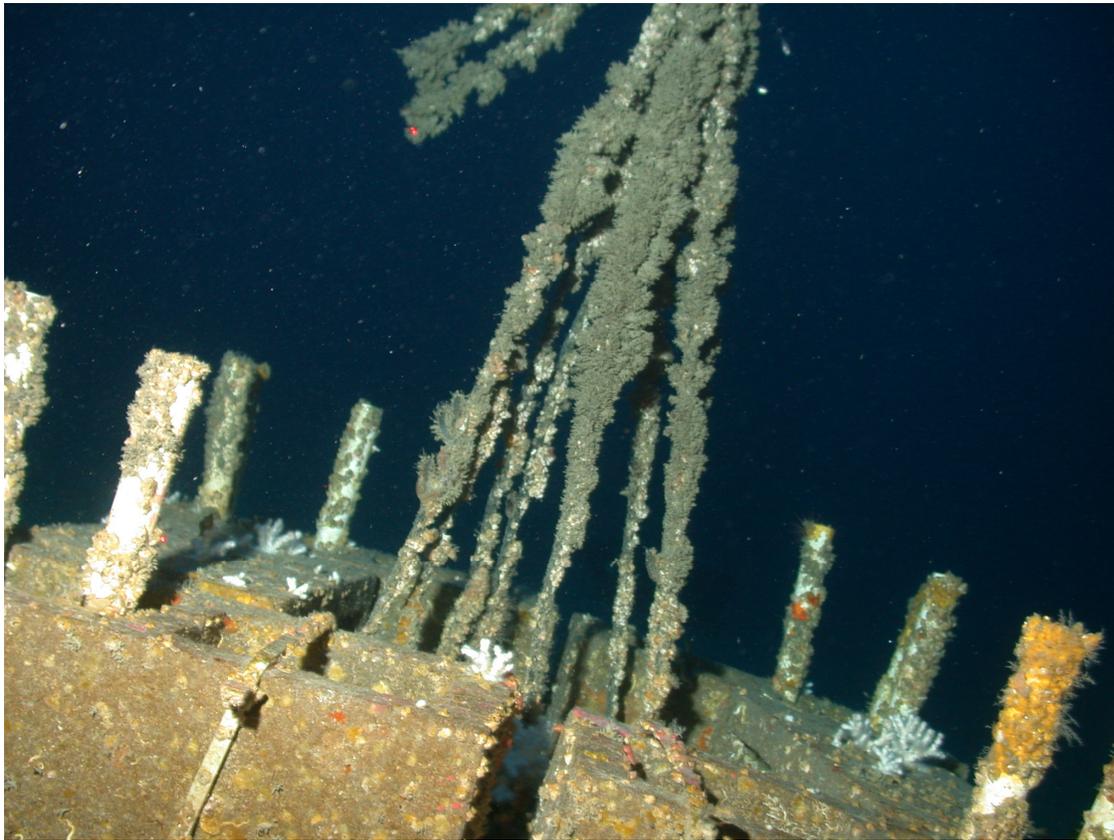


Figure 6. Reef blocks with *Oculina* recruits at 80 m within OECA (Reed and Shepard 2003).



Figure 7. Close-up of *Oculina varicosa* coral growing on a reefball (80 m depth) in the Sebastian Pinnacles (Reed et al. 2005).

PART II. HUMAN AND POLICY DIMENSIONS

History of management

Recognizing the importance of the *Oculina* reefs, and the threats they face from destructive fishing methods, the South Atlantic Fishery Management Council established the *Oculina* Habitat Area of Particular Concern (HAPC) in 1984. The original *Oculina* HAPC encompassed 316 km² of *Oculina* reef habitat, and was the first marine protected area in the world established to protect deep sea coral reefs (see Fig. 1). Trawling, dredging, longlining, trapping, anchoring, and possession of rock shrimp were prohibited in this area.

Research documenting the decline of reefs, and of snapper and grouper populations spurred the Council to increase protections for the *Oculina* reefs beginning the mid-1990s. In 1994 the Council renamed the *Oculina* HAPC the *Oculina* Experimental Closed Area (OECA), and closed the area to all anchoring and bottom fishing for snappers and groupers (SAFMC 1994). These restrictions, set to sunset in 2004, were intended to protect fish populations from fishing pressure, and to increase recruitment of new fish to the area. The Council added rock shrimp to the shrimp management unit through in 1995 (SAFMC 1996). This amendment also prohibited trawling for rock shrimp east of 80 degrees W, and between 28 30 N and 27 30 N at depths less than 100 fathoms (~180 meters). This area became known as the rock shrimp closed area (see Fig. 8).

The Council expanded the *Oculina* HAPC in 1998 to include the rock shrimp closed area (see Fig. 1; SAFMC 1998). This area is off limits to fishing with bottom longlines, bottom trawls, dredges, fish pots, and traps. Additionally, no fishing vessel may anchor in the *Oculina* HAPC. The prohibitions on fishing for and retention of snappers and groupers is in effect only

for the OECA. There are no restrictions on trolling for pelagic species, such as dolphin and sailfish.

Since 2003 the Council has required all vessels in the rock shrimp fishery to have vessel monitoring systems (VMS) on board (SAFMC 2002). VMS is a satellite tracking system that allows law enforcement officials to remotely monitor the locations of vessels outfitted with the devices. If their computer output shows a vessel in the protected area, the Coast Guard, or other law enforcement agency, can dispatch enforcement agents to intercept the violator. While it is sometimes difficult to determine from the VMS whether vessels are trawling or simply steaming through the protected area, VMS has dramatically improved law enforcement officials' ability to monitor illegal activity in the *Oculina* HAPC.

Also in 2003, the Council amended the Snapper Grouper Fishery Management Plan to indefinitely extend the prohibitions on fishing for, and retaining snappers and groupers in the OECA (SAFMC 2003). This amendment also required the Council to consider changing the size and configuration of the OECA in three years, and to re-evaluate its effectiveness in 10 years. In 2006, the Council began this process by establishing the *Oculina* Evaluation Team, comprised of a range of stakeholders, including scientists, fishermen, and law enforcement officials, and tasked with evaluating the size and configuration of the OECA. The *Oculina* Evaluation Team convened for the first time in August 2006, and produced a report in which they recommended making no changes to the size and configuration of the OECA (Reed et al. 2006). The report also outlined priorities for future research and monitoring projects for the OECA (Reed et al. 2006). However, there is currently no funding available to carry out any of these projects (J. Reed, pers. comm.).

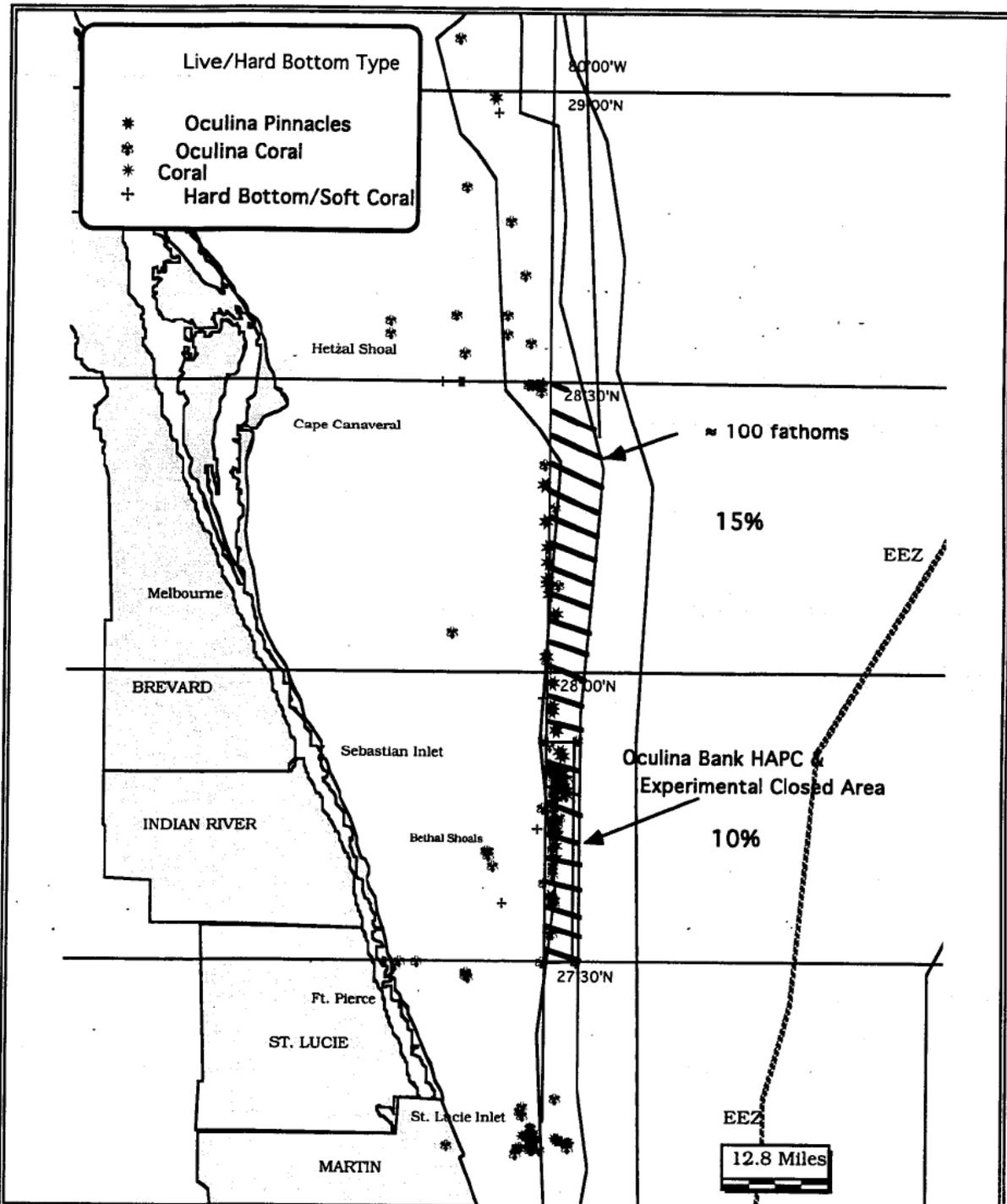


Figure 8. Map of rock shrimp closed area (hatched areas). Also shows coral, coral reef, and live/hard bottom habitat associated with rock shrimp harvest areas. (SAFMC 2005)

The policy problems

Four main policy problems have led to the destruction of the *Oculina* reefs. First, a historical lack of enforcement of the *Oculina* HAPC regulations has left much of the *Oculina* reefs vulnerable to bottom trawling and other damaging fishing methods for many years. Second, a lack of enforcement in the snapper grouper fishery has led to overfishing of spawning aggregations in the OECA. Third, the penalties for violating the *Oculina* HAPC regulations appear to be insufficient to deter some fishermen from using destructive fishing gear in the HAPC. Finally, the *Oculina* HAPC lacks adequate funding for research, enforcement, education, and outreach. This section considers each of these policy problems.

Historical lack of enforcement

By establishing the *Oculina* HAPC in 1984, the Council positioned itself to be a leader in deep-sea coral reef conservation. However, until recently, the strong protections for the HAPC that the Council wrote into its Coral Fishery Management Plan went largely unimplemented. The Council and NOAA Fisheries have been slow to take action to improve enforcement of the *Oculina* HAPC regulations.

The destruction of the reefs probably began in the 1970s, when fisheries for rock shrimp and scallops developed in the area. The scallop fishery employed bottom-scraping dredges in the waters off Florida from the 1970s to the late 1980s. Overfishing caused this fishery to collapse, and it no longer operates in the *Oculina* reef area. The rock shrimp fishery began in 1979, and is still in operation. The original HAPC only protected about one-third of the known reefs; rock shrimp trawling remained legal in the other two-thirds of the known reefs until the HAPC was

expanded in 1998. Additionally, mapping efforts since 2000 have revealed over 100 previously-unknown *Oculina* pinnacles that lie west of the current HAPC boundaries, and thus remain unprotected from rock shrimp trawls (J. Reed, pers. comm.).

It is unclear whether enforcement has been adequate in the original *Oculina* HAPC. This area, now called the OECA, contains the only remaining intact reefs, which suggests that enforcement may have been somewhat successful in excluding trawlers from the area. This area may have received better protection than the northern portion of the *Oculina* HAPC because it is only 15 miles from the nearest Coast Guard station in Ft. Pierce, whereas the northern portion is 30 miles from the Cape Canaveral Coast Guard station. Jeff's and Chapman's Reefs, the two remaining reefs in the OECA, lie far from other reefs; their isolation may have deterred fishermen from seeking them out. These reefs could have been spared because of enforcement efforts, or because they happen to lie far from other popular shrimp trawling areas.

In the mid-1990s, approximately 10 years after the *Oculina* HAPC was established, the Council began taking steps to improve protection and enforcement of the area. With the 1994 ban on fishing for snappers and groupers in the HAPC, and the expansion of the HAPC in 1998, the Council took important steps toward protecting *Oculina* reefs and the fish that depend on them. Enforcement improved significantly when the Council mandated VMS on all rock shrimp vessels in 2003. The Florida Fish and Wildlife Conservation Commission's (FWC) purchase of a new enforcement vessel, the C.T. Randall, in 2004, allowed for increased enforcement presence in the *Oculina* HAPC. Though these recent changes have dramatically improved enforcement of the HAPC, the Council was slow to implement them, and most of the reefs were destroyed before these measures were put in place. The stronger enforcement measures emplaced in the

last several years are critical to protect Jeff's and Chapman's reefs, and to allow coral larvae to settle and potentially begin to rebuild destroyed reefs.

Lack of enforcement in the snapper grouper fishery

A lack of enforcement in the snapper grouper fishery has allowed overfishing to continue in the OECA. Snapper and grouper fishermen continue to poach in the OECA, as evidenced by discarded longline gear found tangled around *Oculina* colonies (see Fig. 9), and by admissions from recreational fisherman that these reefs are among their favorite fishing spots (G. Gilmore, Estuarine, Coastal, & Ocean Science, Inc., pers. comm.). While both commercial and recreational snapper grouper fishermen can damage the coral with their gear, and contribute to overfishing, the recreational sector poses the greater threat. This is because many more recreational boats operate in this fishery than do commercial boats. Furthermore, Fort Pierce, which lies just 15 miles from the OECA, is the largest port serving recreational fishermen from the greater Orlando area (G. Gilmore, pers. comm.). Since VMS is not required in this fishery, enforcement officers must rely on patrols by vessel or aircraft to catch violators. Enforcement officers also claim that it is difficult to observe the difference between fishermen legally fishing for pelagics in the OECA, and those who are bottom-fishing for snappers and groupers (J. Reed, pers. comm.).

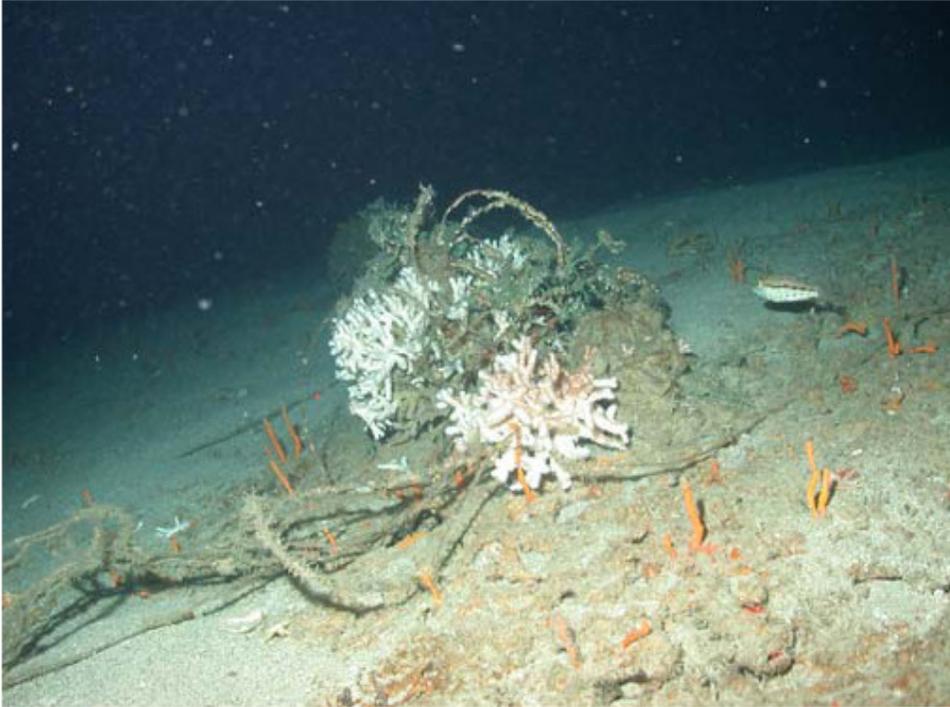


Figure 9. Longline fishing gear wrapped around an *Oculina* colony (Sebastian pinnacles, 80 m depth). (Reed 2006)

Insufficient penalties for violations

While enforcement of the *Oculina* HAPC has improved recently, the penalties for violations have proven insufficient to deter some fishermen from continuing to trawl over the reefs. Fishermen can incur fines and permit sanctions for anchoring, trawling, longlining, and having rock shrimp, *Oculina* coral, or snapper/grouper on board within the HAPC. Enforcement officials may also confiscate a violator's catch.

While most fishermen abide by the regulations, the penalties are not high enough to deter some fishermen. When a fisherman violates the *Oculina* HAPC regulations, the boat's owner and captain are usually assessed a fine and a permit sanction (R. Chesler, NOAA Office for Law Enforcement, pers. comm.). For violations in the *Oculina* HAPC, the Coast Guard assesses the penalties based on the NOAA General Counsel Penalty Schedule (See Table. 1; NOAA-OGC

2003). The boat owner and captain can then decide to enter negotiations to have the penalties reduced. The settlement amount must be in accordance with the NOAA General Counsel Settlement Schedule (see Table 2; NOAA-OGC 1999). For example, a rock shrimp vessel caught violating *Oculina* HAPC regulations is typically assessed a fine of \$25,000-\$50,000, and a permit sanction of 45 days (R. Chesler, pers. comm.). The owner and captain often negotiate a settlement, whereby their fine is typically reduced to about \$6,000-\$10,000 and the penalty is reduced to approximately 15 days (R. Chesler, pers. comm.). The penalties are much lower for recreational fishermen. Only two cases were made against recreational snapper grouper fishermen in the *Oculina* HAPC in the last three years. They were assessed fines between \$2,500 and \$5,000. Recreational fishermen do not receive permit sanctions because there is no federal recreational fishing permit (R. Chesler, pers. comm.).

Table 1. NOAA Office of the General Counsel penalty schedule for violations of the *Oculina* HAPC regulations (From NOAA-OGC 2003).

Violation	Violation history – penalty amount		
	First	Second	Third
Violations regarding fishing/possessing/dealing at the wrong time and place (including the <i>Oculina</i> HAPC)	\$500-\$50,000 Permit sanctions 0-45 days	\$2,500-\$90,000 Permit sanctions 30-90 days	\$5,000- STATUTORY MAXIMUM Permit sanctions 60 days- revoke

Table 2. NOAA Office of the General Counsel settlement schedule for violations of the *Oculina* HAPC regulations (From NOAA-OGC 1999).

Violation	Summary settlement amount
Trawling and bottom longline in an HAPC	\$6,000
Possession of snapper/grouper in <i>Oculina</i> HAPC (1-50 fish)	\$750

Lack of funding for research, enforcement, and education and outreach

Research and monitoring. Little funding exists for research and monitoring efforts in the *Oculina* HAPC (Reed et al. 2006). Recent research since 2000 has focused primarily on mapping and characterizing *Oculina* reef habitat, and documenting changes to the reefs and associated fish populations (Reed et al. 2005). Understanding *Oculina* reef ecology, and changes to reefs over time is vital to determining whether management has been effective, and whether the management strategy needs to be altered. However, since early work by John Reed in the 1980s, almost no funding has been dedicated to understanding the basic biology and ecology of *Oculina* reefs (M. Miller, NOAA Fisheries Southeast Fisheries Science Center, and A. Shepard, NOAA Undersea Research Center, University of North Carolina-Wilmington, pers. comm.). In fact, resources are so scarce that researchers cannot procure enough funding to retrieve experiments from the *Oculina* HAPC, or to monitor existing experiments, such as the artificial reef modules (G. Gilmore, C. Koenig, University of Florida, and J. Reed, pers. comm.). Additionally, only 0.1% of the reefs have been surveyed with remotely operated vehicles, or submersibles since 2001 (Reed et al. 2005).

Sufficient funding is difficult to obtain, in part, because the *Oculina* HAPC is a challenging and expensive place to conduct research. The *Oculina* HAPC lies offshore, in relatively deep, cold water. In addition, the strong currents of the Florida Current pass over the reefs, adding to the difficulty and cost of conducting research. The daily cost for a research vessel can be \$25,000 (J. Schull, NOAA Fisheries Southeast Science Center, pers. comm.). While this sounds expensive, it is relatively cheap compared to other oceanographic, and space research; oceanographic research ship costs may exceed \$50,000 a day. Thus, *Oculina* research

lacks funding, not only because it is expensive, but because it is not a high priority for NOAA and other funding agencies (J. Reed, pers. comm.).

Enforcement. The *Oculina* HAPC's large size, and offshore location contribute to the high cost of enforcement. The US Coast Guard and Florida FWC must use larger, more expensive boats, as well as more fuel to patrol the HAPC, compared to areas closer to shore. The cost of operation, including fuel, personnel, and maintenance, for the Coast Guard's main patrol boats used in the *Oculina* HAPC averages \$443 per hour (USCG 2006). At this rate, one vessel patrolling the *Oculina* HAPC for one day could cost roughly \$3,500. The Coast Guard also conducts patrols with helicopters and airplanes, which cost from \$3,580 to \$6,350 per hour of operation (USCG 2006).

Not only are patrols expensive, but the Coast Guard has many missions in addition to protecting the *Oculina* HAPC. Since September 11, 2001, many of the Coast Guard's resources have been directed toward homeland security, leaving fewer resources available for natural resource protection, including the *Oculina* HAPC. Drug trafficking and illegal immigration also top the Coast Guard's list of enforcement priorities in this area, diverting even more assets away from natural resource protection. Though Coast Guard agents work co-operatively with Florida FWC and NOAA Office for Law Enforcement (OLE) to improve enforcement of the *Oculina* HAPC regulations, their resources are spread thin with many other enforcement tasks.

Education and outreach. The *Oculina* Evaluation Team has identified two main constituencies that should be targeted with education and outreach efforts: recreational and commercial fishermen, and citizens and visitors of central eastern Florida. While most commercial fishermen in the area are probably familiar with the *Oculina* HAPC regulations, it is

difficult to reach the many recreational fishermen that fish for snappers and groupers off central eastern Florida. Since recreational fishermen do not take a test or receive a notice of the regulations when entering the fishery, fishermen who are unfamiliar with the area and the regulations could end up fishing in the protected area. In addition, local bait shops carry fishing charts that do not show the *Oculina* HAPC restrictions, and in some cases show the area as 'good' grouper grounds (J. Reed, pers. comm.). Thus, it is particularly important to educate recreational fishermen about the *Oculina* HAPC regulations.

It is also important to educate the public about the importance of the *Oculina* reefs. Recent outreach efforts have included teacher workshops, a port day in which local students learned about the *Oculina* reefs from researchers embarking on an expedition, and the creation of informational posters about the *Oculina* reef (SAFMC 2005). While these outreach efforts have been effective in educating some of the local teachers and students about the *Oculina* reef, more funding would allow education efforts to reach more of the local population, as well as people beyond central eastern Florida. Educating the public about the *Oculina* HAPC is important in order to gain broad public interest and support for protecting the reefs.

Relevant legislation: The Magnuson-Stevens Act

The Magnuson-Stevens Fishery Conservation Management Act (M-SFCMA) of 1976 established the authority for federal fisheries management in the United States. This act claims exclusive fishery management authority over most fishery resources within the U.S.'s Exclusive Economic Zone (EEZ), which generally extends 200 nautical miles from shore. The U.S. Secretary of Commerce, and eight regional fishery management councils share the decision-

making responsibilities for federal fisheries management. The regional councils are responsible for preparing, monitoring, and revising management plans for fisheries within their jurisdiction. The Secretary of Commerce has the authority to issue regulations to implement plans proposed by the regional councils. In most cases the Secretary has delegated this authority to NOAA Fisheries. (SAFMC 2003)

The 2006 reauthorization of the Magnuson-Stevens Act includes specific language related to deep-sea coral conservation. The act authorizes fishery management plans to designate protected areas to prevent the destruction of deep-sea corals that have been identified as essential fish habitat. Fishery management plans must ensure that such closures are based on the best-available scientific information, include criteria to assess a closure's conservation benefit, establish a timetable to review the closure's effectiveness, and are based on an assessment of the benefits and impacts of the closures. (MSA 2006, sec. 105(2))

The act also directs the Secretary of Commerce to establish a deep-sea coral research and technology program that will identify current research on, and known locations of deep-sea corals, as well as find and map yet unknown locations (MSA 2006, Sec. 211). The program will also provide research on deep-sea corals, and develop technologies to reduce the interactions between fishing gear and deep-sea corals. The Secretary must submit biennial reports to Congress and the public on steps taken to monitor, identify, and protect deep-sea corals.

Institutional ecology

Several federal agencies play various roles in the management and enforcement of the *Oculina* HAPC. The South Atlantic Fishery Management Council has the responsibility to

manage fisheries in federal waters off of North Carolina, South Carolina, Georgia, and the Atlantic coast of Florida. Council members are citizens from each of these states, and are appointed by the Secretary of Commerce. Several committees and advisory panels comprised of various stakeholders and experts provide input and recommendations to the Council. The Council must also take input from the public before any proposed rule changes are made final. (SAFMC 2006c)

The Secretary of Commerce has authority for fishery management decision-making. In most cases the Secretary has delegated this authority to NOAA Fisheries. NOAA Fisheries makes the final decision on any management plan or amendment that the Council proposes. NOAA Fisheries must ensure that all management measures are consistent with the M-SFCMA and other applicable laws. (SAFMC 2003)

Three agencies have the responsibility to enforce the borders and regulations of the *Oculina* HAPC and the OECA: NOAA Fisheries Office for Law Enforcement (OLE), the Florida Fish and Wildlife Conservation Commission (FWC), and the US Coast Guard (USCG). NOAA OLE and the USCG are federal entities housed in the Department of Commerce, and the Department of Homeland Security, respectively. The FWC is the state of Florida's natural resource enforcement entity. These three agencies coordinate their efforts under a co-operative enforcement partnership, which began in 2004 (SAFMC 2005). Under this agreement, the USCG and FWC have the responsibility to patrol the *Oculina* HAPC, and NOAA OLE has the responsibility to investigate reported violations.

Human ecology

The main stakeholder groups involved with the *Oculina* HAPC issue are fishermen, scientists, non-profit conservation organizations, and the public. The roles of each of these groups in the management and protection of the *Oculina* HAPC are discussed in this section.

Fishermen involved with the *Oculina* HAPC include commercial rock shrimp fishermen, and both recreational and commercial snapper grouper fishermen. Fishermen hold a wide range of views about the protection of the *Oculina* HAPC. Some support strong protections for the reefs. These fishermen, including members of both the rock shrimp and snapper grouper fisheries, recognize that the reefs support the fish and shrimp they catch, and that in order to continue fishing they must preserve this important habitat. However, other members of both fisheries continue to fish and trawl illegally on the reefs.

Several scientists have been involved in research and monitoring efforts in the *Oculina* HAPC. John Reed of Harbor Branch Oceanographic Institute conducted early research on the *Oculina* reefs, and has been studying the reefs since the 1970s. He was one of the first to witness the effects of rock shrimp trawls on the reefs, and was instrumental in getting the Council to establish the area as an HAPC. Florida State University researcher Dr. Christopher Koenig has studied the fish populations associated with the reefs, including studies testing whether artificial habitat structures would attract fish back to destroyed reef areas. Dr. Grant Gilmore has also studied fish populations on the reefs, and has used acoustic monitoring methods to assess the health of the reef ecosystems. Dr. Sandra Brooke has studied the biology and reproduction of *Oculina* corals. And Dr. Andy Shepard of the University of North Carolina, Wilmington has conducted research on the ecology and distribution of *Oculina* reefs. The scientists who have

studied the *Oculina* reefs and associated fish populations and have documented the declines of both, are passionate about protecting the reefs, and have urged the Council to establish strong protections for the *Oculina* HAPC.

Several non-profit organizations have also been involved in pushing for strong protections of the *Oculina* HAPC. Ocean conservation scientists from Environmental Defense have advocated for protection of the *Oculina* reefs, and have served on Council advisory panels. Oceana campaigns to protect deep sea corals by banning damaging fishing gear, and has followed the *Oculina* issue closely. The Marine Conservation Biology Institute, while not closely involved with *Oculina* specifically, works to get legislation passed to provide stronger protections for deep-sea corals in U.S. waters.

The public is also an important stakeholder group, but is largely unaware of the issues in the *Oculina* HAPC. Many central eastern Florida residents do not know that the unique *Oculina* reef ecosystem lies just off the coast, much less that it is being destroyed. Furthermore, outreach and education efforts have targeted only the local population, so that the broader U.S. public is essentially unaware of the issues in the *Oculina* HAPC. Public knowledge of the *Oculina* reefs will be important to garner increased attention and support for their protection.

PART III. MANAGEMENT ALTERNATIVES

What are possible management solutions that could improve the protection of the *Oculina* reefs, and associated fish populations? The pros and cons of six management alternatives are discussed in this section.

Require vessel monitoring systems (VMS) in the snapper grouper fishery

One option to improve protection of the reefs, and to reverse the decline in snapper grouper populations on the reefs, is to require VMS on all vessels in the snapper grouper fishery. Anecdotal evidence suggests that Jeff's and Chapman's Reefs are favorite fishing spots for many recreational snapper grouper fishermen (G. Gilmore, pers. comm.); with so many recreational boats in the fishery, the Council has little hope of effectively monitoring illegal activity without a remote sensing technology, such as VMS. If every boat in the fishery were required to have VMS on board, law enforcement officials could more effectively track and apprehend boats illegally fishing in the HAPC.

However, it is widely believed that such a requirement would not be politically feasible. Some argue that because there are so many recreational snapper grouper fishermen, it would be extremely difficult to require them all to have VMS on their boats. Another argument against VMS tracking in the snapper grouper fishery is that the hook-and-line fishing of recreational fishermen causes significantly less physical damage to the reefs than rock shrimp trawlers. Thus, while requiring VMS on all snapper grouper boats would significantly improve enforcement of fishing restrictions in the *Oculina* HAPC, many stakeholders do not view requiring VMS on recreational boats as a high management priority for conserving the reefs because it would be

difficult to ensure that all vessels are equipped with VMS, and because the hook-and-line fishing method is much less damaging to the corals than trawling for rock shrimp.

Establish acoustic monitoring systems in the OECA

While VMS may not be a feasible alternative to enforce the restrictions on fishing for snappers and groupers in the OECA, acoustic monitoring could effectively deter fishing on the remaining reefs. Hydrophones placed on the sea floor can be tethered to transmitters buoyed at the surface that relay the signal to a central location. Sounds in the ocean have acoustic signatures that can reveal what is happening below the surface. For example, a healthy coral reef ecosystem is noisy, whereas a degraded system is relatively quiet. Hydrophones can also distinguish human-produced noises, such as boat engines, and SCUBA divers' breathing. Acoustic monitoring systems can pick up sounds from boats miles away. They can also identify individual boats based on the sound signatures of different motor brands. Sounds of a struggling fish can even reveal whether a fisherman caught a fish (G. Gilmore, pers. comm.). Having access to this type of information would help law enforcement officials better understand what is happening in terms of illegal fishing on the reefs, while also helping scientists monitor the health of the reefs. The knowledge that their boats could be identified would deter fishermen from fishing illegally in the OECA.

In addition to being highly effective, an acoustic monitoring system in the OECA would cost significantly less than patrolling the area with law enforcement vessels. The initial set-up cost of an acoustic monitoring system for Jeff's and Chapman's Reefs, including about six hydrophones and transmitter buoys, would be about \$150,000 (G. Gilmore, pers. comm.). After

that, yearly maintenance and up-keep costs would be about \$30,000. Enforcement vessels could then be sent out to apprehend poachers known to be in the area, which would reduce reliance on expensive patrols. By comparison, the costs for a Coast Guard vessel to patrol the area for one day (including the cost of maintenance, fuel, labor, etc.) can be \$2,400 to over \$4,700 (USCG 2006). At these rates, it would cost the Coast Guard, on average, over \$180,000 to patrol the OECA just one day per week for a year. In addition to being much less expensive in the long run, an acoustic monitoring system would provide continuous coverage, collecting information night and day, every day of the year. In order to achieve this level of coverage with a patrol vessel, the Coast Guard would have to spend about \$3,870,000 a year, and would still have the disadvantage of relying on sight to detect violators at night. Therefore, an acoustic monitoring system presents a cost-effective solution for monitoring illegal fishing in the OECA.

Increase penalties for violations of the *Oculina* HAPC

Recent evidence of illegal trawling and fishing imply that the penalties for violating the *Oculina* HAPC and OECA regulations are insufficient. The Council views violations of the *Oculina* HAPC as egregious, because the reefs are biologically and economically important, and once destroyed, may take hundreds of years to grow back to their original size, if they can recover at all. In order to reflect the seriousness of damaging or destroying *Oculina* reef ecosystems, penalties need to be increased. Penalties could include permanently revoking a violator's permit, steeper fines, and seizure of the violator's boat and catch. The fines could be assigned based on the estimated cost of restoring the reef, as is done for violations in the Florida Keys National Marine Sanctuary. Without sufficient penalties, some fishermen will continue to

take the risk of being caught poaching in the *Oculina* HAPC and OECA.

Increase funding for research, enforcement, and education and outreach

Protection of the *Oculina* reefs could be improved by increasing funding for enforcement, research, outreach, and public education. The Coast Guard, FWC, and NOAA OLE have limited resources to devote to natural resource protection. With additional funds, these agencies could conduct more patrols of the *Oculina* HAPC, and assign more agents to the area. Increased funding for research would allow scientists to investigate important questions about the *Oculina* reefs that remain unanswered, such as whether destroyed reefs can be restored, and whether management and enforcement efforts have been effective. Additional funding would enable increased outreach to ensure that recreational fishermen know about the fishing restrictions in the OECA. Also, more funding is needed to educate the public about the importance of the *Oculina* reefs in order to gain support for strengthening protections for the *Oculina* HAPC. In sum, increased funding for enforcement, research, outreach, and education would improve protection of the *Oculina* HAPC and OECA.

Expand the *Oculina* HAPC

Areas known to contain *Oculina* reefs still sit unprotected, vulnerable to rock shrimp trawlers. Over 100 *Oculina* pinnacles have been discovered since 2002 between the two satellite areas adjacent to the northern portion of the *Oculina* HAPC (see Fig. 1; J. Reed, pers. comm.). Since more than 90% of the known *Oculina* reefs have been destroyed, it is critical to protect the few remaining reefs. These surviving *Oculina* corals may be able to disperse larvae to settle and

grow on the destroyed reefs. Over time, if these areas are left undisturbed, new *Oculina* reefs may grow, and spawning snappers and groupers may one day return. Thus, a key to preserving *Oculina* coral reefs is to expand the protected area.

Establish part or all of the *Oculina* HAPC as a National Marine Sanctuary

Designating all or part of the *Oculina* HAPC as a National Marine Sanctuary would increase funding for protection of the corals, and would bring public attention to the importance and destruction of the reefs. Sanctuary designation could provide millions of dollars each year for public education, research, and enforcement in the *Oculina* HAPC. This would be an order of magnitude increase from the current level of funding for such efforts. Establishing all or part of the *Oculina* reef as a National Marine Sanctuary would provide more resources for the protection of the reefs.

The idea of designating the *Oculina* reefs as National Marine Sanctuary has surfaced several times over the last 25 years. According to Billy Causey, the southeast regional director of the National Marine Sanctuary Program, there has never been as much support for the idea as there is now, and the Council supports a sanctuary designation (K. Iverson, SAFMC, pers. comm.). However, there is currently a moratorium on new sanctuaries, and this can only be lifted if additional funding is made available for a new sanctuary (B. Causey, National Marine Sanctuary Program, pers. comm.). This could be accomplished by an act of Congress. Another major hurdle would be to gain sufficient public support, as the sanctuary designation process depends highly on public input.

Conclusion

The *Oculina* HAPC is an important resource to protect. Healthy *Oculina* reefs support high levels of biodiversity, including many commercially important fish species. Studies have shown that it may be possible to re-grow *Oculina* corals in this area, and potentially restore some of the original reef function (Koenig et al. 2005). Thus, the *Oculina* HAPC is not a lost cause even though over 90 percent of the reefs have been destroyed. It is critical that the Council place a strong emphasis on improving enforcement of the *Oculina* HAPC and OECA regulations in order to protect the remaining healthy reefs.

It also important that the Council establish adequate enforcement for these areas so they will be prepared to protect the proposed deep-sea *Lophelia pertusa* coral HAPCs. These reefs occur in much deeper water (400 to over 1,000 meters) than the *Oculina* reefs, and cover a much larger area. Most of these reefs are believed to be intact and relatively undamaged by fishing gear. The Council must have adequate enforcement in place from the beginning in order to keep these reefs from disappearing like the *Oculina* reefs have done.

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