Investigation of *Acropora palmata* Colonies in Southeast Florida Along Broward County First Reef

Thomas R. Cuba and Esther C. Peters

Stillwater Research Group, Inc.
447 3rd Avenue North, Suite 309
St. Petersburg, FL 33701

March 29, 2011

INTRODUCTION

The elkhorn coral, *Acropora palmata*, has been listed as threatened under the U.S. Endangered Species Act. The listing is supported by extensive research and debate (Bruckner 2002, Shinn 2004, Precht et al. 2004, *Acropora* Biological Review Team 2005, Federal Register 4 April 2007: 16284-16286). This species is a shallow-water framework builder of reefs in the Caribbean Sea and tropical Western Atlantic Ocean. Its relatively rapid linear extension rate and branching morphology provide ideal wave-dampening structures to contribute to the formation and protection of land masses. The morphology also provides structural habitat for fishes, crustaceans, polychaetes, and other reef biota. The organism serves as a prey species for some fishes, the gastropod *Coralliophila abbreviata*, and the polychaete *Hermodice carunculata*. Populations of this species on reefs off Broward County, Florida, are not well documented in the early literature and even though early range and density information in this area is spotty and anecdotal, it is broadly held that populations of this species have declined over the years. Two rapid tissue loss diseases, white band disease and white pox (now called white patch disease), are implicated in the decline of this species. The etiology of white band disease is unknown (Gladfelter 1982, Peters et al. 1983, Peters 1984, Bythell et al. 2004, S.W. Polson and C.M. Woodley, pers. comm.). In white patch disease, the coral tissue is degraded by the bacterium *Serratia marcescens* (Patterson et al. 2002, Patterson-Sutherland and Ritchie 2004, CRTR 2008). Physical damage due to natural disturbances like hurricanes and predation, as well as human-induced from anchoring and grounding of ships, has affected individuals and even entire patch reefs.

These disturbances, as well as stress from fluctuations in water temperatures and water quality, are suspected to have decreased Florida's total population levels (e.g., Bythell and Sheppard 1993, Miller 2001, Bruckner and Bruckner 2002, Porter et al. 2002, Aronson and Precht 2006, Somerfield et al. 2008). *A. palmata* formed dense thickets on shallow spurs and patch reefs in the Florida Keys to the Dry Tortugas in the 1970s–1980s. The northern limit of the elkhorn coral as a reef builder was considered to be Biscayne National Park (http://www.nmfs.noaa.gov/pr/species/invertebrates/elkhorncoral.htm) or individually north to Fowey Rocks, off Miami (IUCN 2010 Red List, http://www.iucnredlist.org/apps/redlist/details/133006/0, Porter 1987, Aronson et al. 2008).

This paper is one of three resulting from an exploratory investigation into the dynamics of individuals along the east coast of Florida and aggregations forming patches in the lower Florida Keys. The investigation originally was restricted to the lower keys, where the authors examined one patch in the back reef associated with Looe Key and several patches on spurs on the fore reef of Looe Key. In Broward County, at five sites approximately one-half mile offshore along the seaward dropoff of the ridge complex or "first reef" as it is known locally, reports on *A. palmata* colony sightings by Ken Banks, David Stout, and Dan Clark had been filed with the Florida Department of Environmental Protection (FDEP) and the project was expanded to include these specimens. Along the east coast, the authors observed individual specimens of *A. palmata* because no aggregates were known (Banks et al. 2008). This paper, therefore, is a survey paper. The purpose of the study was to locate and confirm colonies that had been reported to the FDEP, characterize their condition and describe the habitat, and visually survey the areas surrounding these colonies for additional specimens.

METHODS

The project team received the coordinates of several colonies reported to the Florida Department of Environmental Protection (Chantal Collier, pers. comm.) and searched the sites inshore of the first or inner linear reef. The Broward study area was surveyed September 28, 2009 through October 2, 2009.

Some of the previously reported *A. palmata* colonies were located easily; however, others were not readily apparent. Photographs taken on August 15, 2008 (by others), were then provided by the County and surveys continued until all of the colonies were located. At each of these sites, a 50-ft radius circle with the colony(ies) at its center was searched for other *A. palmata* colonies. All colonies were photographed, measured, and the condition recorded.

The team expanded the survey area after noting that the previously reported colonies were located either along the seaward edge of the first reef or landward from the first reef, along the ridge complex. To expand the surveyed area, several drift dives at 10–15 ft depths were undertaken by buddy teams. Divers were tethered with a 10-m cord stretched out between them, looking side to side during dive. The estimated swath covered was 20 m wide. One search was conducted by a single diver on a scooter searching for additional colonies along these features. When a new colony was located, a 50-ft radius circle was searched as before. The colony size was recorded and the condition was assessed in the same manner as before. These new colonies were designated "SRG" and consecutively numbered.

The habitat features at the locations where colonies were discovered were described from the divers' notes and photographs. Information included the depth, topography, substratum, key recognition features (e.g., largest *A. palmata* colonies present, species, size, placement), other coral species present and how common, other benthos present (e.g., algae, sponges, zoanthids, gorgonians, urchins), and fishes present.

The GPS coordinates of all the Southeast Florida first reef *A. palmata* colonies were used to map their positions off Broward County. Spatial relationships were derived from simple mapping of the surveyed colonies along with annotations of condition. Geographic mapping was augmented with notes on the subsurface features allowing the team to derive spatial preferences on a small and local scale.

The condition of the *A. palmata* colonies was assessed based on a modification of the *Demographic Monitoring Protocols for Threatened Caribbean* Acropora *spp. Corals* (NOAA Technical Memorandum NMFS-SEFSC-543, Williams et al. 2006). The length, width, and height above the substrate were measured; estimates were made of the percent live coral tissue cover and presence, extent, and type of recent mortality, growth anomalies, bleaching, and damselfish impacts; and branch breaks were counted by branch diameter size categories. These data were recorded on preprinted sheets of DURACopy paper. At the end of each day, the data sheets were rinsed in fresh water and air dried, and then a copy was made.

RESULTS

All locations examined during this period where *A. palmata* colonies were found are presented in Table 1, including their GPS coordinates and areas searched around each colony. GPS coordinates were collected at each site in NAD83.

Table 1. Locations of sites surveyed off Broward County first reef.

Colony Site	Date(s) of Observations	Coordinates	Area Examined Around Colony(ft^2)
DC (T331)*	0/28/2009	N26°10.910' N, W080°05.594' W	7,850
DS1 (T338)	9/28/2009	N26°12.502' N, W080°05.091' W	7,850
BC (T336)	9/28/2009, 10/1/2009	N26°13.162' N, W080°05.018' W	7,850
DS2 (T335)	9/29/2009	N26°13.271' N, W080°05.003' W	7,850
KB3 (T334) 2 colonies	9/29/2009	N26°13.495' N, W080°04.975' W	7,850
KB2 (T332)**	9/29/2009, 10/1/2009	N26°13.616' N, W080°04.961' W	7,850
KB1 (T333)**	9/29/2009	N26°13.640' N, W080°04.961' W	7,850
SRG1	9/29/2009	7 ft bearing 080°from DS2	7,850
SRG2	10/1/2009	N26°13.250' N, W080°04.998' W	7,850
SRG3	10/1/2009	N26°13.694' N, W080°04.960' W	7,850
SRG4	10/1/2009	N26°13.161' N, W080°05.018' W	7,850

*T-numbers are tags set by Broward County
**These colonies were in the provided list as KB1 = T332 and KB2 = 333, but the order in the above table was confirmed by comparing photographs and tags on site.

The areas searched during the drift and scooter dives are presented in Table 2.

Table 2. Drift dive searches.

Number	Date	Start	End	Area Examined
1	9/29/2009	N26°13.366' W080° 04.994'	N26°13.157' W080° 05.004'	North to South on reef break 0.2 mi
2	9/29/2009	N26° 11.005' W080° 05.587'	N26° 10.695' W080° 05.632'	Inshore reef line, start was 100 m north of DC, North to South 0.2 mi
3	9/30/2009	N26° 11.300' W080° 05.300'	N26° 13.58' W080° 04.994'	South to North on reef break 3.5 mi
4	10/1/2009	N26°10.910' W080°05.594'	N26° 13.904' W080° 04.943'	Variable – scooter dive: track not recorded
5	10/1/2009	N26° 11.292' W080° 05.245'	N26° 11.438' W080° 05.231'	South to North on reef break 0.2 mi

Colony locations are presented on the map in Figure 1.

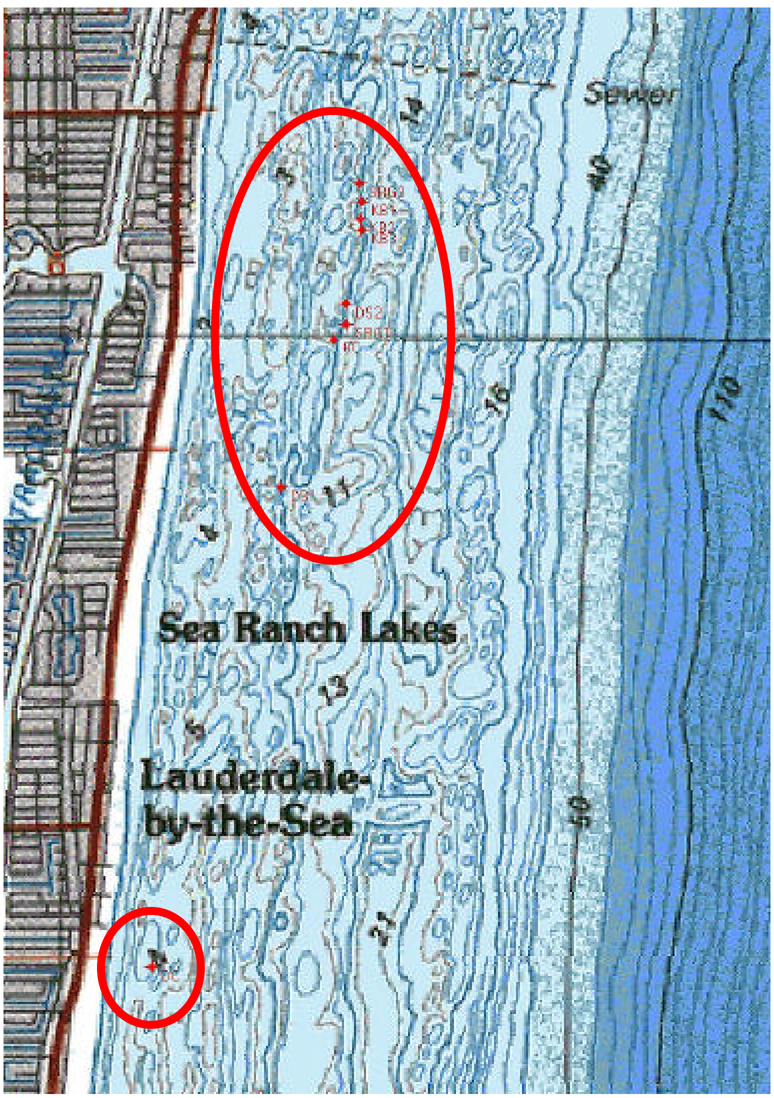

Figure 1. Distribution of the *A. palmata* colonies found during this project.

Of the seven sites previously reported as supporting *A. palmata*, all seven were located. Of these, one had been reported as a single colony, but on receipt of the photograph taken by Ken Banks in 2008 it was learned that this was actually two colonies set close together, bringing the total to eight. Of the eight, seven remained alive. The team located one additional colony bringing the total (live and dead) examined to nine. Of these, eight colonies were alive in September 2009. KB1 and the two colonies at KB3 (KB3a and KB3b) retained 90% to 100% dark brown tissue cover. DS1 and DS2 were the largest colonies found (Figures 2 and 3). Both of them had circular or annular (a circular band) white (unpigmented) tissue areas over the colonies' surfaces, which were otherwise normally pigmented by zooxanthellae. About 70% of the tissue on DS1 was affected and a yellowtail damselfish (*Microspathodon chrysurus*) was present. No damsels were observed at DS2. The other colonies were in very good

Figure 2. Colony DS 1. Note location on lip of ledge and damselfish bites on base of colony.

Figure 3. Colony DS 2. Note location at and hanging over lip of ledge, largest colony seen.

condition, without bleaching and only minimal worm holes or fish bites on the bases, which wrapped over the seaward ledge and underneath it. The smaller of the two colonies at KB3 (KB3b) was in competition with *Palythoa caribbaeorum*, the colonial zooanthid that is common off the southeast Florida coast, and was also spreading over one small area of the base on DS2. *P. caribbaeorum* was near the larger (KB3b) of the colonies but not yet in competition for space; however, KB3b was overgrowing the holdfasts of a sea fan and young gorgonian. KB3a and KB3b were located away from the ledge. The other of the eight original colonies (KB2) was an upright skeleton, with a well-developed fouling community and indistinct corallites, indicating the colony had been dead for more than several months. Within the turf algae, small coralline algae and sponges were noted, and a small *P. caribbaeorum* was adjacent to it. It had been photographed alive in August 2008 (Ken Banks, pers. com).

The colony inshore of the first reef, DC, was originally documented during the summer of 2006 (Dan Clark, pers. com.). It was reported to Broward County in 2007. On June 11, 2008, one of the upright branches was found to have broken off and was cemented to the substrate near the base of the colony on June 17 (Vone Research 2008). Three days after the cementing, divers observed that both the fragment and parent colony had white splotches on them, along with denuded areas on the reattached fragment and proximal end that had been on the sand before it was reattached. Dr. Peters visited the colony in July 2008 and found that the colony was losing tissue rapidly resulting in irregularly shaped patches of denuded skeleton, suggesting it was being affected by white patch disease. Mucus samples taken from the surface of the colony (July 2008) and analyzed by Dr. Cheryl Woodley at Hollings Marine Laboratory, Charleston, South Carolina, for the presence of four specific microorganisms known to be pathogenic to corals, revealed the presence of *Vibrio corallilyticus* (strong positive) and *Aurantimonas coralicida* (weak positive) associated with the receding tissue margin mucus samples, but they were not detected in the samples of mucus taken from apparently healthy tissue areas on the reference or reattached portions. When examined in September 2009, the original colony had about 10% live

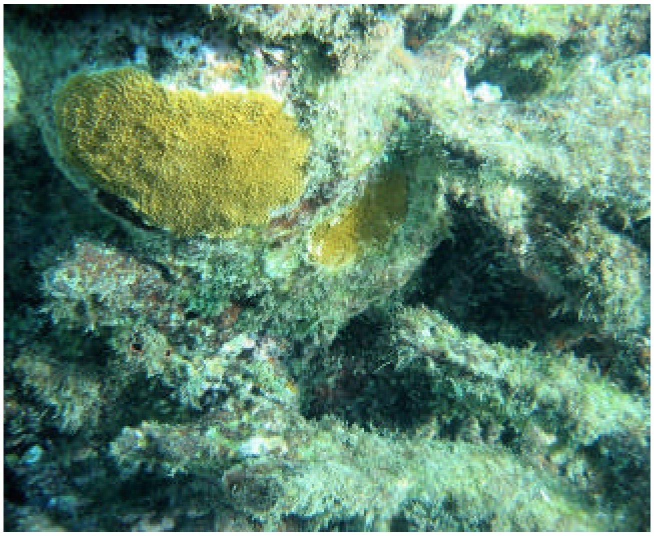

Figure 4. Colony DC. Resheeting after massive tissue loss.

tissue and the cemented branch had about 5% live tissue cover, which consisted of seven patches of tissue scattered over the base and branches (Figure 4). The parent colony had four patches, one of which was starting to form two upright branches. The cemented fragment had three patches, one of which was also starting to develop two branches. All of them were in good condition, however, with uniform brown coloring and white margins indicating active growth. Algae and sponges were noted around the base and two dusky damselfish (*Stegastes fuscus*) were swimming around the colony. The substrate was generally colonized by algae, *P. caribbaeorum*, and widely scattered other corals (*Montastraea cavernosa* and *Siderastrea siderea*). Several heavily bioeroded knobs of former staghorn colonies were found in a line to the west of DC.

Colony BC had only 2% live tissue remaining: one branch tip of about 4 polyps and a flat basal patch of about 14 cm^2 (Figures 5 and 6). Neither patch had white margins, which indicated they were not actively growing, and both were pale in color. The skeleton had a fine green algal turf on it, indicating it had probably been denuded for more than two months. A dusky damselfish swam in a crevice and around the area. This colony was on the surface substrate, about 5 cm away from the ledge. It was difficult to measure the length and width of the base plate, because the turf was starting to blend into the adjacent turf on the substrate.

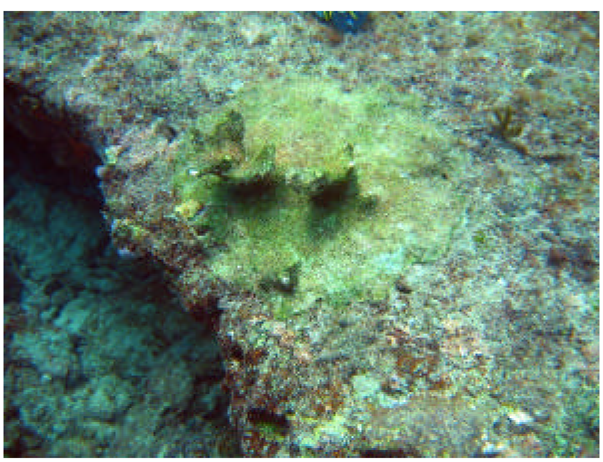

Figure 5. BC showing location at ledge, and near dead state, approximate age only a few years old.

Figure 6. Live patch of polyps at one edge of broad base on broad colony BC, note pale color, non-white margins.

Of the original seven sites with living colonies, only one was discovered to have a second colony within the 50-ft circle, which was named SRG1. This was a small fragment with 100%

live tissue cover caught in a crevice just 7 ft from DS2. It could not be sourced to the other colony (i.e., DS2 had axial polyps on all branch tips and no obvious breaks) and its origin is unknown. It had not yet developed a spreading base of polyps and skeleton and did not appear to be attaching, so it had only recently become lodged in the crevice.

The divers found three more colonies that had not been previously reported. SRG2 was located during the swims along the seaward reef platform between the mooring buoys. It was next to a colony of *Dichocoenia stokesii* on top of a boulder, but down in a crevice off the seaward reef ledge. This colony was 100% alive, with only a small worm hole present, and was in excellent condition. Another colony was located north of KB1, identified as SRG3, but it was entirely dead, completely covered in fine filamentous brown and green algae. The level of skeletal erosion was minimal and corallites were still visible suggesting that this colony had also only recently died, perhaps within the past month. Dusky (*S. fuscus*) and yellowtail (*M. chrysurus*) damselfish were present in the crevice beside this colony.

During the three drift dives conducted along the seaward break of the reef, two colonies were located. The first was SRG2, described previously. The second was located while divers swam north along the reef break from KB1. SRG4 was located near the perimeter of the 50-ft circle searched around colony BC and was a completely dead, upright, and bioeroded skeleton. The scooter dive conducted to the east and the one drift dive along the inner edge of the reef produced no new colonies. The condition of the nine living colonies are summarized in the following table (KB2, SRG3, SRG4 were completely dead skeletons). No growth anomalies or bleaching was observed on any of these colonies, nor were any branch breaks found.

Size and condition of all the live colonies found are summarized in Table 3.

Table 3. Condition information for the colonies examined along Broward County first reef.

Colony	Habitat Substrate[1]	Percent Live	Size (L x W x H); Type; Complexity[2]	Recent Mortality and Other Notes[3,4]
BC	CA	2	41 x 35 x 13; BC; broad base, 2 upright branches	No recent mortality, only two patches of tissue remain, one is 6 cm^2 at colony margin, one is about 4 polyps on branch tip, both pale, turf algae over 98% of colony, corallites still visible under turf
DC	AR	10 parent colony 5 cemented fragment	83 x 35 x 64; RC; parent colony: 4 patches of tissue, no branches on any of them 41 x 39 x 51; RC; cemented fragment: 3 patches of tissue, no branches on any of them	No lesions on any of the patches, all patches had white-lipped margins, indicating growth

Colony	Habitat Substrate[1]	Percent Live	Size (L x W x H); Type; Complexity[2]	Recent Mortality and Other Notes[3,4]
DS1	UK	95	75 x 38 x 37; BC; 1 cluster of 4 upright, multiple branches center, 4 single upright branches on base, well-wrapped around underside and spreading on surface of ledge	Damselfish bites = 4, yellow tail damselfish bites on 100% of colony, 70% affected
DS2	UK	90	107? x 65 x 66; BC; broad plate base with 7 uprights and multiply branched, well-wrapped around underside and spreading on surface of ledge (length estimated from photo, was 115 cm in field estimate)	WPA =1 on base, damselfish bites = 1
KB1	UK	100	33 x 22 x approx 25. BC; large plate base with 1 upright bifurcated branch (height could not be confirmed in photos)	Damselfish bites = 1 (white circular spots on base of colony, dusky damselfish in crevice), base growing over holdfast of gorgonian
KB3a	CA	100	22 x 17 x 10; BC; 1 bifurcated upright and multiply branching, 1 growing knob on base	No lesions, *P. caribbaeorum* on tissue at base
KB3b	CA	100	Approx 8 x approx 6 x 5; BC; 1 upright, 1 early starting on base (length and width estimates in field unclear and affected by *P. caribbaeorum* overgrowth)	No lesions
SRG1	OS (turf)	100	3 x 0.5 x 2; SF; branch tip, no apparent growth	No lesions
SRG2	UK	100	20 x 18 x 19; BC; 1 bifurcated upright branch, 1 vertical growth of “chimney” around feather duster worm	Worm hole in colony

[1]AR = acroporid rubble or dead *A. palmata* colony; CA = coralline algae; OS = other substrate; UK = unknown.
[2]L = length in cm, W = width in cm, H = height in cm; BC = branched, “normal-looking,” RC = remnant colony, AF = attached fragment, SF = stable fragment.
[3]Source of recent mortality: WPA = white patch disease; PFB = parrotfish bites (on live tissue only).
[4]Extent: 0 = not present; 1 = present, very sparse occurrence (5%); 2 = moderate colony coverage (10–25%); 3 = high coverage, condition affecting 30–55% of the colony live area; 4 = catastrophic extent, 60–85% of the colony's live area affected; 5 = entire colony (90%) affected.
Codes according to Williams et al. (2006)

DISCUSSION

Our searches along the shallow ridge complex (what is known to local divers as the first or inner reef) resulted in confirming the locations of 12 colonies of *A. palmata*. Banks et al. (2007, 2008) report that *Acropora* formed the framework of the first reef during the Holocene. The species was not, however, reported in surveys conducted by Goldberg (1973), by Moyer et al. (2003) in areas coincident with our search areas (Moyer Corridors 2 and 3), or by Sathe et al. (2008) in one linear inner reef site examined in 2004. Cheryl Miller and Dr. Cuba surveyed large portions of the reefs off of Broward County in 1998 as a part of the Beach Nourishment permit and no specimens of *A. palmata* were found. Most of these surveys were conducted on the second and third reef but the first reef near Port Everglades was included. The literature consistently noted that *A. palmata* was the one species from the Florida Keys Reef Tract that was not present off the southeast coast.

Cry of the Water (2010) presented an underwater photograph of a snorkeler sitting on a large elkhorn colony off Lauderdale-by-the-Sea taken in 1957 and had photographed another one in that area in 2002. Broward County began installing mooring buoys around 1993, but it appears that most of the *A. palmata* colonies known to Broward County staff were discovered when a line of mooring buoys was installed along the seaward margin of the ridge complex south of Hillsboro Inlet, these are known as the Pompano Ledge buoys, along the Pompano Drop Off (Broward County, No Date; South Florida Diving Headquarters, 2005-2011).

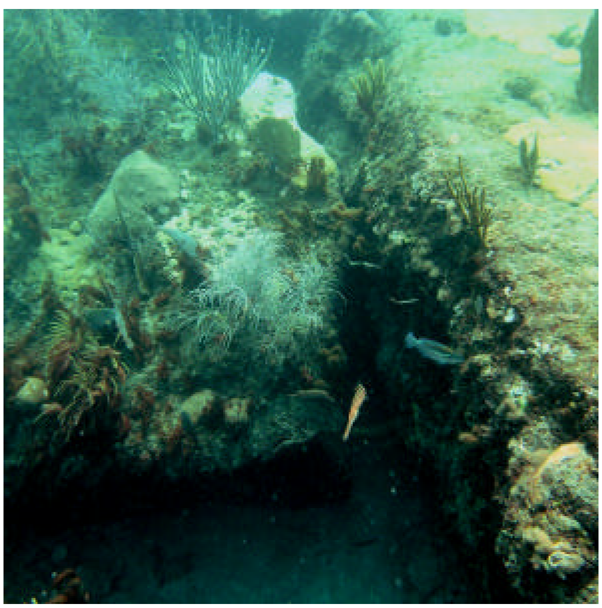

Figure 7. Calving of large blocks along the platform, showing the settlement location on the ledge dropoff to the right where most of the colonies were found.

The seaward margin of the Pompano Drop Off is a flat-topped platform that has fractured extensively and collapsed in some areas, probably due to solution beneath the cap of the aragonite or calcite. The result is a sometimes steep face with large blocks lying in the deeper sand (Figure 7). Depth changes can be gradual or steep and the blocks can be widely separated from the platform or only slightly canted creating a crevasse type feature. The platform itself is generally populated with octocorals and poriferans with only scattered scleractinians. On the inshore margin, the ridge complex consists of scattered boulders at various distances from the platform. The platform is at times partially covered with a veneer of sand.

The coral communities off Broward County are within a few km of one of the most heavily urbanized areas on the East Coast, and are known to be affected by sewer outfalls; harbor, inlet, and canal discharges; sedimentation and turbidity from increased runoff and beach nourishment; shipping and boating activities, including groundings and anchoring damage; recreational and commercial fishing; diving; and marine construction (Goldberg 1973, Banks et al. 2008, Sathe et al. 2008). During our exploratory dives nearest Hillsboro Inlet, we ascended through a bolus of warm, brown, less dense water, floating on the sea. The mirage-like shimmer indicated salinity differentials were present and the water was suspected to be of terrigenous origin. It is noteworthy because, when it accidentally was taken into the mouth of divers, it left a pasty film on the teeth and mouthpieces of the regulators. Camera housings were so fouled with an almost paraffin like coating that simple rinsing in freshwater was insufficient and mild soaps were required to clean the equipment. This water was encountered on ebb tides, flowing south, along the Pompano Drop Off.

Of the 12 colonies being discussed, one (SRG1) is a very recent fragment of small size trapped in a crevice on the platform, which might have come from its nearest neighbor, DS2. DC is on the inshore edge of the ridge complex, and remnants of several *A. palmata* skeletons there suggest that several larvae may have settled at one time, possibly on older elkhorn skeletons, but only DC remains.

Nine of the remaining ten were located on or very near the edge or eastern lip of the reef platform at the place where blocks were calving. The tenth (SRG2) was located on a rock at the base of the edge of the platform. The locations indicate a strong site selection preference. No acroporid skeletal remains were seen at these sites as an inducement to settling. Of note, the colonies varied in size from the largest, DS2, then DS1 (less than half the base plate area), then BC and KB2 (about one-fifth the base plate area of DS2), then SRG3 and KB1 (about one-tenth the base plate area of DS2), and finally KB3a and SRG2 (about one-nineteenth the base plate area of DS2). The inference is that DS2 settled first and had probably been growing for a few years before DS1 settled. SRG4 is a notably older skeleton than the recently dead KB2 and dying BC, but about the same size (it was not measured because of its degraded state). The most probable deduction is that DS1 and SRG4 settled and survived for 3 to 4 years, then SRG4 died. BC and KB2 settled a few years after DS1. DS1 and DS2 continued to grow and SRG3 and KB1 colonized the area in the same year, with KB3a and SRG2 being the most recent, perhaps settling about 3 or 4 years ago. Of these, KB2 and SRG3 (close in age, perhaps a year or two apart) have since died during the very recent past. Colony BC may be dead or may recover, changing these numbers slightly. Of course, growth rates of individual colonies could vary greatly and we can only speculate about their sizes and ages since settling. DS2 had bulbous bases around its branches, suggesting it might have had branch tips removed during a storm, then recovered and began branching again, and that stressor might also have affected its base plate enlargement. All of the colonies we found had ruffled edges around their base plate margins, while growth was fairly uniform, there were somewhat variable rates based on these features. In any case, three of the previously known colonies were found to be dead. Of the four newly located colonies, two were dead as well. The dead skeleton colonies are mentioned here because of their size, location, and time of death as inferred from the state of erosion of the calices.

The implication is clearly that larvae arrive infrequently and colonize based on factors which do not include conspecific skeletal material. Given the location, the most likely factor is sedimentary thickness and water movement. Moyer et al. (2003) stated that Soloviev et al. (2003) reported a localized reversal from the general south to north flow of the Florida current in this area during late summer, with a north to south flow that might concentrate coral larvae in the south, preventing much colonization of the southeast Florida reefs by corals. As the flow returns from south to north, larvae would be re-dispersed to the northern coastal reefs. Thus, the timing of spawning in relation to the current reversal could lead to occasional recruitment of *A. palmata* off Broward County. The individuals have not formed thickets of sufficient size to support successful breeding and eventually die off.

Colony death may be from multiple factors and perhaps is due to synergistic factors. The largest specimens were heavily spotted, the apparent victims of predation by damselfish. Previous records of disease resulting in partial mortality exist for the colony identified as DC. If elkhorn colonies are in less than optimal physiological condition, a more severe stressor may result in death. Moyer et al. (2003) noted that some years the temperatures remain optimal for corals in these reef communities, however, cold upwelling events or heavy freshwater runoff can be common stressors, but not necessarily an annual occurrence. The stressor may be an unusually cold winter such as in 2009-2010 (El Nino). There are also indications that specimens are not continually stressed. Specifically, one colony was observed to be successfully competing for space with *Palythoa caribbaeorum*. Other accounts indicate that this is not common and implies a robust acroporid.

Reproduction by fragmentation is not in evidence except for the one small and very recent fragment (SRG1). The success of that fragment has not been determined, but the lack of colonies in proximity to each other and the lack of suitable parent material from well developed colonies indicate asexual reproduction is not a factor for population expansion here (Fong and Lirman 1995). The survival and growth of the seven patches on colony DC suggest that resheeting may progress and aid in its recovery (Bonito and Grober-Dunsmore 2006). The existing colonies we located along Pompano Ledge are not likely to be from fragments given their location on the lip of the boulder and the lack of any evidence of parent colonies. Because KB3b was much smaller than KB3a, it might have originated as a fragment from KB3a, but that cannot be ascertained. Re-examination of these colonies after hurricanes may change this perception, as well.

Goldberg (1973) conducted an ecological survey of the reefs off of Palm Beach County in which he reports that *A. cervicornis* occurs only rarely. *A. palmata* is not reported at all and is dismissed as “not occurring north of Miami” along with *Porites porites*, and *Diploria strigosa*. Goldberg, citing Kinzie (1970; re: Jamaica) and Cary (1918; re: Dry Tortugas) presents an inverse relationship between the population density of scleractinians and gorgonians which is still apparent in current data sets (CREMP, Personal Obs.). He also notes that the “shallow acroporid rubble” common in Jamaica is absent in Palm Beach County. Given the haphazard and epehemeral populations of *A. palmata* which are now reported north of Miami and the coincidental reports of the spotty occurrence of *Porites porites* and *Diploria strigosa* north of Miami, it is worth considering that range extensions in all these species may be occurring as coastal seas become warmer. Such an hypothesis is also consistent with the overall poor survival rate and lack of large assemblages capable of reliable reproduction.

The dynamics observed are also consistent with a species being near the limits of its present range undergoing expansion and contraction in response to multi-decadal cyclic events or more unpredictable El Nino related fluctuations. *A. palmata* is a warmwater species and a broadcast spawner. The habitat of the Broward reefs is not optimal and often becomes unsuited for periods of time which are long enough to eliminate individual specimens (Banks et al. 2008). The presence of individuals does not indicate long-term habitat suitability, but short-term fluctuations. Should the predictions of global warming be accurate, the habitat may become better suited and single specimens may be able to form actual populations. Pollution and other adverse conditions need to be controlled and sources of planulae maintained for this to occur, however.

We conclude that the active management of *A. palmata* is not warranted in these waters, at least until such time that global warming produces more stable warm water habitat along this coast. Continued study and observation, however is strongly supported. Precht et al. (2004) stated that existing and developing populations of acroporids should be studied to identify factors responsible for their recovery, persistence, or decline. We speculate that the species may be subjected to forces of genetic selection and the survivors may be sources of hardy genes useful in managed repopulation efforts in more accommodating waters. Knowledge of the conditions favoring recruitment of elkhorn larvae in particular substrate and knowledge of disease susceptibility will support efforts to expand the populations off South Florida. The role of the microflora and other successional cues influencing site selection are also in need of study (see Sammarco and Heron, 1994; Chia and Rice 1977 for reviews).

ACKNOWLEDGMENTS

We thank Chantal Collier, Florida Department of Environmental Protection, and Ken Banks, Broward County Department of Environmental Protection and Growth Management, for providing the coordinates and photographs to help us locate some of the *A. palmata* colonies. Lauren Waters, Stillwater Research Group, Inc., and Dan Clark, Cry of the Water, provided boating and diving assistance during the surveys.

LITERATURE CITED

Acropora Biological Review Team. 2005. Atlantic *Acropora* Status Review Document. Report to National Marine Fisheries Service, Southeast Regional Office. March 3, 2005. 152 pp. + App.

Aronson, R., A. Bruckner, J. Moore, B. Precht, and E. Weil 2008. *Acropora palmata*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Downloaded on 28 November 2010.

Aronson, R.B., and W.F. Precht. 2006. Conservation, precaution, and Caribbean reefs. *Coral Reefs* 25(3):441-450.

Banks, K.W., B.M. Riegl, V.P. Richards, B.K. Walker, K.P. Helmle, L.K.B. Jordan, J. Phipps, M.S. Shivji, R.E. Spieler, and R.E. Dodge. 2008. The reef tract of continental southeast Florida (Miami-Dade, Broward and Palm Beach Counties, USA). In *Coral Reefs of the USA*, Vol. 1 of *Coral Reefs of the World*, pp. 175-220, Springer Science + Business Media B.V.

Banks, K.W., B.M. Riegl, E.A. Shinn, W.E. Piller, and R.E. Dodge. 2007. Geomorphology of the Southeast Florida continental reef tract (Miami-Dade, Broward, and Palm Beach Counties, USA). *Coral Reefs* 26:617-633.Bonito, V., and R. Grober-Dunsmore. 2006.

Resheeting of relict *Acropora palmata* framework may promote fast growth, but does it compromise the structural integrity of the colony? *Coral Reefs* 25:46.

Bruckner, A.W., 2002. Proceedings of the Caribbean *Acropora* Workshop: Potential Application of the US Endangered Species Act as a Conservation Strategy. NOAA Tech. Mem. NMFS-OPR-24.

Bruckner, A.W., and R.J. Bruckner. 2001. Condition of restored *Acropora palmata* fragments off Mona Island, Puerto Rico, 2 years after the *Fortuna Reefer* ship grounding. *Coral Reefs* 20:235-243.

Broward County. No Date. *Mooring Buoy Location and Usage*, http://www.broward.org/EnvironmentAndGrowth/EnvironmentalProgramsResources/Publications/Documents/pub_marine_2.pdf. Accessed November 26, 2010.

Bythell, J., O. Pantos, and L. Richardson. 2004. White plague, white band, and other "white" diseases. In *Coral Health and Disease*, ed. E. Rosenberg and Y. Loya, pp. 351–366. Springer-Verlag, Berlin, Heidelberg, New York.

Bythell, J. and C. Sheppard. 1993. Mass mortality of Caribbean shallow corals. *Mar. Pollut. Bull.* 26:296–297.

Chia, F., and M.E. Rice (ed). 1977. Settlement and metamorphosis of marine invertebrate larvae. Elsevier, New York.

Cry of the Water. 2010. Outstanding Florida Waters and Lauderdale-by-the-Sea Marine Park. Presentation made February 24, 2010, to the U.S. Coral Reef Task Force, Washington, DC.

Fong, P., and D. Lirman. 1995. Hurricanes cause population expansion of the branching coral *Acropora palmata* (Scleractinia): wound healing and growth patterns of asexual recruits. *Mar. Ecol.* 16:317–335.

Gladfelter, W.B. 1982. White-band disease in *Acropora palmata*: Implications for the structure and growth of shallow reefs. *Bull. Mar. Sci.* 32P:639–643.

Goldberg, W.M. 1973. The ecology of the coral-octocoral communities off the southeast Florida coast: Geomorphology, species composition, and zonation. *Bull. Mar. Sci.* 23:465-488.

Miller, M.W. 2001. Corallivorous snail removal: evaluation of impact on *Acropora palmata*. *Coral Reefs* 19:293-295.

Moyer, R.P., B. Riegl, K.Banks, and R.E. Dodge. 2003. Spatial patterns and ecology of benthic communities on a high-latitude South Florida (Broward County, USA) reef system, *Coral Reefs* 22:447-464.

Patterson, K.L., J.W. Porter, K.B. Ritchie, S.W. Polson, E. Mueller, E.C. Peters, D.L. Santavy, and G.W. Smith. 2002. The etiology of white pox, a lethal disease of the Caribbean elkhorn coral, *Acropora palmata. Proc. Nat. Acad. Sci.* 99(13):8725–8730.

Patterson-Sutherland, K., and K.B. Ritchie. 2004. White pox disease of the Caribbean elkhorn coral, *Acropora palmata*. In *Coral Health and Disease*, ed. E. Rosenberg and Y. Loya, pp. 289-300. Springer-Verlag, Berlin, Heidelberg, New York.

Peters, E.C. 1984. A survey of cellular reactions to environmental stress and disease in Caribbean scleractinian corals. Helgo. Meeresunters. 37:113–137.

Peters, E.C., J.J. Oprandy and P.P. Yevich. 1983. Possible causal agent of "white band disease" in Caribbean scleractinian corals. J. Invertebr. Pathol. 41:394–396.

Porter, J.W. 1987. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida): Reef-Building Corals. Biological Report 82(11.73), TR EL-82-4, August 1987, Coastal Ecology Group, U. S. Army Corps of

Engineers, Waterways Experiment Station, Vicksburg, MS, and Fish and Wildlife Service, National Wetlands Research Center, U.S. Department of the Interior, Washington, DC.

Porter, J.W., V. Kosmynin, K.L. Patterson, et al. 2002. Detection of coral reef change by the Florida Keys Coral Reef Monitoring Project. In J.W. Porter and K.G. Porter, *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook*, pp. 749–769. CRC Press, Boca Raton, FL.

Precht, W.F., M.L. Robbart, and R.B. Aronson. 2004. The potential listing of *Acropora* species under the US Endangered Species Act. *Mar. Pollut. Bull.* 49:534-536.

Sammarco, P.W., and M.L. Heron (ed). 1994. *The Bio-Physics of Marine Larval Dispersal*. American Geophysical Union, Washington D.C.

Sathe, M.P. D.S. Gilliam, R.E. Dodge, and L.E. Fisher. 2008. Patterns in southeast Florida coral reef community composition. *Proc. 11th International Coral Reef Symposium*, Ft. Lauderdale, Florida, 7-11 July 2008. Vol. 2:811-815 (Session number 18).

Shinn, E.A. 2004. The mixed value of environmental regulations: do acroporid corals deserve endangered species status. *Mar. Pollut. Bull.* 49:531–533.Soloviev, A.V., M.E. Luther, and R.H. Weisberg. 2003. Energetic baroclinic super-tidal oscillations on the southeast Florida shelf. Geophys. Res. Lett. 30(9):16-1–16-4.

South Florida Diving Headquarters. 2005-2011. *Dive Pompano Drop Off - A South Florida Reef Dive and Snorkel Site*, http://www.southfloridadiving.com/dive-sites/reef-dive-sites/pompano-drop-off.html. Accessed November 26, 2010.

Somerfield, P.J., W.C. Jaap, K.R. Clarke, M. Callahan, K. Hackett, J. Porter, M. Lybolt, C. Tsokos, and G. Yanev. 2008. Changes in coral reef communities among the Florida Keys, 1996–2003. *Coral Reefs* DOI 10.1007/s00338-008-0390-7.

Vone Research. 2008. Site Lauderdale-by-the-Sea Elkhorn Coral Reattachment Broward County, FL: One-Week Monitoring Report. Vone Research, Inc., with Cry of the Water and Palm Beach County Reef Rescue, report to Florida Fish & Wildlife Conservation Commission, Re: SAL# 08SRP-1091 (Site Lauderdale-By-The-Sea) Pompano Beach, FL.

Williams, D.E., M.W. Miller, and K.L. Kramer. 2006. Demographic monitoring protocols for threatened Caribbean *Acropora* spp. corals. NOAA Technical Memorandum MFSSEFSC-543. 91 pp.