8 Address Emerging Issues

Introduction

This spend plan category has principally addressed activities relating to the conservation and management of two Caribbean coral species, elkhorn coral (*Acropora palmata*) and staghorn coral (*A. cervicornis*), that were listed as threatened under the U.S. Endangered Species Act (ESA) in 2006, as well as other emerging issues related to human population growth, invasive species, and control methods for crown-of-thorns starfish, a large-scale coral predator.

Acroporids were formerly two of the three most important Caribbean reef building corals, forming extensive spatially complex structures that provided refuge and habitat to a high diversity of marine invertebrates and fish and served as breaker zones protecting back reef and coastal areas. Beginning in the late 1970s, an outbreak white of band disease (WBD) spread throughout the region and produced extensive mass mortality throughout the corals' range. WBD brought about a cascading set of events that changed the shallow structure of coral reefs throughout the Caribbean, including significant loss of biomass and productivity associated with the mortality of these corals, collapse of the framework structure provided by coral skeletons, and a shift from coral-dominated to algae-dominated communities. In the last 20 years, Caribbean acroporids have continued to decline with overall losses of 90-98% as a consequence of WBD outbreaks and subsequent impacts of hurricanes, bleaching, predation, bioerosion, and emergence of new, extremely virulent diseases. Even though there are some reports of recovery, populations in general seem to continue declining in most Caribbean reef areas.

In 1998, NOAA initiated a review of important reef building species to identify species of concern that could benefit from additional federal protection and voluntary conservation actions. This review resulted in the designation of the two acroporids as Candidate Species for the ESA. Through NOAA CRCP funding, a comprehensive process was initiated to improve knowledge of Caribbean acroporids from throughout their range, with emphasis on the population trends and threats preventing recovery. In response to a petition to list the species on the ESA, NOAA convened a team of experts to complete a Status Review and on May 9, 2006, listed both elkhorn *(Acropora palmata)* and staghorn *(A. cervicornis)* corals as threatened species under the ESA. These are the first coral species ever to be listed under the ESA as threatened or endangered. Research, restoration, management and outreach activities have increased to abate the threats affecting these two coral species with the ultimate goal that protection under the ESA is no longer needed, and the species have recovered as functioning members of the Caribbean coral reef ecosystem.

CRCP support under the Emerging Issues spend plan category is also directed at development of strategies to address: human population pressures in American Samoa; control methods for crown-of-thorns starfish, a large-scale coral predator: and *Carijoa riisei* (commonly called snowflake coral), an invasive soft coral from the Atlantic/Caribbean. This non-indigenous species overgrows and kill black coral colonies in Hawai'i, prevents recruitment of other coral species, and threatens a $30 million per year Hawaiian precious coral fishery.

Between 2002 and 2006, the CRCP provided $868K to support 17 projects in this category, which accounted for 1% of the overall number of projects and less than 1% of the overall CRCP funding (Exhibit III-8-1). The Emerging Issues category does not include any subcategories, although certain monitoring activities related to *Acropora* are also discussed under the *Assess and Characterize U.S. Coral Reefs* spend plan category.

Exhibit III-8-1
Investments to Address Emerging Issues, 2002-2006

Spend Plan Category	Number of Projects	% Category Projects	% Total Projects	Funding	% Category Projects	% Total Projects
Address Emerging Issues	**17**	**1.3**	**1.3**	**867,698**	**0.7**	**0.7**
Address Emerging Issues	17	100.0	1.3	867,698	100	0.7

The distribution of funds and effort by tool for this category is shown in Exhibits III-8-2a and -2b.

Exhibit III-8-2a
Address Emerging Issues
Investments by Tool

Tool	2002		2003		2004		2005		2006		TOTALS 2002-2006			
	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
Ecosystem Research	1	$95,000	1	$100,000	3	$174,882	2	$125,400	1	$98,620	**8**	**47.1**	**$593,902**	**68.4**
Socioeconomic Research	0	$0	0	$0	0	$0	0	$0	0	$0	**0**	**0**	**$0**	**0.0**
Mapping and Monitoring	0	$0	0	$0	0		1	$50,000	1	$49,258	**2**	**11.8**	**$99,258**	**11.4**
Outreach	1	$20,000	0	$0	3	$10,500	0	$0	1	$21,000	**5**	**29.4**	**$51,500**	**5.9**
Management: Direct Implementation	0	$0	0	$0	0	$0	1	$49,073	1	$73,965	**2**	**11.8**	**$123,038**	**14.2**
Management: Training/Technical Assistance	0	$0	0	$0	0	$0	0	$0	0	$0	**0**	**0**	**$0**	**0**
None or N/A	0	$0	0	$0	0	$0	0	$0	0	$0	**0**	**0**	**$0**	**0**
TOTAL	**2**	**$115,000**	**1**	**$100,000**	**6**	**$185,382**	**4**	**$224,473**	**4**	**$242,843**	**17**	**100**	**$867,698**	**100**

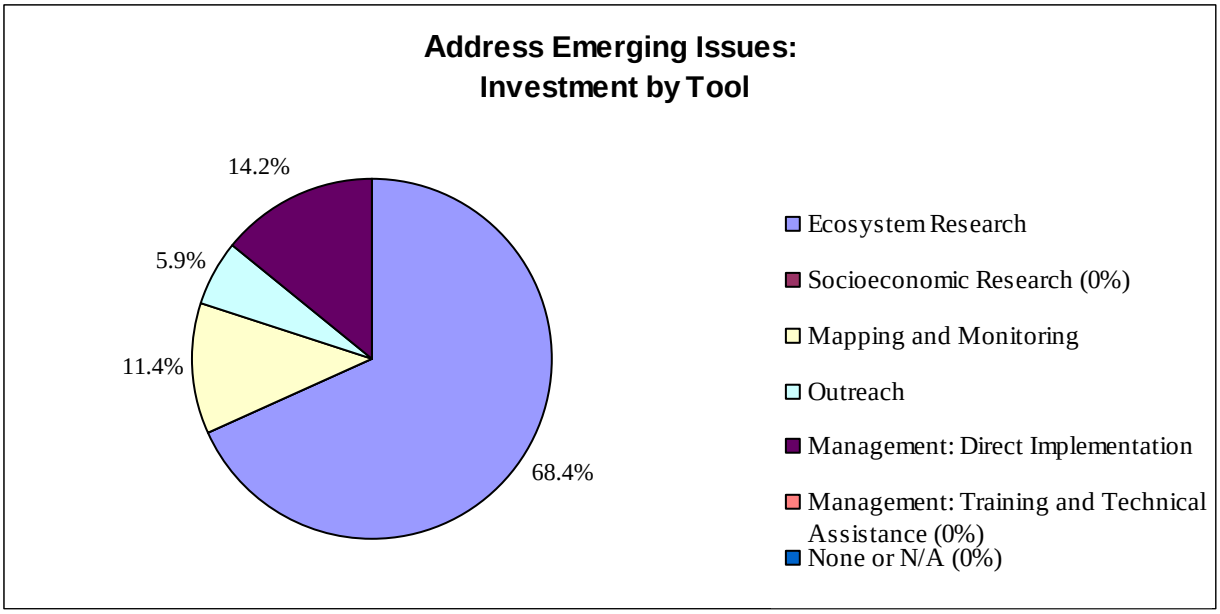

Exhibit III-8-2b. Distribution of Investments by Tool, 2002-2006

The distribution of funds and effort by region for this category is shown in Exhibits III-8-3a and -3b.

Exhibit III-8-3a
Address Emerging Issues
Investments by Region

Region	2002		2003		2004		2005		2006		TOTALS 2002-2006			
	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
Atlantic/Caribbean	2	$115,000	0	$0	2	$111,410	2	$125,400	3	$221,843	**9**	**52.9**	**$573,653**	**66.1**
Pacific	0	$0	0	$0	4	$73,972	2	$99,073	1	$21,000	**7**	**41.2**	**$194,045**	**22.4**
Freely Associated States	0	$0	0	$0	0	$0	0	$0	0	$0	**0**	**0**	**$0**	**0**
International	0	$0	1	$100,000	0	$0	0	$0	0	$0	**1**	**6**	**$100,000**	**12**
All Regions	0	$0	0	$0	0	$0	0	$0	0	$0	**0**	**0**	**$0**	**0**
TOTAL	**2**	**$115,000**	**1**	**$100,000**	**6**	**$185,382**	**4**	**$224,473**	**4**	**$242,843**	**17**	**100**	**$867,698**	**100**

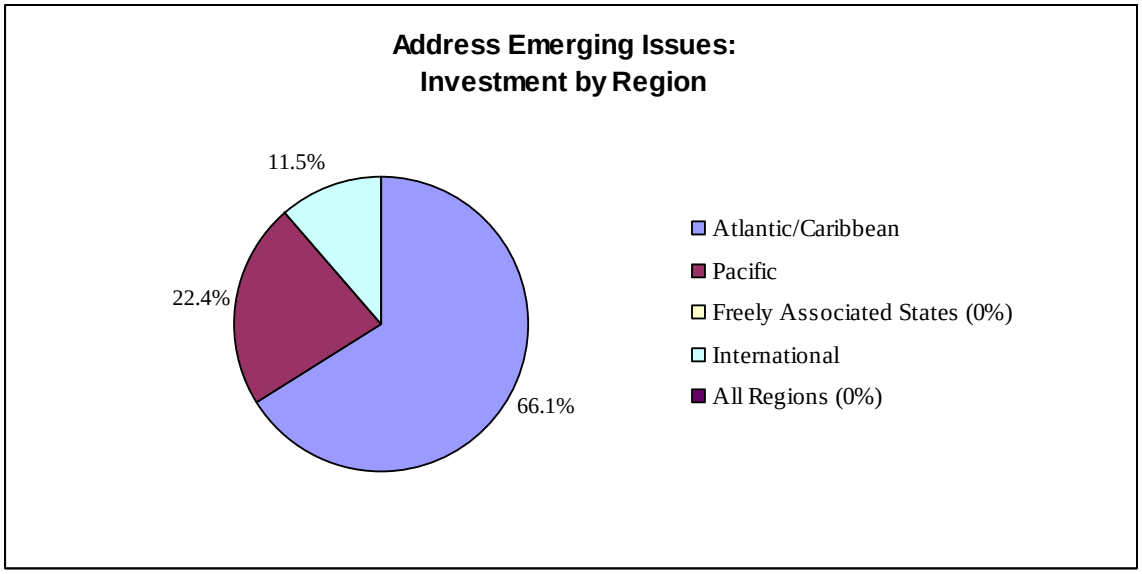

Exhibit III-8-3b. Distribution of Investments by Region, 2002-2006

Performance Measures

The main goals of these initiatives are to:

1. Mitigate threats and promote recovery of degraded acroporid coral populations.
2. Reduce the impacts of pest species (e.g., coral predators and invasives) by preventing population explosions and controlling their geographic spread.

Several performance measures are being developed, particularly in regard to ESA provisions. However, the CRCP is not yet actively tracking these.

a. Activities

Acropora

Research activities have focused primarily in the areas of population genetics of *A. palmata;* field studies of *Acropora* population dynamics, threats and trends; characterization of the prevalence and impacts of disease; and population biology of a major *Acropora* predator, the corallivorous snail *Coralliophila abbreviata*. Additional efforts were directed at recovery of the corals through collection and culture of gametes during annual spawning season, the propagation of corals through fragmentation, the development of *Acropora* nurseries, and outplanting of fragments.

While basic reef monitoring programs (initially focused in the Florida Keys and Puerto Rico) provided some info on *Acropora spp*. status, a targeted demographic (i.e. following individual colonies and populations over time) approach has been developed and, since the listing, gradually expanded throughout the Caribbean through partnerships with NGOs and other agencies. Monitoring activities have also expanded in nature in order to incorporate genetic tools developed in the research components of this activity to better understand the status of the monitored populations.

NOAA also collected and compiled GIS and remote sensing data (e.g., benthic habitat type, water depth and temperature, and presence or absence of *Acropora* colonies) to aid in the identification and mapping of areas that may qualify as critical habitat, with mapping activities conducted in parts of Florida, Navassa, USVI, and Puerto Rico.

NOAA detected and responded to a disease outbreak affecting *Acropora cervicornis* in the Florida Keys in the spring and summer of 2003. The Coral Disease and Health Consortium (CDHC), in cooperation with the Florida Keys National Marine Sanctuary (FKNMS) and the National Park Service, sampled acroporid colonies for histological and microbiological studies, conducted an evaluation of the role of corallivores as a vector for this disease, and characterized the total microbial community through subsequent tissue culture and DNA-based analyses.

Management efforts focused on the initial review of the status and trends of Caribbean acroporids and the major threats affecting them, responding to a petition for listing of these species as Candidates for the ESA, further consultations and evaluation of the biological status, and the listing of both elkhorn *(Acropora palmata)* and staghorn *(A. cervicornis)* corals as threatened species under the ESA. The listing is accompanied by a series of requirements, including designation of critical habitat, development of a recovery plan, and identification of conservation actions necessary on a site-by-site basis, including provisions for legal non-detrimental take and review of proposed Federal actions to ensure they do not threaten these coral species. Because of the unique biology and ecology of these two coral species, it was difficult to draw upon existing ESA implementation experiences for other species, which created the need for many new initiatives. These activities included engaging the participation of regional stakeholders and coordinating seven public information-gathering workshops in Florida, Puerto Rico, and USVI.

Population growth

To address American Samoa's high annual population growth rate, the American Samoa government and partners are conducting outreach to village leaders and improving local agency awareness of infrastructure needs resulting from population growth.

Invasive and pest species

NOAA, the Western Pacific Fishery Management Council, Hawai'i Division of Aquatic Resources, and University of Hawai'i Grant are working to determine the distribution and abundance of snowflake coral, its rate of spread to new areas, impacts to black coral colonies, and reproduction and developmental characteristics.

NOAA and the University of Guam are characterizing the distribution, abundance, and importance of crown-of-thorns starfish (*Acanthaster planci*) and are developing options to control future outbreaks. These efforts include development of bait stations and traps using known feeding attractants for *Acanthaster*, and identification of potential new alarm pheromones from *Acanthaster*, which could be used to keep the starfish out of certain sensitive reef areas.

b. Funding Recipients and Partners

To carry out the projects in this category, the CRCP partnered with the NOAA offices and external partners listed in Exhibit III-8-4.

Exhibit III-8-4
Address Emerging Issues
Funding Recipients and Partners

NOAA Offices	Other Federal Agencies	Fisheries Management Councils	States and Territories	Academic Institutions	Non-Governmental Organizations
• NMFS - Southeast Fisheries Science Center	• DOI - National Park Service	• Western Pacific	• American Samoa	• University of North Carolina, Wilmington (NURP Center)	• Curacao Seaquarium
• NMFS - Office of Habitat Conservation	• DOI – U.S. Geological Survey			• University of Guam	• John G. Shedd Aquarium
• NMFS - Southeast Regional Office				• University of Hawaii, Hawaii Undersea Research Laboratory (NURP Center)	• Sea-mester
• NOS - National Marine Sanctuaries				• University of Miami/RSMAS	

Exhibit III-8-4
Address Emerging Issues
Funding Recipients and Partners

NOAA Offices	Other Federal Agencies	Fisheries Management Councils	States and Territories	Academic Institutions	Non-Governmental Organizations
• NOS - National Center for Ocean and Coastal Science • OAR - National Undersea Research Program (NURP)				• Penn State University	

c. Outputs

Acropora research efforts have resulted in numerous peer-reviewed publications, popular articles, presentations, and white papers (see Appendix III-8). The ongoing mapping effort has provided data necessary for determination of critical habitat for these species and data on the status of *Acropora* spp. and the extent of *Acropora* habitat in the upper Florida Keys, southwestern Puerto Rico, St. Croix and St. John, and Navassa. A detailed manual of monitoring protocols was produced to enable comparative assessment of population dynamics and trends of acroporids populations throughout the Caribbean.

The FLKNMS disease study provided detailed information on microbial communities within diseased and healthy corals, and an understanding of spatial and species specific variations, including the potential diagnostic value in characterizing shifts within the microbial community and species that may be potential disease agents, as well as documenting the role of corallivores as disease vectors. This study represents the largest-scale study of coral microbial communities undertaken to date. It has provided answers to some key questions in coral microbiology. It has further resulted in the establishment of a publicly available sequences database with over 20,000 coral-associated bacterial sequences.

Acropora management efforts have resulted in an ESA listing, improved education and awareness among state and territorial governments and key stakeholders, reports summarizing the biological status of the corals and *Acropora* Conservation Workshops findings, outreach and education materials regarding the ESA listing, and an outline for the development of the species recovery plan.

Mapping activities resulted in the development of a comprehensive GIS database for the two listed coral species, with data on locations, distribution of colonies, size frequency and condition information, and relevant environmental parameters.

Other projects in this category have resulted in peer-reviewed publications and presentations and reports to resource managers (on *Carijoa* and *Acanthaster*) and printing of a revised and updated American Samoa government Population Plan, Population Plan summary booklets for a more general audience, and a Population Plan LAS workshop.

d. Outcomes

Stakeholder workshops concerning ESA implementation provided sufficient information to develop a proposed rule for threatened corals on actions necessary and advisable to provide for the conservation of the species (the 4(d) rule), as well as a Recovery Outline, which serves as interim guidance until a recovery plan for these species is finalized. The regional stakeholder contacts and partnerships created through these workshops aided in the appointment of an *Acropora* Recovery Team to understand these species' endangerment and devise an effective recovery program. It is anticipated that identifying conservation activities, prohibited actions, and recovery strategies for these two coral species also will benefit other species within the coral reef ecosystem.

Results of targeted monitoring in the Florida Keys have documented: 1) the impacts and interaction of episodic disturbance events (e.g., hurricanes and disease); 2) the threat to *A. palmata* from chronic predation by corallivorous snails, including potential benefits of snail removal efforts; and 3) continued decline of *A.palmata* due to both adult mortality and lack of both sexual and asexual recruitment.

The CDHC response to the disease outbreak affecting *A. cervicornis* provided information on relationships between gross disease signs, cellular (histological) changes, and the microbial community present. Evidence from this work indicates that similar gross signs of disease do not necessarily translate into identical disease processes. This serves as an important cautionary tale for coral management and research. This information should aid researchers in the field to identify useful predictive and diagnostic tools that can assist resource management.

Results from NOAA-led research, mapping, and monitoring fed directly into deliberations by the Biological Review Team. The results of research and monitoring efforts constituted a substantial part of the "best available science" for listing considerations by NMFS, which culminated in the listing of *A. palmata* and *A. cervicornis* as threatened under the ESA. Data from subsequent mapping efforts is being included in a comprehensive *Acropora* GIS database, which will facilitate direct management actions by the Southeast Regional Office such as Critical Habitat designation and consultations on Federal actions. Monitoring information has also been provided directly to reef managers at the Florida Keys National Marine Sanctuary and Biscayne

National Park. This information has provided notice and assessments of damage from hurricanes, bleaching, and disease events.

American Samoa population growth: The LAS Workshop led to population pressure being accepted as one of four local action strategies (LAS) for American Samoa. These activities also helped lay the groundwork for American Samoa's 2007 Year of Population Campaign.

Carijoa riisei research suggested management options for controlling this invasive species, including findings that boat harbors are high risk areas for introduction; eradication efforts should target large, dense aggregations as reproduction is density dependent; and fragments have low survival rates, so mechanical removal should not worsen an infestation.

Acanthaster research: Both feeding cues in traps and alarm pheromones could give local fisheries agencies new tools for the management of chronic infestations as well as potential control of crown-of-thorns starfish mass outbreaks.

e. Challenges

Challenges associated with the implementation of the ESA listing for the Caribbean acroporids included obtaining adequate information to determine whether these species qualify for listing due to severe gaps in spatial coverage of monitoring. Another challenge was determining specific prohibitions to provide for the conservation of the species as well as advisable exceptions necessary to avoid impacts to critical research. The fundamental challenge in recovering these species is the basic fact that for the major threat (disease) we lack basic understanding of mechanism and hence strategies for mitigation. This dictates the need for *Acropora* disease research to be a major component of recovery planning and action.

There remain huge gaps in monitoring coverage for both species, particularly for *A. cervicornis* which in many areas is so sparse that effective monitoring is logistically infeasible. Challenges associated with conducting research on acroporids are often due to the ecology and habitat preferences of the species. They occur in turbulent shallow water; fragmentation, growth patterns, and partial mortality make individual colonies difficult to track. Additionally, colonies undergo sudden mortality events that may be missed if monitoring is infrequent.

Work to address the invasive snowflake coral is logistically difficult and expensive due to challenges working at the great depths at which these species colonize.

f. Future Directions

ESA Implementation efforts include:

- Future public comment hearings in Florida, Puerto Rico, and USVI to address critical habitat proposed rules.

- Meetings of the *Acropora* Recovery Team and other expert meetings to complete recovery planning efforts and develop a Recovery Plan, which will serve as a roadmap for conservation efforts.
- Analysis of the *Acropora* GIS database to identify areas with immediate conservation needs as well as potential data gaps.

Monitoring Efforts: Suggested future directions include expanding the spatial and temporal coverage of monitoring in U.S. waters and promoting strategically placed, comparable monitoring programs at other sites in the Caribbean to provide a range-wide sample of the population performance, through adoption of the *Acropora* monitoring manual.

Research Efforts: Research to develop effective disease mitigation strategies is crucial to successful recovery as required by the ESA. Other important research activities include:

- Genetic studies such as identifying genotypes that are resistant to disease and other stressors.
- Research to enhance reproduction and recruitment success.
- Improved technology to understand the associated microbial community.

Restoration Efforts: Given their fast growth rate and tendency to fragment, acroporid corals are extremely amenable to asexual propagation, although mortality rates of fragments may be fairly high. Future work may evaluate existing efforts to propagate and transplant corals and develop guidelines for optimal reproductive strategies. Ecological restoration approaches may be directed towards the mitigation of corallivores, improvement of habitat condition to enhance natural recruitment, and methods to raise corals from larvae.

Other emerging issues include:

- *Carijoa riisei*—Future efforts might focus on development of methods to control and eradicte this coral, including biocontrol options (e.g., use of predatory nudibranchs) and direct removal.
- Population growth—NOAA continues to work with American Samoa through the LAS process to curb American Samoa's population growth through traditional school visits and newspaper articles, and will begin to focus on key constituencies such as influential people from villages and churches.

Appendix III-8
Publications and Presentations Resulting from CRCP Funding

PUBLICATIONS

Acropora

Miller MW, Baums IB, Williams DE (2007) Visual discernment of sexual recruits is not feasible for *Acropora palmata.* Mar Ecol Prog Ser 335:227-231.

Johnston L, Miller MW (2007) Variation in life-history traits of the corallivorous gastropod *Coralliophila abbreviata* on three coral hosts. Marine Biology 150: 1215-1225.

Gleason ACR, Lirman D, Williams D, Gracias NR, Gintert BE, Madjidi H, Reid RP, Boynton GC, Negahdaripour S, Miller M, Kramer P. (2007) Documenting hurricane impacts on coral reefs using two dimensional video-mosaic technology. Marine Ecology 28:1-5.

Williams DE, Miller MW. (2006) Morphology offers no clues to sexual vs. asexual origin of small *Acropora cervicornis* colonies. Rev Biol Trop 54 (Suppl. 3): 145-151.

Baums IB, Miller MW, Hellberg ME (2006) Geographic variation in clonal structure in a reef building Caribbean coral, *Acropora palmata*. Ecological Monographs 76:503-519.

Williams DE, Miller MW (2006) Importance of disease & predation to the growth & survivorship of juvenile *Acropora palmata* & *Acropora cervicornis*: A demographic approach. Proc. 10th International Coral Reef Symposium. Pp. 1096-1104.

Williams DE, Miller MW, Kramer KL (2006) Demographic monitoring protocols for threatened Caribbean Acropora spp. corals. NOAA Technical Memorandum NMFS-SEFSC-543. 91pp.

Baums I.B., Hughes C.R. & Hellberg M. (2005a) Mendelian microsatellite loci for the Caribbean hard coral *Acropora palmata*. Marine Ecology Progress Series, 288, 115-127

Baums IB, Miller MW, Hellberg ME (2005b) Regionally isolated populations of the imperiled Caribbean coral, *Acropora palmata*. Molecular Ecology 14:1377-1390

Williams DE, Miller MW. (2005) Coral disease outbreak: pattern, prevalence and transmission in *Acropora cervicornis*. Marine Ecology Progress Series 301:119-128.

Baums IB, Miller MW, Szmant AM. (2003a) Ecology of a corallivorous gastropod, *Coralliophila abbreviata*, on two scleractinian hosts I: population structure of snails and corals. Marine Biology 142: 1083-1091

Baums IB, Miller MW, Szmant AM. (2003b) Ecology of a corallivorous gastropod, *Coralliophila abbreviata*, on two scleractinian hosts II: feeding, respiration, and growth. Marine Biology 142: 1093-1101

Bruckner AW (2002) Proceedings of the Caribbean Acropora workshop: potential applicatoin of the US Endangered Species Act as a Conservation Strategy. NOAA Technical Memorandum NMFS-OPR-24, Silver Spring, MD 199 pp

Miller MW, Bourque AS, Bohnsack JA. (2002) An analysis of *Acropora* species loss at Looe Key, Florida, USA: 1983-2000. Coral Reefs 21:179-182.

Miller MW. 2002. Elkhorn coral and white pox: an answer and more questions. Sounding Line (FKNMS Newsletter), Autumn 2002. pp. 6-7.

Miller MW, Baums IB, Williams DE, Szmant AM (2002) Status of Candidate coral, *Acropora palmata*, and its snail predator in the upper Florida Keys National Marine Sanctuary: 1998-2001. NOAA Technical Memorandum NMFS-SEFSC-479, 26 pp.

Other

Kahng, S.E. & R.W. Grigg (2005) Impact of an alien octocoral (*Carijoa riisei*) on black corals in Hawaii. Coral Reefs 24(4):556-562.

SELECTED PRESENTATIONS

Acropora

"Effects of Multiple Hurricanes on *Acropora palmata* in the Florida Keys (U.S.A.)" DE Williams, MW Miler, KL Kramer. Meeting of the Association of the Marine Labs of the Caribbean, St. Thomas USVI, June 2007.

"Acropora Spp Monitoring and Research" DE Williams and MW Miller, US Coral Reef Task Force, St. Thomas USVI, Oct 2006

"What is an endangered coral?" MW Miller, Invited Seminar, Smithsonian Marine Station, Ft. Pierce FL, Jan 2006

"Recovery from apparent white pox disease outbreak." Williams DE, Miller MW (2005) Benthic Ecology Annual Meeting, April 2005

"Gross manifestations of acroporid white disease(s): a continuum from white band to white pox" DE Williams & MW Miller, Meeting of the Association of the Marine Labs of the Caribbean, Curacao, NA, June 2005.

"What is an endangered coral?" MW Miller, Departmental Seminar, Division of Marine Biology and Fisheries, RSMAS, Univ of Miami, April 2004

"Corallivorous snails as coral disease vectors in Caribbean acroporids." with DE Williams , 10th Int Coral Reef Symposium, Okinawa, July 2004

Presentation at FKNMS-sponsored Public Meeting, D.E. Williams, Key Largo FL. Aug 2003

"What is an endangered coral?" MW Miller, Lecture for FKNM Sanctuary Teachers Workshop, Key Largo FL, 17 May 2003

"Photo-monitoring of Acropora cervicornis & Acropora palmata on Florida reefs: importance of predation to growth & survivorship."Williams DE, Miller MW. Marine Benthic Ecology Meeting. March 2003.

WEB-AVAILABLE INFORMATION ON *ACROPORA* LISTING

http://sero.nmfs.noaa.gov/pr/protres.htm#acropora

- Recovery Outline: Elkhorn & Staghorn Corals
- Summary Report: Acropora Conservation Workshops
- Acropora sp. Final Listing Under the ESA: Frequently Asked Questions
- ESA Listing Timeline for Acropora sp.
- Frequently Asked Questions About 4(d) Rules (English & Spanish)
- Frequently Asked Questions About Critical Habitat (English & Spanish)
- Acropora sp. and Coral Conservation Information Resources (Informational Handout)
- Acropora Conservation Workshop (.PDF of Power Point Presentation) (English & Spanish)