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Demographic comparison of threatened Elkhorn coral, *Acropora palmata*, in the Caribbean: A case study in successful volunteer partnerships in a regional-scale monitoring program.

K.L. Kramer[1,2], D.E. Williams[2], M.W. Miller[3], C. Bégin[4], J. Fry[4], A. Valdivia[2]

1) National Park Service, PACN Inventory and Monitoring, P.O. Box 52, Hawaii NP, HI 96718
2) University of Miami, CIMAS, 4600 Rickenbacker Cswy, Miami, FL 33149
3) NOAA Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149
4) SeaMester, P.O. Box 5477, Sarasota, FL, 34277

Abstract. Due to severe and ongoing population declines, *Acropora palmata* received US federally threatened status in 2006. NOAA has since released a protocol for demographic monitoring of this genus in order to assess population status, and to encourage monitoring partnerships throughout the Caribbean (Williams et al 2006). In 2006, NOAA partnered with the SeaMester program to include monitoring sites along their sailing routes, including the British Virgin Islands (BVI), Bequia (St. Vincent Grenadines), and Green Island (Antigua). Monitoring data collected by the SeaMester program in the BVI are presented here, along with NOAA monitoring data from Curacao (Netherlands Antilles). Six fixed *A. palmata* monitoring plots were established in BVI, and 9 were established in Curacao. Within these plots, 12-15 randomly selected colonies have been measured annually and examined for signs of disease, predation, and other notable conditions. Live area index (LAI), and white syndromes, snail predation, and damselfish territory prevalence were statistically compared between the two regions. The relatively user-friendly protocol coupled with basic field trainings with partners allowed for substantial spatial expansion of this monitoring program. This broader monitoring coverage is needed to guide prioritized Caribbean-wide management based on observed population condition and resilience.

Key words: *Acropora*, demographic monitoring, *Coralliophila*, *Stegastes*.

Introduction

The elkhorn coral, *Acropora palmata*, is a spectacular shallow-water branching coral species that offers structural framework, protective habitat, and tourist-appeal to coral reef ecosystems. Like many other coral reef species, disease and bleaching events, hurricanes, and stressors associated with coastal development have driven dramatic population declines over the past 40 years (Gladfelter 1982, Nagelkerken and Nagelkerken 2004, Boulon et al 2005).

In response, *A. palmata* and congener, staghorn coral (*A. cervicornis*), were listed as threatened under the US Endangered Species Act (ESA) in May 2006 (NMFS 2006). To satisfy the ESA mandate for regular status updates, the National Oceanographic and Atmospheric Administration (NOAA) released a protocol for *Acropora* spp. demographic monitoring (Williams et al. 2006). The protocol aims to directly document population status, and to apply findings to management activities. Also, the protocol was designed to promote collaborative monitoring partnerships throughout the Caribbean.

Material and Methods

In January 2006, education staff from the SeaMester program volunteered to participate in monitoring efforts along its Caribbean sailing route, which provided a unique opportunity to address the significant gap in *A. palmata* monitoring and research in the eastern Caribbean. After receiving field training and guidance from the protocol authors, staff and students from the SeaMester program initiated *A. palmata* monitoring off Virgin Gorda and West Dog Island (British Virgin Islands), Bequia (St. Vincent Grenadines), and Green Island (Antigua). These complement existing NOAA monitoring locations in the Florida Keys, Puerto Rico, Navassa Island, and Curacao (Netherlands Antilles) (See Fig. 1). Results presented here will focus on monitoring efforts in Curacao and the BVI.

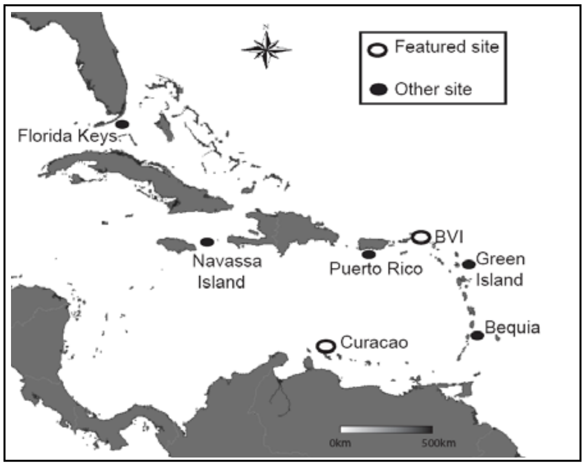

Figure 1: Current *A. palmata* demographic monitoring sites.

Detailed monitoring methods are available in Williams et al. (2006). In each monitoring region, we located 2-3 reef areas with moderately dense *A. palmata* colonies (avoiding thickets and isolated colonies). In these areas, we haphazardly established three 7m radius permanent monitoring plots, and within in each plot, 12-15 colonies were randomly selected for tagging and detailed monitoring. Each tagged colony has been annually measured, and examined for signs of disease, predation, bleaching, fragmentation, growth anomalies and other notable conditions.

Using size measurements, we calculated a live area index (LAI) for each tagged colony, where: LAI= $((\text{length x width x height})/3)^2$ x % live. This served as an index (not a direct estimate) of change in colony live tissue coverage. Importantly, LAI generally underestimates actual surface area, and this underestimate increases with colony complexity.

When additional resources were available, we also conducted annual total live tissue inventories (including recruitment) within each plot, genotype analysis, growth measurements, and exploratory regional mapping.

Datasets and photographs were received within one month of each monitoring event conducted by SeaMester staff and students. NOAA staff regularly addressed field questions, and datasets were quality-assured by verifying observations with colony photographs and through discussion with the observers.

We compared Curacao and BVI datasets for: a) white syndrome prevalence (including white-band disease (WBD), white pox (WPx), and rapid tissue loss (RTL)), b) average colony live area index (LAI), c) snail (*Coralliophila abbreviata*) predation prevalence (defined by regions of exposed, clean white skeleton along the colony live tissue edges), and d) three-spot (*Stegastes planifrons*) damselfish territory prevalence (defined by live tissue 'chimney' structures topped with algal tufts (Fig. 2).

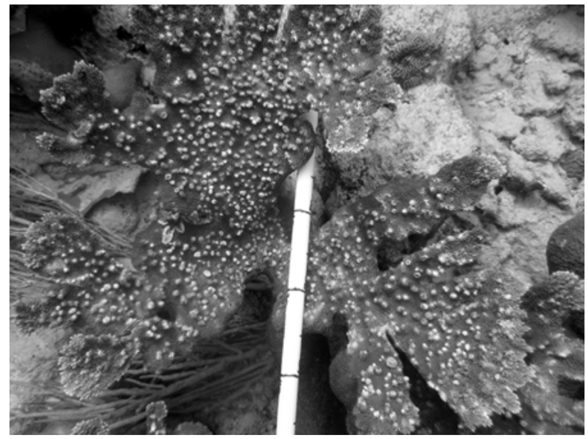
Figure 2: A colony from a Curacao monitoring plot at site 'SeaAqrm' impacted by an extensive three-spot damselfish (*S. planifrons*) territory. *S. planifrons* repeatedly bites areas of live coral tissue, which heal and overtime become chimney-like structures topped with fleshy macroalgae.

Datasets were first tested for normality and homogeneity of variance (Levene's test), and if needed, transformed ($\log_{10}$, square-root) to correct for failed assumptions. Usable datasets were statistically compared using a repeated measure (annual) hierarchical design ANOVA with survey plot nested within site and region.

Results

Live Area Index (LAI): Colony assemblages in the BVI and Curacao were very distinct, which was reflected in the live area index (LAI). A typical colony in the monitored areas of Curacao was relatively large, with many long branches, and low partial mortality (resulting in a high LAI). A typical colony in monitored areas of the BVI was small and mostly encrusting with sometimes a few short branches, and a moderate level of partial mortality (resulting in a low LAI). LAI varied significantly by region, and was twice as high for Curacao plots (Fig. 3). LAI increased slightly at all plots between 2006 and 2007.

Disease Prevalence: White syndrome (WPx, WBD, RTL) prevalence varied significantly by year and by region (Fig. 4). In 2007, white syndromes affected 23.9-56.9% of monitored colonies in Curacao, compared to 19.4-36.0% in 2006, and to 0-2.8% for the BVI in 2006. By 2008, white syndrome prevalence in Curacao fell to 14.6-29.3% of colonies affected, and healing lesions were frequently observed.

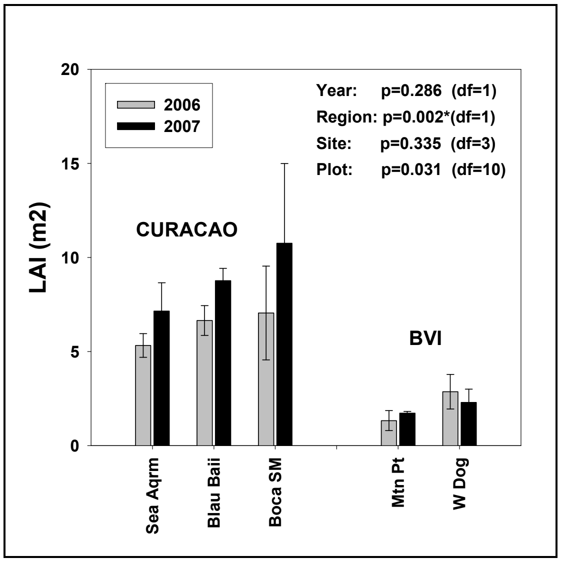

Figure 3: Mean colony live area index (LAI) (±1 SE) for *A. palmata* colonies in Curacao and the BVI in 2006 and 2007. *Indicates a statistically significant factor.

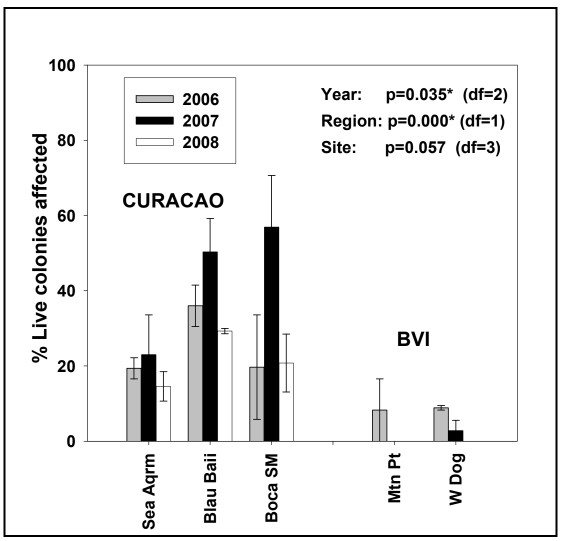

Figure 4: Mean prevalence of white syndromes (WBD, WPx, RTL) affecting *A. palmata* colonies in Curacao in 2006-2008 and the BVI in 2006-2007 (±1 SE). *Indicates a statistically significant factor.

Snail Predation: The prevalence of live tissue grazing by the coral-eating snail, *C. abbreviata,* ranged from 2.1-22.2% of monitored colonies affected in Curacao, and 0-15.9% in the BVI. Predation prevalence was highly variable, and did not vary significantly by year, region or site (Fig. 5).

Damselfish Territories: Three-spot damselfish (*S. planifrons*) territories varied significantly by monitoring site (Fig. 6). Prevalence was generally low at all sites (ranging from 0-9.9% of monitored colonies affected, except Curacao site 'SeaAqrm,' which ranged from 19.4-33.7%) (Fig. 2, Fig. 6).

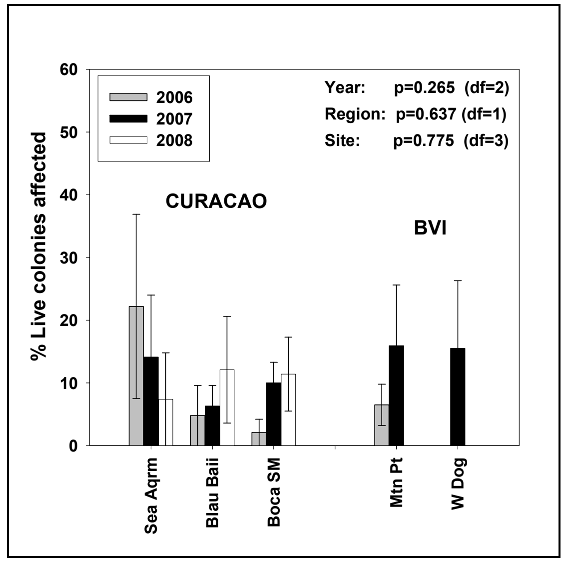

Figure 5: Mean prevalence (% live colonies affected) of snail (*C. abbreviata*) predation in Curacao in 2006-2008 and the BVI in 2006-2007 (±1 SE).

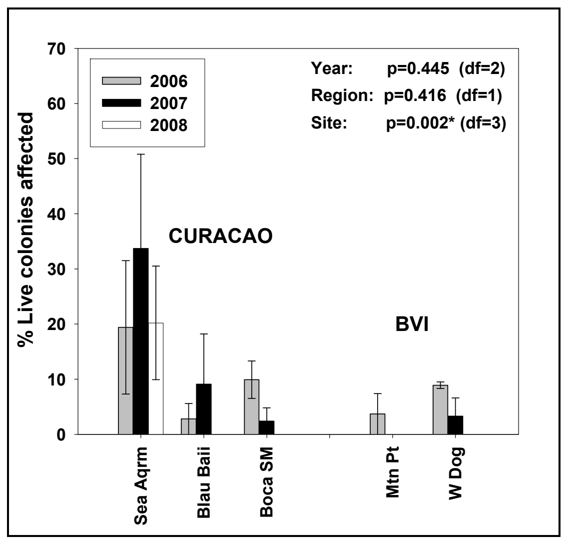

Figure 6: Mean percentage of *A. palmata* colonies impacted by three-spot damselfish (*S. planifrons*) territories in Curacao in 2006-2008 and the BVI in 2006-2007 (± 1 SE). *Indicates a statistically significant factor.

Discussion

Monitoring and Management: Regional differences in *A. palmata* populations, such as observed differences in 'reactions' to and recovery from threats, can have important implications for managers. Population variability based on the surrounding environment, habitat-driven morphology (Hubbard 1988), and genetics (Baums et al. 2005) allows certain populations to flourish under varying 'threat' circumstances. Regional monitoring programs such as this one can track population responses to threats, can assist managers in appropriate mitigation, and can potentially help predict the likelihood of population survivorship, allowing managers to prioritize accordingly (Vardi et al. 2008).

Typical colony morphologies in Curacao and in the British Virgin Islands were very distinctive; an average colony in monitored areas of Curacao was relatively large and frondose, while a typical colony in BVI plots was small and mostly encrusting, sometimes with a few short branches. These morphology differences resulted in significant differences in LAI (Fig. 3), and can have important implications for asexual fecundity in this species (Fong and Lirman 1995, Williams et al. 2008). Thus, a typical colony in Curacao would be expected to yield greater asexual recruitment in a moderate storm or other fragmentation event, which suggests that the population is relatively better able to sustain itself reproductively. Importantly, LAI generally underestimates actual surface area (particularly for more complex colonies) (Williams et al. 2008), so the regional difference in actual live tissue was probably greater.

Monitored areas in Curacao recovered well following frequent White pox (WPx) observations. In 2007, white syndromes (usually WPx, but also sometimes WBD) affected 23.9-56.9% of monitored colonies in Curacao, compared to 19.4-36.0% in 2006, and to 0-2.8% for the BVI in 2006. By 2008, white syndrome prevalence in Curacao fell to 14.6-29.3% of colonies affected, evidence that colonies were able to overcome WPx, at least on the short-term. Partial mortality from WPx lesions in 2007 was often still visible on the affected colonies during 2008 surveys, but was usually characterized by an advancing line of live tissue working toward the center of the old lesion.

The long-term effects of three-spot damselfish territories are not well understood. In this study, territory prevalence was generally low at all monitored sites, ranging from 0-9.9% of colonies affected, except for Curacao site 'Sea Aqrm,' which hosted significantly more territories, ranging from 19.4-33.7% (Fig. 2, Fig. 6). Subsequent annual surveys will likely shed light on the long-term consequences of these territories on *A. palmata* colony condition.

Snail predation was low to moderate at the monitored sites (Fig. 5), ranging from 2.1-22.2% of monitored colonies affected in Curacao, and 0-15.9% of affected in the BVI. In areas with substantial *A. palmata* population declines, such as the Florida Keys, *C. abbreviata* grazing activities have been shown to be particularly detrimental, as snail density and predation increased on surviving colonies (Miller et al 2002). Observations of detrimental snail predation can potentially serve as justification for emergency removal by managers (Miller 2001). Snail predation will continue to be monitored at all sites.

Volunteer Involvement in a Monitoring Program: Threatened and endangered species receive a great deal of attention from the media, often creating public interest and volunteers willing to assist with fieldwork. This enthusiasm can potentially dramatically expand the spatial scale of regional monitoring studies. However, channeling this interest and participation into scientifically meaningful and consistent data can be challenging. For the *Acropora* spp. monitoring protocol (Williams et al. 2006), our successful partnership with the SeaMester program in the British Virgin Islands was facilitated by field trainings with experts during monitoring plot set-up and initial surveys. The SeaMester program was an ideal volunteer partner because of its on-board education staff with a background in marine biology, and because it allowed us to gather consistent data from remote areas that would otherwise be inaccessible.

Observations and data collected by SeaMester and other collaborators are always documented photographically, allowing NOAA staff to quality-assure data by reviewing a subset of observations (including all unusual observations). Any questions from the field crews were addressed as quickly as possible, and a consensus was obtained prior to final data entry.

The protocol (Williams et al. 2006) is designed with various levels of participation options, based on the time and expertise constraints of potential collaborators. Even if a potential partner is only able to collect very basic monitoring data, odd or alarming observations can serve as an 'early warning system' for further investigation by dedicated field teams.

Demographic *Acropora* spp. monitoring requires field training and advanced scuba diving abilities, particularly for *A. palmata* surveys (relative to surveys of *A. cervicornis*, which tends to inhabit deeper reef areas, and is slightly more compact and less structurally delicate). Monitoring sites are usually very shallow, and located along at the reef crest where wave energy and surge is maximized. Volunteers are required to have a certain degree of buoyancy expertise in order to conduct monitoring activities safely and without damaging corals.

Broad scale monitoring projects like this one offer a unique chance at understanding regional differences in *Acropora* spp. population response to a variety of challenges. As global climate change, disease outbreaks, and coastal development continue to affect the Caribbean region, our broader knowledge of *A. palmata* can potentially guide prioritized Caribbean-wide management based on observed regional population condition and resiliency.

Acknowledgements

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References

Baums IB, MW Miller, and ME Hellberg (2005) Regionally isolated populations of an imperiled Caribbean coral, *Acropora palmata*. Mol Ecol 14:1377-1390

Boulon R, M Chiappone, R Halley, W Jaap, B Keller, B Kruczynski, M Miller, C Rogers (2005) Atlantic *Acropora* Status Review. Report to National Marine Fisheries Service, Southeast Regional Office.

Fong P, Lirman D (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 WB (1982) White-Band Disease in *Acropora palmata*: Implications for the structure and growth of shallow reefs. Bull Mar Sci 32:639-643

Hubbard DK (1988) Controls of modern and fossil reef development common ground for biological and geological research. Proc. 6th Int. Coral Reef Sym 1: 243-252

Miller MW (2001) Corallivorous snail removal: Evaluation of impact on *Acropora palmata*. Coral Reefs 19(3): 293-295

Miller MW, IB Baums, DE Williams, AM Szmant (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-479:1-26

Nagelkerken I, WP Nagalkerken (2004) Loss of coral cover and biodiversity on shallow *Acropora* and *Millepora* reefs after 31 years on Curacao, Netherlands Antilles. Bull Mar Sci 74(1): 213-223

NMFS (2006) Endangered and threatened species: Final listing determinations for Elkhorn and Staghorn coral. Federal Register 71:26852-26861

Vardi T, DE Williams, KL Kramer (2008) What is the future of threatened *Acropora palmata*? Population projections and management recommendations. Proc 11th Int Coral Reef Sym (in review)

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

Williams DE, MW Miller, KL Kramer (2008) Recruitment failure in Florida Keys *Acropora palmata*, a threatened Caribbean coral. Coral Reefs 27(3): 697-705