Artificial Colonies of Elkhorn Coral, *Acropora palmata,* as a Habitat Restoration Technique

Colonias Artificiales de *Acropora palmata* Como una Técnica de Restauración del Hábitat Artificial

Colonies Artificiels de *Acropora palmata* comme une Technique de Restauration de l'Habitat

MARIANA C. LEÓN-PÉREZ [1], ANTONIO ORTIZ-PROSPER[2], and JORGE GARCÍA-SAIS[1]

[1]*University of Puerto Rico, Mayagüez, PO Box 3424, Lajas, 00667, Puerto Rico.*

[2]*University of Puerto Rico, Aguadilla, PO Box 6150, Aguadilla, 00604-6150, Puerto Rico.*

ABSTRACT

Elkhorn coral, *Acropora palmata,* was the dominant coral species of shallow reefs in the Caribbean, but has suffered widespread mortality since the 1980s. The reef topography provided by live and dead Elkhorn coral colonies is an important factor influencing fish community structure on *A. palmata* reefs. Thus, the overall reduction of topographic relief has caused loss of critical habitat for reef fishes, including commercially important species and associated fauna and flora. This project will examine the feasibility of using artificial structures simulating Elkhorn's coral three-dimensional complexity as a reef restoration alternative. Three treatments will be tested against one control: live coral, dead coral and the artificial structures. A mixture of cement and crushed recycled PVC will be used for the production of artificial structures. Time-series surveys of fish, motile megabenthic invertebrates and percent cover by sessile-benthic biota will be performed monthly during one year. Multivariate statistics will be used to analyze variations of fish and invertebrates species assemblages within and between treatments. The main research hypothesis is that artificial Elkhorn coral structures provide a recruitment and protective habitat for the reef community similar to that provided by simulated standing dead coral structures. This initiative may represent a new habitat restoration technique that will be fast to construct and more durable than standing dead colonies.

KEY WORDS: Elkhorn coral, *Acropora palmate,* habitat, restoration

IMPORTANCE OF *ACROPORA PALMATA*

Acropora palmata is a large branching coral considered a major reef building species that provides most of the three dimensional structure critical to the reef ecosystem (Plater 2004). This species dominates the shallow fore reef of southern Florida, the east coast of Central America, the northeast coast of South America, and reefs throughout the Caribbean (Plater 2004). It can form monospecific stands or *thickets* in shallow waters known as the *palmata zone*, described by Goreau (1959). The *palmata zone* reduces incoming wave energy protecting the coastlines from erosion and offering calm waters for seagrass to establish (Plater 2004). Acroporids are critical components of Caribbean coral reef ecosystems and both its structural and ecological roles are unique and cannot be filled by other species (Bruckner 2002).

The structural complexity of the *Acropora palmata* reefs provide essential fishery habitat (Bruckner 2002). Lirman (1999) found the highest abundance of reef fish on the zone of high topography and low coral cover of *A. palmata* followed by high topography and high coral cover whereas, the low cover and low topography section had the lowest abundance. The results of Lemoine and Valentine (2012) corroborate the results of Lirman (1999) showing that *haemulids* and *lutjanids* aggregate within live standing *A. palmata*. However, schools of grunts and snappers also aggregate around standing dead colonies and almost never on the areas of low topography (Lirman 1999). Because of the combination of shelter and food availability, dead standing colonies had the highest mean fish abundance (Lirman 1999). Given that the structural complexity modifies community composition on coral reefs (Almany 2004, Lee 2006, Lemoine and Valentine 2012), the results of Lirman (1999) confirm that the high topography provided by *A. palmata* is the main factor influencing fish distribution and abundance, and not whether the coral is dead or alive. Garcia-Sais et al. (2011) observed juvenile stages of snappers (*Lutjanus analis, L. apodus, L. synagris*) during surveys from 2004 to 2011 in a shallow *A. palmata* reef, which confirms the role of the Elkhorn coral biotope as a nursery habitat for commercially important species in Puerto Rico (Garcia-Sais,\ 2011). In addition, *acroporid* corals provide essential habitat for turtles, lobsters, crabs, echinoids, and gastropods (Bruckner 2002). At present, there is no indication that any other Caribbean coral species can replace the important role that *acroporid* corals play within reef communities of the region (Bruckner 2002).

THREATS

Acropora palmata has suffered widespread mortality since the 1980s (Bruckner 2002). A decline of 80% to 98% in the number of colonies and a drastic reduction of its geographic distribution (Bruckner 2002) has forced its designation under the U.S. Endangered Species Act. Diseases are believed to be the most important cause of the region-wide decline of Atlantic *Acropora* spp. (*Acropora* Biological Review Team 2005). One of the causes has been the highly contagious white pox disease (Patterson et al. 2002) that only affects *A. palmata* and is linked to human sewage pollution (Sutherland et al.

2011). Monitoring information after 2000 indicates that white pox disease has higher prevalence in *A. palmata* than the white band disease, although during 1970s and 1990s the *Acropora* spp. declines were attributed to the white band disease (*Acropora* Biological Review Team 2005). Other disturbances that contributed to the decline include storms and hurricanes, temperature extremes, bleaching, predation by snails, sedimentation, and other factors (Bruckner 2002), such as the intrusive colonization of clionid sponge, *Cliona langae* (Weil et al. 2002). As *A. palmata* dies, its three-dimensional structure suffers rapid deterioration due to bioerosion and mechanical breakage (Bruckner 2002). Alvarez-Filip et al. (2012) suggests that in the Caribbean, the greatest impacts on biodiversity are expected to occur only with the breakdown of the reef matrix because no fish species feed exclusively on live coral. Thus, the overall reduction of topographic relief has caused loss of critical habitat for reef fishes, including commercially important species and associated fauna and flora. Their loss threatens the entire reef ecosystem and the immeasurable number of humans and marine organisms that depend upon functioning reefs (Plater 2004).

RESTORATION EFFORTS

Historically, most restoration efforts of *Acropora palmata* reefs in the U.S. were conducted in response to ship groundings (Bruckner et al. 2008). Efforts to restore the structural habitat provided by *A. palmata* in reef areas impacted by ship groundings have been attempted by planting Elkhorn coral fragments, but not with much success (Bruckner et al. 2008). Soon after the 1997 Fortuna Reefer grounding off Mona Island, the first restoration effort for *A. palmata* in Puerto Rico was done (Bruckner et al. 2008). A total of 1,857 coral fragments were secured to the reef and to dead standing colonies using wrapping stainless steel wire and nails, and cable ties. Ten years after only 6% of the fragments were alive. Some causes of the low fragment survival were wire failure, inability of corals to overgrow wire, limited fragment fusion, and the attachment of fragments to inappropriate substrates.

On the other hand, positive results have been accomplished by Nedimyer et al. (un-published data) on developing effective methods to asexually propagate *A. palmata*. All methods yielded outstanding results with survival rates above 95%. Sexual reproduction techniques are been tested by SECORE with the objective of enhance sustainability among *A. palmata* populations. However, these restoration efforts have been focused on the wellbeing of the species, not on the habitat it creates. Taking into account that the recovery of this species can take a long time and may be vulnerable to natural threats during that process, action should be taken to ensure persistence of the habitat.

ARTIFICIAL COLONIES FOR HABITAT RESTORATION

Alvarez-Filip et al. (2012) has stated that the major challenge for scientists and policy-makers concerned with maintaining reef ecosystems and the security and wellbeing of Caribbean coastal communities is reversing declines in reef architecture that is provided mainly by *Acropora* spp. and massive robust species. Recruitment limitation resulting from the lack of appropriate settlement substrates and refuges for species of commercial importance (Graham et al. 2007) may compromise the long-term sustainability of fisheries in Caribbean reefs (Alvarez-Filip et al. 2012). We plan to examine the feasibility of using structures simulating the three-dimensional complexity of *Acropora palmata* as a restoration alternative.

Three treatments will be tested against one control: live coral, dead coral and the artificial structures**.** Each treatment will have a total of 10 replicates. The structures will consist of a base (truncated square pyramids of 30 x 30 x 30 cm made with concrete) and four blades at each side (~32 cm long) and four on the top (~16 cm long). The control will have no blades. The artificial blades will be made of a mixture of cement and crushed recycled PVC. For this design, one experimental unit will consist of three structures of the same treatment placed at a distance of 1 m from each other. The experimental units will be separated by a minimum distance of 5 m and arranged in a 4 X 30 matrix within a patchy reef on the back reef of Cayo Media Luna, La Parguera, Puerto Rico. The placement of experimental units will follow a Latin Square format, allowing each treatment to be on each column and each row controlling the variability associated with a gradient in the habitat type.

Using a modified point count with a 1.5 m radius (Bohnsack and Bannerot 1986), census of demersal and territorial reef fish populations and motile megabenthic invertebrates will be done around each experimental unit, each month during one year period. CPCe (Coral Point Count with Excel extensions) will be used to analyze the photos of each experimental unit for the determination of the percent cover by sessile-benthic biota. Monthly variations of the percent substrate cover of sessile-benthic biota, and fish and invertebrates species assemblages within each treatment will be tested using multivariate statistics (nMDS, ANOSIM and SIMPER).

The main research hypothesis is that artificial Elkhorn coral structures provide a recruitment and protective habitat for the reef community similar to that provided by simulated standing dead coral structures. Based on the findings of Gratwicke and Speight (2005) the presence of a variety of different shapes is enough to significantly increase the numbers of fish species on artificial reefs, even though those growth forms do not offer a range of different potential food resources. We hypothesize that the availability of a variety of niches within the artificial structures may provide areas for recruitment and refuge for noncommercial and commercial important fish species.

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.

Almany, G.R. 2004. Differential effects of habitat complexity, predators and competitors on abundance of juvenile and adult coral reef fishes. *Oecologia* **141**:105-113. (doi:10.1007/s00442-004-1617-0).

Alvarez-Filip, L., N.K. Dulvy, J.A. Gill, I.M. Côté, and A.R. Watkinson. 2009. Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. *Proceedings of the Royal Society of Britain* (doi: 10.1098/rspb.2009.0339).

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. *NOAA Technical Report National Fish and Wildlife Service* **41**:1-15.

Bruckner, A.W. 2002. *Proceedings of the Caribbean* Acropora *Workshop: Potential Application of the U.S. Endangered Species Act as a Conservation Strategy*. NOAA Technical Memorandum NMFS-OPR-24, Silver Spring, Maryland USA. 199 pp.

Bruckner, A.W., R.J. Bruckner, and R. Hill. 2008. Improving restoration approaches for *Acropora palmata*: Lessons from the Fortuna Reefer grounding in Puerto Rico. *Proceedings of the 11th International Coral Reef Symposium*. [www.reefbase.org/download/download.aspx?type=1&docid=13908].

Garcia-Sais, J.R., R. Castro, J. Sabater-Clavell, R. Esteves, and M. Carlo. 2010. Monitoring of Coral Reef Communities from Natural Reserves in Puerto Rico: Isla Desecheo, Rincon, Guanica, Ponce, Caja de Muerto, Vega Baja, Vieques and Mayaguez, 2010-2011. Final Report submitted to the Department of Natural and Environmental Resources (DNER), U. S. Coral Reef National Monitoring Program, NOAA in Puerto Rico. 7-18 pp.

Goreau, T.F. 1959. The ecology of Jamaican coral reefs. I. Species composition and zonation. *Ecology* **40**(1):67-90.

Graham, N.A.J., S.K. Wilson, S. Jennings, N.V.C. Polunin, J. Robinson, J.P. Bijoux, and T.M. Daw. 2007. Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. *Conservation Biology* **21**:1291-1300. (doi:10.1111/j.1523-1739.200700754.x).

Gratwicke, B. and M.R. Speight. 2005. Effects of habitat complexity on Caribbean marine fish assemblages. *Marine Ecology Progress Series* **292**:301-310.

Lee, S.C. 2006. Habitat complexity and consumer-mediated positive feedbacks on a Caribbean coral reef. *Oikos* **112**:442-447. (doi:10.1111/j.0030-1299.2006.14247.x)

Lemoine, N.P. and J.F. Valentine. 2012. Structurally complex habitats provided by *Acropora palmata* influence ecosystem processes on a reef in the Florida Keys National Marine Sanctuary. *Coral Reefs* **31**:779-786.

Lirman, D. 1999. Reef fish communities associated with *Acropora palmata*: Relationships to benthic attributes. *Bulletin of Marine Science* **65**:235-252.

Nedimyer, K., K. Grablow, A. Northrop, and W. Precht. [2010]. Producing *Acropora palmata* in offshore coral nurseries for reef restoration. Poster on, Linking Science to Management: A Conference and Workshop on the Florida Keys Marine Ecosystem. Unpublished.

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*. *Proceedings of the National Academy of Sciences* **99**:8725-8730.

Plater, B. 2004. Petition to list *Acropora palmata* (elkhorn coral), *Acropora cervicornis* (staghorn coral), and *Acropora prolifera* (fused staghorn coral) as endangered species under the Endangered Species Act. Center for Biological Diversity, Oakland, California USA. 106 pp.

Sutherland, K.P., S. Shaban, J.L. Joyner, J.W. Porter, and E.K. Lipp. 2011. Human pathogen shown to cause disease in the threatened elkhorn coral *Acropora palmata*. *PLoS ONE* **6**(8):e23468. doi:10.1371/journal.pone.0023468.

Weil, E., E. Hernández-Delgado, A. Bruckner, A. Ortiz, M. Nemeth, and H. Ruiz. 2002. Distribution and status of Acroporid coral (Scleractinia) Populations in Puerto Rico. In: A. Bruckner (ed.) *Proceedings of the Caribbean Acropora Workshop: Potential Application of the U.S. Endangered Species Act as a Conservation Strategy*. NOAA Technical Memorandum NMFS-OPR-24. 190 pp.