Reef Fish Habitat Use as a Measure of Coral Reef Restoration Success at the Fortuna Reefer Grounding Site, Mona Island, Puerto Rico

RONALD L. HILL[1], MICHELLE SCHÄRER[2], MICHAEL NEMETH[2], and ANDY BRUCKNER[3]
NOAA/NMFS, 4700 Avenue U, Galveston, Texas 77551 USA
Dept. of Marine Sciences, Univ. of Puerto Rico-Mayagüez, Lajas, Puerto Rico
NOAA Fisheries, OHC Coral Reef Ecosystem Div., SSMC3, Silver Spring, Maryland USA

ABSTRACT

Following the grounding of the M/V Fortuna Reefer on Mona Island in 1997, a multi-agency emergency restoration reattached over 1800 *Acropora palmata* fragments. Since shortly after the grounding, we have monitored the restoration using coral reattachment, survival, and growth and the recovery of fish assemblages as measures of success. Although we have no surveys from before the grounding, we have neighboring undisturbed areas for comparison and we can analyze temporal changes within the site. In early surveys reef fish assemblages were significantly different from adjacent control sites. With almost a decade of monitoring complete, we are starting to see increases in species diversity and increases in juvenile haemulids, species known to be habitat selective. Additional monitoring will determine when the conditions can be considered "normative" however experimental approaches might be required to improve restoration of fish habitat and encourage the coral-fish interactions that can contribute to the effectiveness of coral reef restoration.

KEY WORDS: Ship grounding, coral restoration, habitat use, *Acropora palmata*

Uso del Habitad de Peses del Filón como Medida de Éxito de la Restauración del Arecife Coralino en el Sitio que el Fortuna Reefer Pego a Tierra en la Isla de Mona, Puerto Rico

Después de pegar en tierra el M/V Fortuna Reefer en la isla de Mona en 1997, una restauración de emergencia de la multiagencia reatado mas de 1800 fragmentos de *Acropora palmata*. Poco después de poner a tierra, hemos supervisado la restauración usando el reacoplamiento coralino, supervivencia, y crecimiento y la recuperación de las ensambladuras de los peses como medidas de éxito. Aunque no tenemos ningúnos examenes antes de poner a tierra, tenemos áreas imperturbadas vecinas para la comparación y podemos analizar cambios temporales dentro del sitio. En primeros examenes de peses del filón las ensambladuras eran perceptiblemente diferentes al sitio adyacente de control. Con casi una década de supervisión completa, estamos comenzando a ver aumentos en diversidad de especies y aumentos en los haemulids juveniles, especies ser conocidos como selectivos para siertas habitades. La supervisión adicional determinará cuando las condiciones se pueden considerar "normativos" sin embargo acercamientos experimentales se requieren para mejorar la restauración del habitad de los peses y para animar las interacciones de coral-peses que pueden contribuir a la eficacia de la restauración del filón coralino.

PALABRAS CLAVES: Barcos encallados, restauración de corales, uso del habita, *Acropora palmata*

INTRODUCTION

Coral reef ecosystems are subject to a number of disturbances but have historically been able to maintain their biogenic integrity. Recently reefs have been affected by both anthropogenic and natural environmental changes in air and water quality and by physical alterations. One consistent physical impact is the damage caused by boats that run aground. In the Florida Keys, it is estimated that approximately 500, reported, and as many as 1000, unreported, small vessels run aground each year on coral reefs, in addition to the larger vessels that tend to draw more media attention (Jaap 2000). Similar situations occur wherever boats operate around coral reefs and where coral reefs lie near to shipping lanes or recreational areas.

The M/V Fortuna Reefer, while transiting the Mona Passage, grounded on the forereef off the southeast coast of Mona Island on 24 July 1997. The primary damage, caused by the 99.4 m freighter's grounding, and the secondary damage, caused by the tug boats and cables during removal of the grounded vessel, affected a total of 6.8 acres (2.75 ha). The grounding site ranges from 3 - 9 meters deep (Iliff *et al.* 1999). While some massive corals (e.g., *Diploria* and *Montastrea*) were damaged, *Acropora palmata* Lamarck 1816, elkhorn coral, which has been recently listed as "threatened" under the Endangered Species Act, was most affected. Using a novel approach, the National Oceanic and Atmospheric Administration (NOAA) and Puerto Rico Department of Natural and Environmental Resources (DNER), reached a partial settlement in which the "responsible party" paid for emergency restoration while the remainder of the damage settlement was worked out. In this way, the restoration was completed within 2.5 months of the grounding. During September and October, NOAA, DNER, US Fish and Wildlife, and other partners working with a marine contractor restored the grounding site.

The objectives of the emergency restoration were to re-establish the physical structure of the coral reef community and reduce coral mortality. *A. palmata* fragments were removed from sand channels where they were being smothered and abraded and affixed to standing relic *Acropora* skeletons with stainless steel wire or to the reef

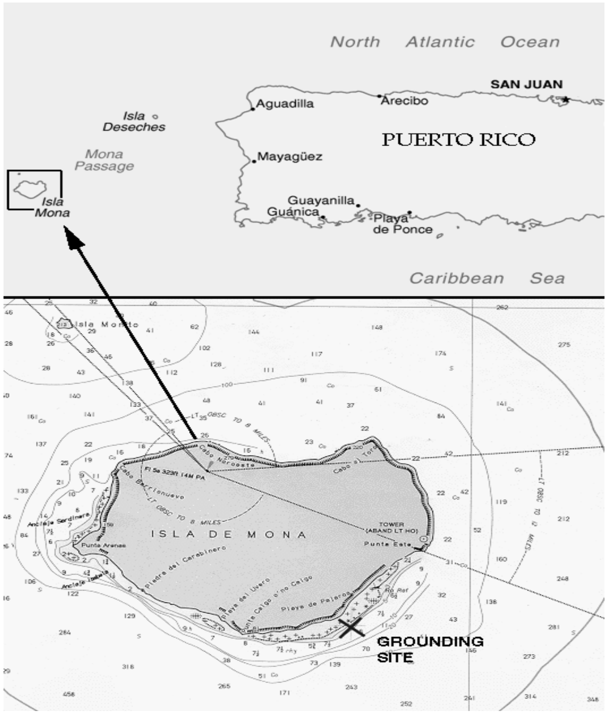

Figure 1. Fortuna Reefer grounding/restoration site is located windward of the fringing reef on the southeast coast of Mona Island, approximately 65 km from the west coast of mainland Puerto Rico and west of the deep-water Mona Passage.

substrate with stainless steel wire and nails. Some previously used restoration techniques, such as securing fragments with cement or epoxy and cable ties, were deemed unsuitable because of high energy wave conditions at the site during the restoration activities. During the restoration effort, 1,857 coral fragments were stabilized. Within 2.5 months after the grounding, all restoration work was accomplished.

The Oil Pollution Act of 1990, the primary legislation providing authority for assessing and recouping damage and for restoration of ship grounding sites in the US, requires "restoration" rather than experimentation. Monitoring of restoration success is typically limited to a small portion of the monetary settlement. The purpose of work reported here was to go beyond the limited restoration monitoring allowed in the settlement agreement and institute independent monitoring to assess the Fortuna Reefer restoration. Monitoring focused on survival and growth rates of *A. palmata* transplants, percent tissue cover and reattachment of transplants, and microtopography of the transplant site. In addition, we have tracked changes in the fish assemblage over time to assess the success in restoring habitat value to the site. Our hypothesis is that as habitat value is restored, habitat-dependent fishes will return to the site either through recruitment or immigration.

METHODS AND MATERIALS

The Fortuna Reefer grounding site is on the southeast coast of Mona Island (18.05643° N 67.86952° W; Fig. 1), 65 km across the deepwater Mona Passage from the west coast of mainland Puerto Rico. The site is routinely exposed to high wave action, strong currents, and heavy swells, and has been hit by several recent storms from the Atlantic and Caribbean, including Hurricane Georges in 1998. The grounding occurred on the shallow forereef, just seaward of the reef crest within a well-developed *Acropora palmata* stand. Primary and secondary damage extended across 2.75 ha, ranging from 3 - 9 m in depth.

Coral fragments, benthic assemblages and fish assemblages were evaluated in August 1999, approximately two years after the grounding, and in May and August 2000, 2001 and 2003. During the surveys, we measured the number and condition of attached fragments and fragments that had broken loose and/or were missing. Each identified fragment was assessed for:

i) Maximum length, using a one meter bar divided into 1 cm increments;
ii) Orientation, recorded as up, down or sideways with respect to its orientation on its original colony prior to breakage;
iii) Attachment location (reef or skeleton); and
iv) Status (live or dead).

Live fragments were examined for tissue growth over wire or exposed skeleton, the number and size of protobranches, natural cementation (fusion) to the substrate, and growth onto the reef or skeletons. The amount of partial tissue mortality on upper branch surfaces was recorded for all live fragments as a percentage of the total fragment length. Partial or total mortality was attributed to particular causes when possible, including wire abrasion, disease, predation by parrotfish, gastropods or fireworms, competition with algae, overgrowth by encrusting invertebrates (especially the brown boring sponge, *Cliona* spp.), and damselfish algal lawns. Details of coral fragment surveys can be found in Bruckner and Bruckner (2001, 2006)

Within and adjacent to the grounding site, belt transects (30 m x 2 m,) were performed to census the diversity, abundance and size-classes of reef fishes. Our standard method is to perform eight transects inside the grounding site and eight outside. A species list, modified from the Atlantic and Gulf Rapid Reef Assessment (AGRRA) census method and consisting of 62 species or taxa included those judged to be ecologically and economically important. Within transects, all species of the following families are recorded: groupers, snappers, grunts, parrotfishes, surgeonfishes, triggerfishes, angelfishes, boxfishes, and butterflyfishes. Counts of yellowtail damselfish (*Microspathodon chrysurus*), hogfish (*Lacholaimus maximus*), Spanish hogfish (*Bodianus rufus*), barracuda (*Sphyraena barracuda*), and bar jack (*Caranx ruber*) were included. Fish sizes were estimated to the

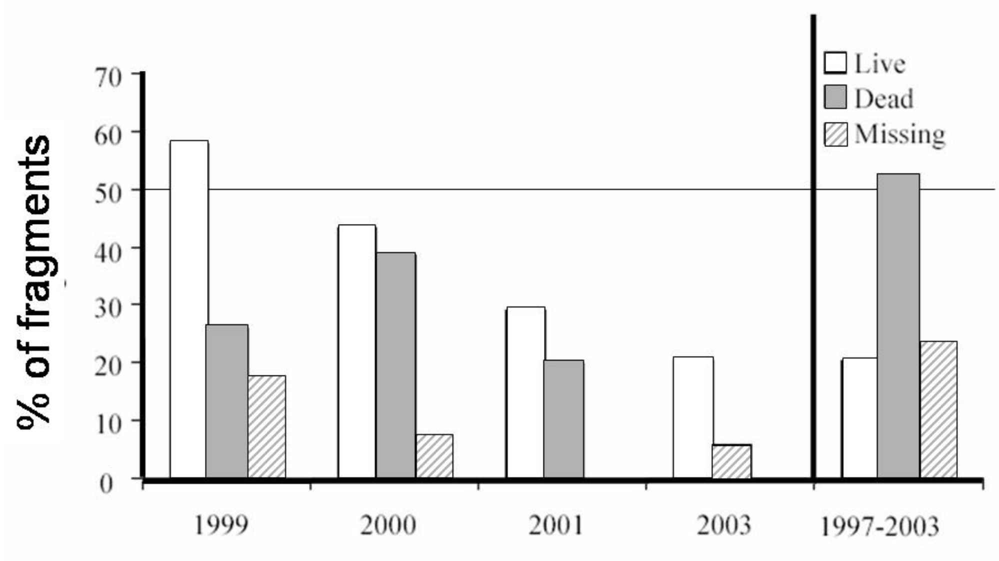

Figure 2. Survival of *Acropora palmata* fragments at the Fortuna Reefer restoration site between 1993 and 2003. Last group (to the right of the chart) summarizes findings for the entire period. (Modified from Bruckner and Bruckner 2006)

nearest centimeter using a ruled slate edge for scale. Data through 2003 - 2004 will be presented comparing fish richness and abundance to coral survival and development of protobranches.

RESULTS

Species richness of recorded reef fish species within the restoration site varied from 2.53 (± 0.95) in 1999 to 7.46 (±1.62) in 2003 (Figure 3). Surveys from 2004, with species richness of 7.33 (± 2.34), indicated possible stability in this range. Mean abundances of key families also showed increases. Parrotfishes increased from 1.4 fish per transect to 7.13, grunts from 0.3 to 4.13, snappers from 0 to 1.3, groupers from 0.3 to 2.0, and surgeonfishes from 11.6 to 35.3. The surgeonfish abundances were affected by large roaming schools foraging through the area. The increase in abundance of grunts was also accompanied by an increase in diversity of sizes. Between 1999 and 2001, grunts were represented only by larger *Haemulon carbonarium*, Caesar grunt, and *H. macrostomum*, Spanish grunt, ranging from 28-30 cm TL. In 2003, sizes ranged from 16-30 cm TL, all Caesar grunts.

DISCUSSION

Six years after the grounding, 20.3% (377) of the restored fragments were living, while the remainder had died (56%) or were detached and removed (23.7%) from the site (Bruckner and Bruckner 2006). Dead fragments were observed during every survey (Figure 2), although a higher proportion of fragments died in the first four years (20-38% per year) and fewer fragments died between August 2001-August 2003 (5.4%) (Bruckner and Bruckner 2006). During the same time period, species richness of reef fishes tripled and seemed to find a stable level even though the number of surviving fragments was decreasing. Fragment survival may not have been the factor most strongly influencing fish diversity.

The increases in species richness and abundance were more likely tied to the restoration of 3-dimensional structure in the grounding site. In August 1999 only 108 (19%) of the fragments sampled (705 reattachment sites; 38% of the fragments originally restored) had grown one or more small protobranches (2 - 10 cm in height). By August 2003 all reattachment sites had been sampled and more than half of the surviving branches (58%, n = 218) had developed branching patterns characteristic of standing colonies. On average, fragments had four protobranches (maximum of 30) each, ranging in size from a mean of 21 cm to a maximum of 73 cm. Larger surviving fragments showed a trend of increasing protobranch size ($r^2 = 0.60$, $p<0.01$) and number of protobranches ($r^2 = 0.58$, $p = 0.01$) (Bruckner and Bruckner 2006).

In parallel with the development of protobranches and the resulting increase in 3-dimensional structure, the number of reef fish species more than tripled and many species, such as snappers and grunts, that are known to be habitat-dependent increased. In the early surveys only large adult grunts were recorded but later surveys included medium sized juveniles. These juvenile schools are known to select particular sites influenced by habitat characteristics (Appeldoorn *et al.* 1997, Ogden and Ehrlich 1977).

As indications of change and restoration success both coral survival/growth patterns and size-structured fish assemblages can be informative metrics. Documented behaviors such as settlement preferences, e.g., in juvenile grunts, can be useful in establishing success criteria for a restoration. Knowledge of the habitat value lost during a grounding or other physical impact and the effect of the

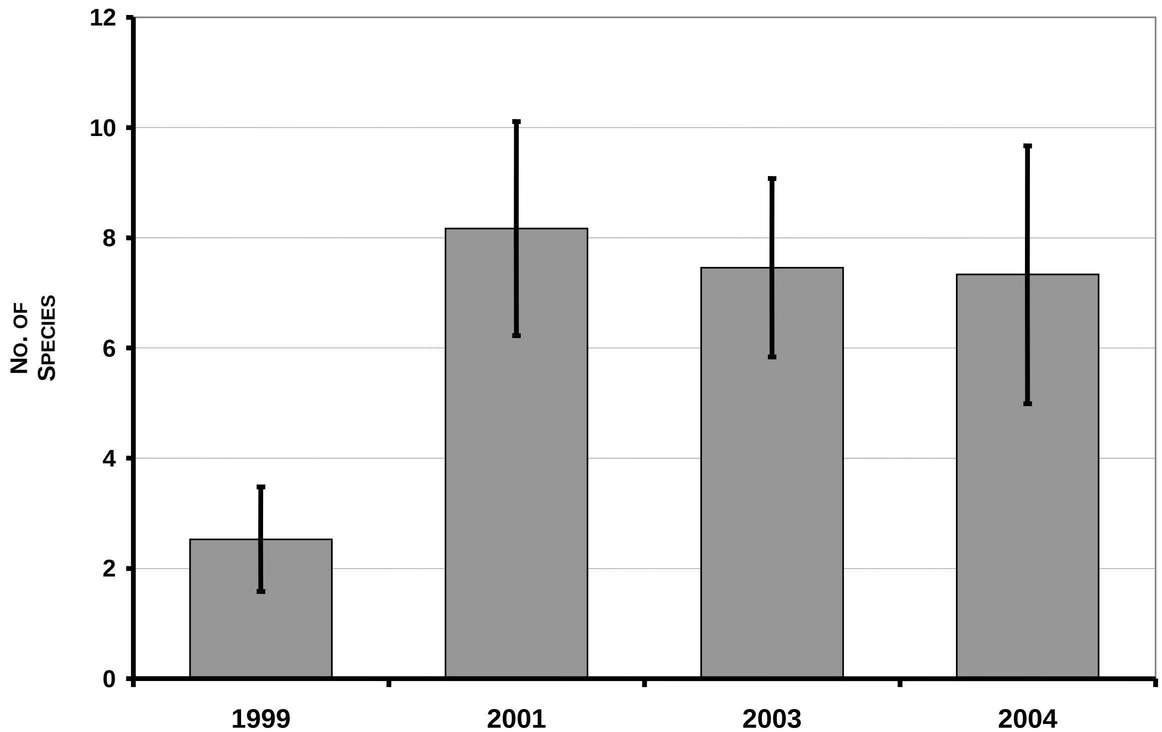

Figure 3. Reef fish species richness within the Fortuna Reefer restoration site between 1999 and 2004 plotting number of species against years. Error bars represent SE.

loss on economically important fishery populations can contribute to more accurate documentation of the costs associated with grounding. Research has also shown that these fish schools contribute to increased growth and improved condition of branching corals (Meyer and Schultz 1985). Devising ways to rapidly increase settlement and survival of fish, e.g., restoring colonies so that 3-dimensional structure is optimized, may increase the success coral reef restoration and improve reclamation of habitat value.

ACKNOWLEDGMENTS

The opinions and views expressed in this document are those of the authors and do not necessarily reflect those of an institution, including the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, US Department of Commerce, or the U.S. Government. The work was supported by the NOAA Coral Reef Conservation Program and Earthwatch. We are grateful to the many Earthwatch volunteers and UPR graduate students who participated in the field research. PR DNER has generously supported our efforts with permits and logistic support. Paco García (of Mona Aquatics) has been a valued partner in our research.

LITERATURE CITED

Appeldoorn, R.S., C.W. Recksiek, R.L. Hill, F.E. Pagán, and G.D. Dennis. 1997. Marine protected areas and reef fish movements: The role of habitat in controlling ontogenetic migrations. *Proceedings of the 8th International Coral Reef Symposium*, Panama City, Panama. **2:**1917-1922.

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

Bruckner, A.W., and Bruckner, R.J. 2006. Survivorship of restored *Acropora palmata* fragments over six years at the M/V Fortuna Reefer ship grounding site, Mona Island, Puerto Rico. *Proceedings of the 10th International Coral Reef Symposium* **1**:1645-1650.

Iliff, J.W., W.B. Goodwin, J.H. Hudson, and M.W. Miller. 1999. Emergency stabilization of *Acropora palmata* with stainless steel wire and nails: impressions, lessons learned, and recommendations from Mona Island, Puerto Rico. *International Conference on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration*. National Coral Reef Institute, Florida. 110 pp.

Jaap, W.C. 2000. Coral reef restoration. *Ecological Engineering*. **15**:345-364.

Meyer, J.L., and E.T. Schultz. 1985. Tissue condition and growth rate of coral associated with schooling fish. *Limnology and Oceanography*. **30**(1):157-166.

NOAA (1997) Web Site: http://www.darp.noaa.gov/southeast/fortuna/restore.html Damage Assessment, Remediation, and Restoration Program (DARRP) updated: 2008

Ogden, J.C., and P.R. Ehrlich. 1977. The behavior of heterotypic resting schools of juvenile grunts (Pomadasyidae). *Marine Biology* **42**:273-280.