Evaluating the Effectiveness of the No-take Zone within the Mona Island Natural Reserve, Puerto Rico

DANIEL MATEOS-MOLINA[1]*, MICHELLE SCHÄRER-UMPIERRE[1],
RICHARD S. APPELDOORN[1], and JOSE ANTONIO GARCÍA-CHARTON[2]
[1]*Department of Marine Science, University of Puerto Rico, Mayaguez, Puerto Rico. *dmateos5@hotmail.com.*
[2]*Departamento de Ecología e Hidrología, Universidad de Murcia, Campus de Espinardo, 30100 Murcia, Spain.*

ABSTRACT

No-take marine reserves or no-take zones (NTZ) have become an effective tool for restoring marine populations threatened by overfishing by allowing populations to recover from excessive extraction and eventually export larvae and/or adults to adjacent areas (spillover). In 2004, a NTZ was established within the Mona Island Natural Reserve, Puerto Rico's largest and most distant marine protected area (MPA). Mona Island is important as a potential stepping stone across a partial biogeographic barrier, yet populations there are thought to be largely dependent upon self–recruitment. Thus, it is critical that the effectiveness of this NTZ be evaluated. The objective of this study is to evaluate the effectiveness of the Mona Island NTZ with respect to coral reef fish populations threatened by overfishing. We used a before-after-control-impact (BACI) design to analyze these effects. Fish abundance and biomass of selected species known to be fishery targets were used as indicators of NTZ effect. Belt transects and roving surveys, stratified by habitat type and depth, were used to quantify fish abundances and sizes in areas previously sampled in 2005/06 (before reserve effects would be evident). Permutational multivariate analyses of variance (PERMANOVA) were carried out to assess temporal changes between 2005/06 and 2009/10, and spatial differences between take and NTZ of Mona Island. Significant increases in fish abundance and biomass were observed, suggesting a NTZ effect for important fishery resources. This study provides information to determine if marine reserve goals are being achieved at this bio-geographically important Caribbean site.

KEY WORDS: Coral reef fishes, threatened species, marine reserve, no-take zones, Mona Island, Marine Protected Area, fisheries management

Evaluando la Efectividad de la Zona de No pesca en la Reserva Natural Isla de Mona, Puerto Rico

Reservas marinas o zonas de no pesca (ZNP) han llegado a ser una herramienta efectiva para la restauración de poblaciones marinas amenazadas por la sobrepesca, permitiendo la recuperación por extracción excesiva y exportando larvas y/o adultos a zonas adyacentes (efecto de derrame). En 2004 se estableció una ZNP dentro de la Reserva Natural de Isla de Mona, el área marina protegida (AMP) más extensa y alejada de la costa puertorriqueña. La Isla de Mona sirve como un importante paso intermedio para atravesar la barrera biogeográfica parcial del Canal de la Mona, aunque sus poblaciones dependen en gran medida del reclutamiento local; por ello, su crucial evaluación. El objetivo de este estudio es evaluar la efectividad de la ZNP para proteger poblaciones de peces de arrecife amenazados por la sobrepesca. Se utilizó un diseño antes-después-control-impacto (ADCI) para analizar tales efectos. La abundancia y biomasa de especies conocidas por ser objetivos pesqueros, fueron utilizadas como indicadores del efecto de la ZNP. Transectos de banda y búsquedas aleatorias, estratificados por hábitat y profundidad, se utilizaron para cuantificar las abundancias y tamaños de los peces en áreas muestreadas previamente durante 2005/06 (anterior a que fueran evidentes los efectos). Se utilizó un análisis de varianza multivariado por permutaciones (PERMANOVA) para evaluar los cambios temporales entre 2005/06 y 2009/10, y diferencias espaciales entre zona de pesca y ZNP en Isla de Mona. Se observó un incremento significativo en la abundancia y biomasa de peces, sugiriendo un efecto importante de la ZNP para los recursos pesqueros. Este estudio aporta información relevante que determinará si los objetivos de la reserva marina están siendo logrados en este importante lugar de la biogeografía del Caribe.

PALABRAS CLAVE: Peces de arrecife de coral, especies amenazadas; reservas marinas; zona de no pesca; Isla de Mona; conservación de los recursos pesqueros

Evaluation de L'efficacité de L'aire Marine Protégée à L'intérieur de la Réserve Naturelle de l'île Mona, Porto Rico

Les réserves marines sans pêche (NTZ pour l'acronyme anglais) ou Aire marine protégée (AMP) catégorie 1, sont devenues un outil efficace pour la restauration des populations marines menacées par la surpêche en permettant aux populations de récupérer de l'extraction massive et aussi à l'émigration de larves et/ou adultes aux aires adjacentes (effets de déversement). En 2004, une AMP a été mise en place dans la réserve de l'île Mona, la plus grande et la plus éloignée aire marine protégée (AMP) de Porto Rico. L'île Mona est un important point de passage pour franchir la barrière géographique partielle du Canal de la Mona, bien qu'il est pensé que les populations locales sont largement dépendante de l'autorecrutement. Ainsi, il est essentiel d'évaluer l'efficacité de cette aire marine protégée (NTZ). L'objectif de cette étude est d'évaluer l'efficacité de l'AMP de l'île Mona à l'égard des populations des poissons coralliens menacés de par la surpêche. Nous avons utilisé un contrôle avant-après impact (BACI pour l'acronyme anglais) conçu pour analyser ces effets. L'abondance de poisson et la biomasse des espèces sélectionnées connues pour être des cibles de la pêche ont été utilisées comme indicateurs de l'impact de la NTZ. Des transects en bande et des recherches aléatoires, stratifiés par types d'habitats et de profondeurs, ont été utilisés pour quantifier l'abondance et la taille de poissons dans des zones échantillonnées auparavant en 2005/2006 (avant que les effets de la réserve ne soient notables). Des Analyses de la Variance Multivariée avec

permutations (PERMANOVA) ont été réalisées pour évaluer les changements temporels entre 2005/2006 et les différences spatiales entre les zones de pêche et l'AMP de l'île Mona. Un accroissement significatif dans l'abondance et la biomasse de poisson ont été observés, ce qui suggère un important effet de la réserve pour les ressources halieutiques. Cette étude fournit des informations pour déterminer si les objectifs de la réserve marine sont atteints pour ce site important bio-géographiquement.

MOTS CLÉS: Poisson de récif corallien, Espèces menacées, Réserves Marines, Aire marine protégée catégorie 1, Ile Mona, Conservation des ressources halieutiques.

INTRODUCTION

Over recent decades, natural marine resources have drastically deteriorated, threatening ecosystem stability and, therefore, the economic, social and cultural services healthy ecosystems provide. This deterioration is most obvious in areas where the synergistic action of human activities (habitat destruction, coastal eutrophication, overfishing, etc.) with natural stressors (hurricanes, floods, fires) impedes the regeneration and recuperation of natural populations. A precautionary approach for the conservation of marine ecosystems is urgently needed to protect marine populations that have undergone substantial human induced disturbance (Jackson et al. 2001). Marine protected areas (MPAs) are used as a management tools to protect, maintain, or restore natural and cultural resources in coastal and marine waters. MPAs have been used to meet conservation and fisheries management goals in natural systems by protecting biodiversity and conserving the habitats they occupy (Appeldoorn 1998). They have been used effectively both nationally and internationally to conserve biodiversity, manage natural resources, protect endangered species, provide educational and research opportunities, and enhance commercial and recreational activities (Salm et.al. 2000). Yet, many MPAs are dysfunctional, so after MPA design and implementation it is important to monitor MPA performance to ensure initial objectives are being achieved.

The appropriate size, location, management and distribution of MPAs constitute the design criteria of these areas (Ballantine 1997). MPAs with areas that prohibit extractive uses also known as Marine Reserves or No-Take Zones (NTZ) have become a common tool to sustainably manage fisheries and rebuild overexploited stocks (National Academy of Sciences 2001). No-take MPAs are powerful areas to recuperate marine species stocks, increasing fish density, mean size and longevity; decreasing mortality rates and improving the production of propagules, which increase the resilience of the associated habitat. In order to achieve the sustainability of marine resources, the success of the MPAs should be evaluated and monitored.

The goal of this study is to provide scientific information for the management of the Mona Island Natural Reserve, an MPA with NTZ. Specifically, this study will measure changes of reef fish abundances for species threatened by overfishing. The information will provide a basis to better understand the changes in the populations of predatory fishes in coral reef habitats after the NTZ designation. The following objectives were pursued:

i) Measure changes in the abundance and biomass of selected species compared to 2005 baseline data at Mona Island Natural Reserve.
ii) Determine the spatial distribution of reef fish at Mona Island in different locations and in relation to the no-take zone.

MATERIAL AND METHODS

Mona Island is located distant (72 km) from the main island of Puerto Rico and thus removed from most direct anthropogenic stressors, except historic fishing and currently, visitors to the island during the hunting season (December to April) or for fishing and camping trips. While its resources are most probably dependent, to a significant degree, of self-recruitment, Mona Island also serves as a stepping stone for connectivity across a known partial biogeographic boundary within the Mona Passage. Thus, the conservation role of the no-take zone (NTZ) serves critical functions at both the local and regional scales. Yet, the function of the NTZ in conserving resources has not been evaluated.

Mona Island was designated a Natural Reserve by the PR Department of Natural and Environmental Resources in 1986 (Aguilar-Perea et al. 2006). Within the Natural Reserve a NTZ was designated in 2004 extending 0.5 nautical miles from shore around all of Monito and most of Mona Island. This zone was modified in 2007 to include most of both island's platform up to the 100 fathom (182 m) depth contour except for a swath on the western coast where recreational fishing is allowed (DNER 2007).

In this study, the information available on the target species in Mona Island for 2005/06 was analyzed to provide the baseline for evaluating the success of the NTZ through 2009/10. A benthic habitat map of Mona Island (Schärer 2009) provided the basis to design the sampling scheme for underwater surveys of fish communities in selected habitats. The methodology to be employed included the identification, enumeration and length estimation of the top predators on relatively shallow reefs (10 to 20 m) at insular shelf areas.

Within coral reef habitats, sampling points were randomly distributed. With the aid of GIS, three different areas were defined: one Take Zone (west of Mona) and two No-Take Zones (south and east of Mona). The sampling effort for each area was the same as that used in 2005/06.

Underwater visual fish surveys in these areas with SCUBA or mixed gas diving techniques were carried out with the same methodology as in 2005. Selected reef

fishes were quantified in band transects (30 x 2 m) and after that along with a five minute roving survey to help determine abundance of rare species. The following species were targeted: *Lutjanus jocu, Epinephelus guttatus, Epinephelus striatus, Mycteroperca venenosa, Mycteroperca tigris Cephalopholis cruentata, Cephalopholis fulva, Balistes vetula, Lutjanus apodus, Lutjanus mahogani*. Visual estimates of fork length were classified into 5 cm slots for analysis. Data was used to determine species abundance, and calculate biomass for each transect or roving survey. The approach followed a Before/After-Control/Impact (BACI) design to detect spatial and temporal effects.

Permutational multivariate analysis of variance (PERMANOVA) was used to compare fish abundance and biomass over time (2005/06 - 2009/10) and among different areas (east and south NTZ, and west Take Zone). PERMANOVA is a "semiparametric," multivariate version of a univariate one-way ANOVA (Anderson 2001), producing a pseudo *F*-statistic, and a *P*-value, and was tested using 4999 random permutations. For some terms in the analysis, there were not enough permutable units to get a reasonable test by permutation, so a p-value was obtained using a Monte Carlo random sample from the asymptotic permutation distribution (Anderson and Robinson 2003).

RESULTS

A total of 216 transect for each technique were completed during the 2009 - 2010 sampling event.

Transects

The main PERMANOVA test with the two factors: time and zone, showed significant differences ($p < 0.05$) in the fish abundance related with time; and non-significant differences in fish biomass ($p > 0.05$). In addition, the main test showed the interaction between time of sampling (2005/06 - 2009/10) and the differences between the TZ and NTZs locations (Time x TZ vs. NTZs), where differences were non-significant. PERMANOVA Pairwise test indicated differences in abundance and biomass over time, in relation with the different zones. Only the biomass indicated non-significant differences.

Roving

The main PERMANOVA test detected significant differences in the fish abundance and biomass. The interaction in the main test (Time x TZ vs. NTZs) showed no significant differences in abundance or biomass. PERMANOVA Pairwise tests showed differences in abundance and biomass over time, in relation with the different zones.

DISCUSSION

In general, the results of the present study showed significant differences in abundance and biomass over time. Biomass in transects could be affected by differences in the mean size of fishes due to fishing or not enough time to recuperate the most impacted area.

In relation to the interaction between time and the differences between the TZ and NTZ locations, the results suggest that fishing effect in the TZ may be too small to cause any changes in the population. Therefore, there is no evidence of an impact and the management signals are yet undetected. The different hypotheses that may be driving this result are:

i) Some species are disproportionately affected by overfishing (need more time),
ii) Fishing effort on fish reef populations is randomly distributed throughout the area, and
iii) Spillover may be occurring from the NTZ towards the TZ

Lastly, the spatio-temporal analysis demonstrates how abundance and biomass increased in all zones, except in the TZ where biomass did not change. This could have been due to fishing effects upon the size class distribution such as smaller individuals making up a greater proportion of the population.

LITERATURE CITED

Aguilar-Perera, A., M.T. Scharer, and M. Valdes-Pizzini. 2006. Marine Protected Areas in Puerto Rico: Historical and Current Management Approaches. *Ocean and Coastal Management* **49**:961-975

Anderson, M.J. 2001b. Permutation tests for univariate or multivariate analysis of variance and regression. *Canadian Journal of Fisheries and Aquatic Science* **58**:626–639.

Anderson M.J. and J. Robinson. 2003. Generalised discriminant analysis based on distances. *Australian and New Zealand Journal of Statistics* **45**:301–318.

Appeldoorn, R. 1998. Ecological goals for marine fishery reserve design: Workshop summary. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:295-303.

Ballantine, W. 1997. Design principles for systems of "no take" marine reserves. (Abstract). Pages 4-5 in: T.J. Pitcer (ed). *The Design and Monitoring of Marine Reserves.* University of British Columbia Fisheries Centre Research Reports Number **5**.

Hernandez-Delgado, E. 1996. Marine Protected Area Site Nomination, Mona and Monito Islands, Puerto Rico. Report submitted to reefKeeper International, San Juan, Puerto Rico, 12 pp.

Jackson, J., *et al*. 2001 . Historical overfishing and the Recent Collapse of Coastal Ecosystems. *Science* **293**:629-638.

Jameson S., et al. 2002. The three screen doors: Can marine "protected" areas be effective? *Marine Pollution Bulletin* **44**:1177-1183.

National Academy of Sciences. 2001. *Marine Protected Areas: Tolls for Sustaining Ocean Ecosystems*. National Academy Press, Washington, D.C. USA. 272 pp.

Salm, R.V., J. Clark, and E. Siirila. 2000. *Marine and Coastal Protected Areas: Guide for Planners and Managers*. IUCN- The World Conservation Union, Washington, D.C. USA. .xxi + 371 pp.

Sadovy, Y., and A.-M. Eckland, 1999. S ynopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *Epinephelus itajara* (Lichtenstein, 1822). NOAA Technical Report NMFS **146**. 65 pp.