Replenishing a Near-collapsed Reef Fishery, Montecristi National Park, Dominican Republic

JOAQUÍN RODRIGO GARZA–PÉREZ[1,3] and ROBERT NATHAN GINSBURG[1,2].

[1]Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Rickenbacker Causeway, Miami, Florida 33149 USA; [2]Ocean Research & Education Foundation, 1300 Galiano Street, Coral Gables Florida 33134 USA
[3.] (Current address) UMDI-Sisal, Universidad Nacional Autónoma de México, Puerto de Abrigo S/N, Sisal Yucatán, México, C.P. 97355

ABSTRACT

Montecristi National Park in the northern coast of the Dominican Republic has an outstanding fringing coral reef system associated with extensive mangrove forests. Its remote geographic location and the lack of coastal/urban development made it a perfect area to implement a Marine Protected Area. Nevertheless, the lack of enforcement of the proposed zonation (1999), and the historical fishing pressure in the area, have driven the reef fish communities to a nearly-depletion and to a degraded trophic-network structure. The benthic components of the reef have been exposed to the same natural pressures of other reefs in the Caribbean and Northwestern Atlantic. To Montecristi's advantage it still has a better than average condition but it will not prevail unless specific actions are taken towards the implementation of fishing exclusion zones and the protection of the adjacent coastal areas. This study presents an assessment of the biodiversity, habitat distribution and condition of the Montecristi Coral Reef towards the support of management decisions for the natural resources of the area, and the enhancement of the proposed MPA zonation.

KEY WORDS*:* Fish Biodiversity, Spatial Prediction, No-Take Zones.

Restauración de Una Pesquería Arrecifal Cercana al Colapso, Parque Nacional Montecristi, Republica Dominicana

El Parque Nacional Montecristi en la costa norte de Republica Dominicana posee un extraordinario sistema arrecifal bordeante asociado a extensos manglares. Su aislamiento geográfico y la ausencia de desarrollos urbanos/costeros lo hicieron un area ideal para implementar un Área Marina Protegida. Sin embargo, la falta de aplicación estricta de las regulaciónes de la zonación propuesta (1999) y la presión pesquera existente desde la época pre-colombina han orillado a las comunidades de peces arrecifales a la desaparición y a una estructura trófica degradada. Los componentes bentónicos del arrecife han estado expuestos a las mismas presiones naturales del resto de los arrecifes del Caribe y Atlantico noroccidental. Una ventaja de Montecristi es que aún cuenta con una condición major al promedio, pero esta no persistirá a menos que se tomen acciones específicas para la implementación de zonas de exclusion pesquera y la completa protección de la zona costera adyacente. Aquí se muestra una evaluación de la biodiversidad y el estado de condición del arrecife de Montecristi para el soporte de desiciones de manejo de los recursos del area y para el mejoramiento de la propuesta de zonación del AMP.

PALABRAS CLAVES: Biodiversidad, Predicción Espacial, Zonas de Exclusión Pesquera.

INTRODUCTION

The coral reef ecosystems in the Dominican Republic comprise about 11% of its coastline, and are present in various types, as offshore banks, barrier and fringing reefs. The local population regards them as valuable resources in terms of the services they provide to adjacent ecosystems and human society (Geraldes 2003).

The reef studies in the Dominican Republic are mostly in the form of descriptive documents and characterizations (MAMMA 1994 1995, Silva and Battle 1994, Geraldes *et al.* 1997, Vega *et al.* 1997, Chiappone 2001, Geraldes, 2003), which address the characterization of biodiversity, marine habitats, and in some cases perform ecological evaluations. The most comprehensive document in terms of Dominican reefs description is the chapter "The Coral reefs of the Dominican Republic" by Francisco Geraldes (2003), in the Latin American Coral Reefs, which provides with coral reef habitat maps of the main reef areas and some insight to the general environmental and artificial pressures that influence the reefs.

Montecristi Reef Background

The fringing coral reef system at Montecristi in the Northern coast of the Dominican Republic, has been regarded as one of the most important reef systems of Hispaniola because of its large size its diversity and the overall condition of its benthos. It includes a variety of different coral reef habitats, segrass beds, and associated coastal landscapes (as fringing mangrove forests and beaches), along ~ 48 km of coastline.

The important ecological characteristics of the area prompted the declaration of a Natural Protected Area (Montecristi National Park, Decree 1315) on August 11th 1983. This decree did not specify the territorial limits of the park, and it was until February 26th 1986 (Decree 156-86), when its boundaries were defined. Later on January 22nd 1993 (decree 16-93) the boundaries of the park were significantly increased and this action was ratified on August 18th 2000 by the promulgation of the Law 64-00.

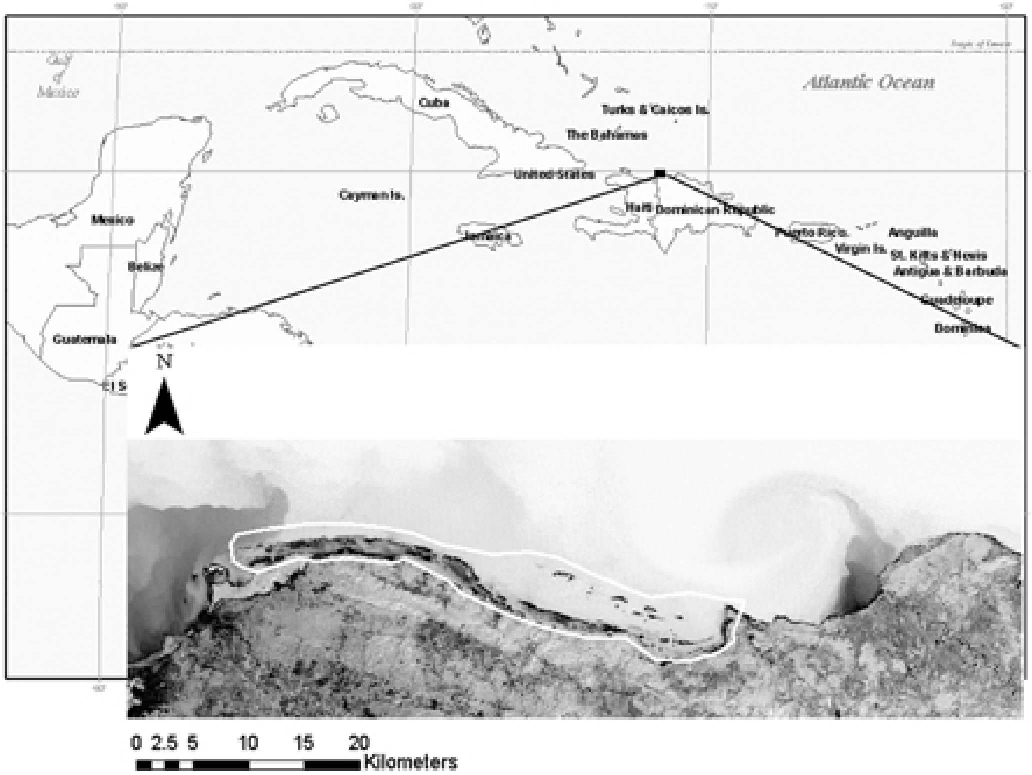

Figure 1. Montecristi Study Zone Area, along the northern coast of La Hispaniola, east of the border of Dominican Republic and Haiti. The highlighted portion corresponds to the available high-resolution satellite imagery (Ikonos, Spaceimaging).

Earlier studies (Geraldes 1996 a,b,c, Geraldes *et al.* 1997) produced essential basic information about this sub-region including the first list of biodiversity for the marine and coastal habitats. This list of marine animals includes 22 classes, 285 families, 525 genera and 742 species, with the highest species richness being found in the hard-bottom reef communities.

Geraldes *et al.* (1997) reported the total area of the Monticristi sub-region is 174 km^2. Of this total area, coral reef structures was estimated as ~13 km^2. (*i.e.* lagoon coral patches, spur and grove systems, walls, etc.), and ~16 km^2 of hard bottom communities. The remainder of the total area, 145 km^2 is hard bottoms dominated by algae, unconsolidated rubble, seagrass prairies and sandy bottoms.

The reef system in Montecristi can be considered as a barrier reef in active expansion growing over a shallow platform (~150 m depth), with high relief structures and large coral colonies. On the landward side are sand beaches, rock cliffs and an extensive mangrove forest. On the seaward side the reef system faces the open Atlantic Ocean. Toward the west end a shallow platform connects the reef system with a series of offshore keys known as "Los siete hermanos."

The general zonation of this reef is comparable with the fringing reef zonation present throughout the Caribbean. Montecristi was categorized as a "*strigosa-palmata* reef" according to Giester's reef classification from 1977 (Geraldes, 2003) identified the five phsiographic/bathymetric subdivisions: Reef lagoon, reef flat/back reef, reef crest, reef front and offshore keys.

Atlantic and Gulf Rapid Reef Assessment (AGRRA) of Montecristi Reef (2004)

In August 2004 we used the well establish AGRRA protocol (http://www.agrra.org) to assess the condition of the Montecristi reef complex. We found that the coral community of the reef crest at Montecristi was dominated (58%) by massive/boulder and foliose colonies of three species (*Montastraea faveolata, Millepora complanata* and *P. astreoides*). The deep sites along the reef front in Montecristi had twenty-eight coral spp. recorded, for the highest coral species richness and the highest coral colonies density, among other reefs surveyed in the Dominican Republic. The coral community of the deep sites was dominated by massive/boulder and foliose colonies of six species (53%) of which the Genus *Montastraea* was the most important contributor. The shallow site at Punta Rusia was dominated (31%) by extensive beds of foliose colonies (*Agaricia tenuifolia*), with high abundance (19%) of massive/boulder colonies (*P. astreoides*), and also beds of digitiform and branching colonies (22%) of *P. porites* and *A. palmata* and had a richness of 13 coral species. The coral community structure of the deep site

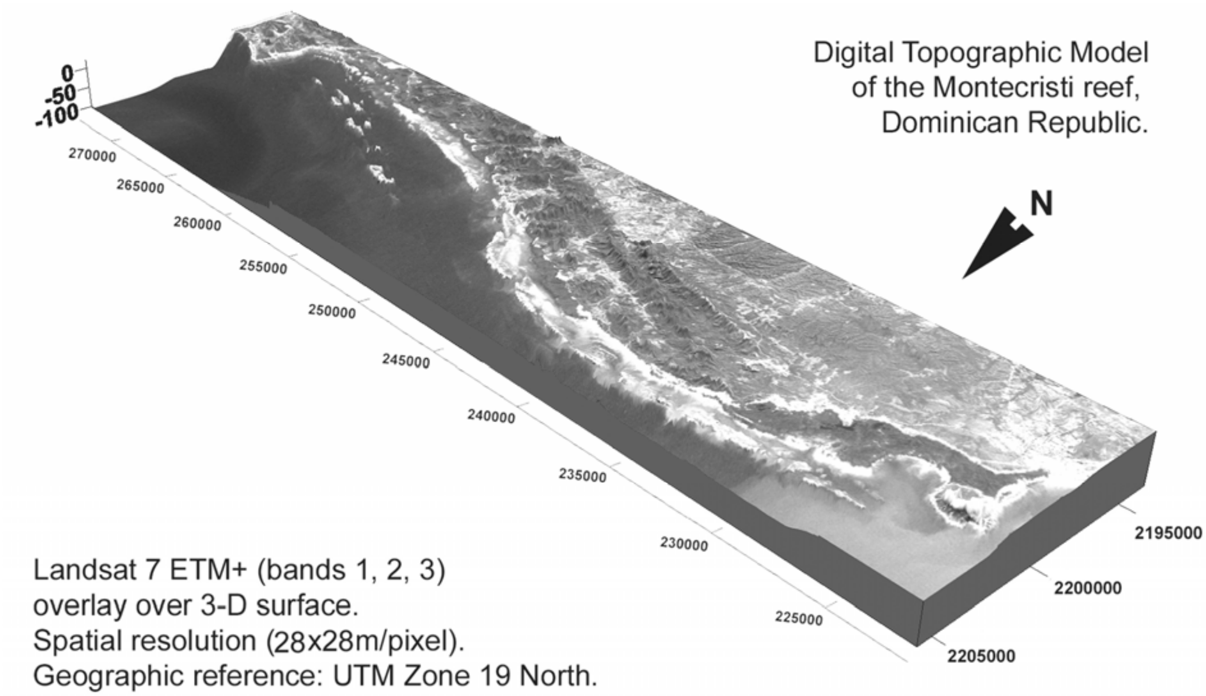

Figure 2. Digital Topographic Model of Montecristi, with satellite image overlay (Landsat ETM+).

had a richness of 19 coral species and was dominated (44 %) by *M. annularis, S. siderea, M. faveolata,* and *A. tenuifolia.*

Fishing Activities in Montecristi

According to Geraldes (2000), this sub-region is one of the least economically developed in the Dominican Republic. As a result, subsistence fishing is a viable economic alternative. The population of fishermen was estimated as approximately 350 in 1997 with 1,750 people depending in some degree on this activity. The fishing is carried out with an "artisanal" fishing fleet, which is composed mainly by wooden boats (~ 50), some with outboard engines (8 - 30 hp) and some still use wooden oars as the means of propulsion. The main species exploited in 1997 and now were snappers, groupers, hogfish, lobster, octopus and conch, but others as grunts, parrotfish, and jacks are also captured. The fishing gear used by this fleet consist of spears, lines, gill nets, traps and long-lines, and the range of operation is all along the coast and up to 15 km seaward. The average daily income of fishermen in 1997 was ~ $5 USD. In 2006 during our assessment, we observed that the main catches were grunts and parrotfish.

Another kind of fishing activity present in this sub-region is the capture of ornate species for aquarium trade. An analysis of the custom's exportation logs shows a list of ~100 species of fish and invertebrates captured for this trade. Our interviews with the local fishermen found that the areas of capture are the shallow reefs close to shore all along the coast.

OBJECTIVES

Main Objective

To enhance the management plan of the Montecristi National Park; regarding the original proposal for the reserve zonation from 1999, focusing on the fringing coral reef system.

Particular Objectives

i) To generate a Digital Bathymetric Model of the fringing coral reef system for characterizing its geomorphology.
ii) To characterize and assess the condition of the reef communities (coral and fish).
iii) To generate enhanced reef habitat maps using rectified and geo-referenced high-resolution satellite imagery.
iv) To generate a biodiversity hot-spots map.
v) To propose a network of permanent monitoring sites.
vi) To propose a series of no-take zones based on the reef communities assessment, and
vii) To generate a Geographic Information System that includes the products generated by this study.

Study Area

The study area is focused on the fringing coral reef of the Montecristi National Park (from 223180 E, 2202910 N to 268530 E, 2198845 N; UTM Z19N), as shown in Figure

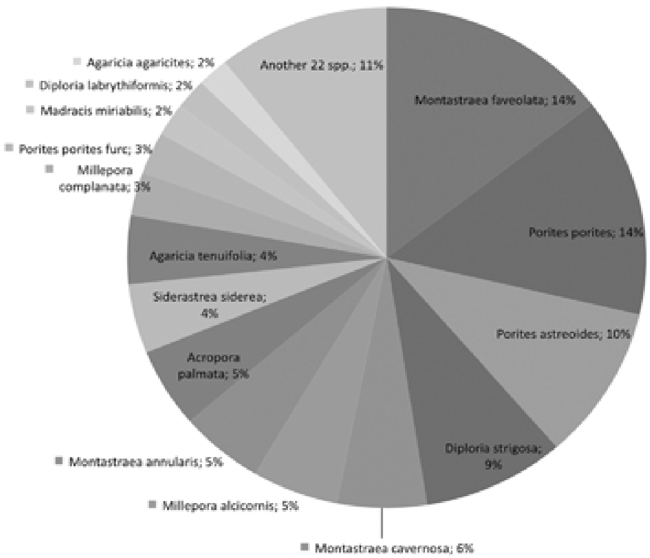

Figure 3. Hard coral community composition, percentage of abundance of species.

1. This polygon was selected because it encloses the main reef structures and because the reef structures within it can be accessed using traditional SCUBA gear (Figure 1). The field surveys were carried out in May and June 2006.

METHODOLOGY

Digital Bathymetric Model

For the generation of the digital bathymetric model (DBM) the methodology proposed by Garza-Perez *et al.* 2004, consisting of surveying the reef in a zig-zag pattern using a depth-sounder with integrated GPS, this method allows the acquisition of x, y, z type data (Latitude, Longitude and depth). This data is coupled with the extraction of reef features from geo-referenced satellite imagery to build a matrix. Processing this matrix with simple kriging in Surfer v6.0 (Golden Software Inc.) generates a digital bathymetric model (DBMs) at the same horizontal resolution of Landsat 7ETM+ (28x28 m/pixel).

Reef Communities Characterization

A stratified random sampling design of one hundred fifty stations was selected for characterizing and assessing the coral and fish communities of Montecristi. This design is considered the most appropriate when previous information on the area of interest is available (Environmental Protection Agency 2002), and because there is a conspicuous zonation across the reef. For coral communities each selected station was surveyed accordingly to Garza-Pérez *et al.* (2004) using one video transect (50 x 0.6 m) for the coral community characterization and a chain transect (16 m) to estimate topographic complexity. The information extracted from the video was percentage of cover of Broad Functional Groups (biotic components as hard coral, octocoral, three different categories of algae, sponges and zoanthids/tunicates) along with bottom type: sand, rubble and calcareous pavement. Species richness by stations was also estimated from the video transects. For fish communities a 50 x 2 m fish-census transect was carried over the video-transect path, in order to relate the fish assemblages to their respective habitats. The fish-census recorded species, number of individuals per species and size-classes of individuals. From this data the values of biomass, families and species richness and biodiversity/evenness were calculated by station.

Prediction of Biodiversity Hot-spots

The Generalized Regression Analysis and Spatial Prediction methodology (Lehmann *et al.* 2002a) was used for the prediction of biodiversity hotspots. This tool has been successfully implemented in reef ecosystems (Garza Perez *et al*. 2004), as well as in other fields as vegetation ecology (Cawsey *et al.* 2002, Lehmann *et al.* 2002a,b, Zaniewski *et al.* 2002, Maggini *et al.* 2006) and terrestrial ecology (Ray *et al*. 2002, Clarkson 2004). GRASP uses Generalized Additive Models -GAMs- (Hastie and Tibshirani 1990, Yee and Mitchell 1991) to predict the spatial distribution of Response Variables (RVs) and to generate predictive maps (Predmaps) using a GIS platform, taking advantage of the spatial structure shown in continuous surfaces (satellite imagery and bathymetric maps) used as predictive variables (PVs). The Predmaps are the spatially explicit characterization of the distribution pattern of the feature of interest for the entire study area, showing average values on a pixel-by-pixel basis. In this case, the RV was Shannon Biodiversity Index, using the values estimated for each station; and the PVs were the red, blue and green bands of the Ikonos satellite images.

Selection of Sites for Monitoring Network and No-Take Zones

The definition of stations for the monitoring network from the cloud of 150 survey-stations, was achieved through the selection of end-member stations (cover, biodiversity) of the main habitats (seagrass beds, coral patches, backcrest, hardground, bank, and reef front), incorporating also information about depth, for safe SCUBA dive practices.

The proposal of no-take zones correspond to an effort to preserve the existing fish communities, and to possibly enhance their structure (in terms of biodiversity and biomass), by providing havens to fish populations through all their ontogenetic changes. A multivariate-statistics approach was used for the selection of candidates for no take-zones, incorporating the information of fish communities, reef habitats, reef zones and depth into a non-metric Multi Dimensional Scaling Analysis (Clarke and Warwick 1999). The outstanding stations defined by the MDS analysis in terms of biodiversity, coral cover and fish biomass were selected and compared against the biodiver-

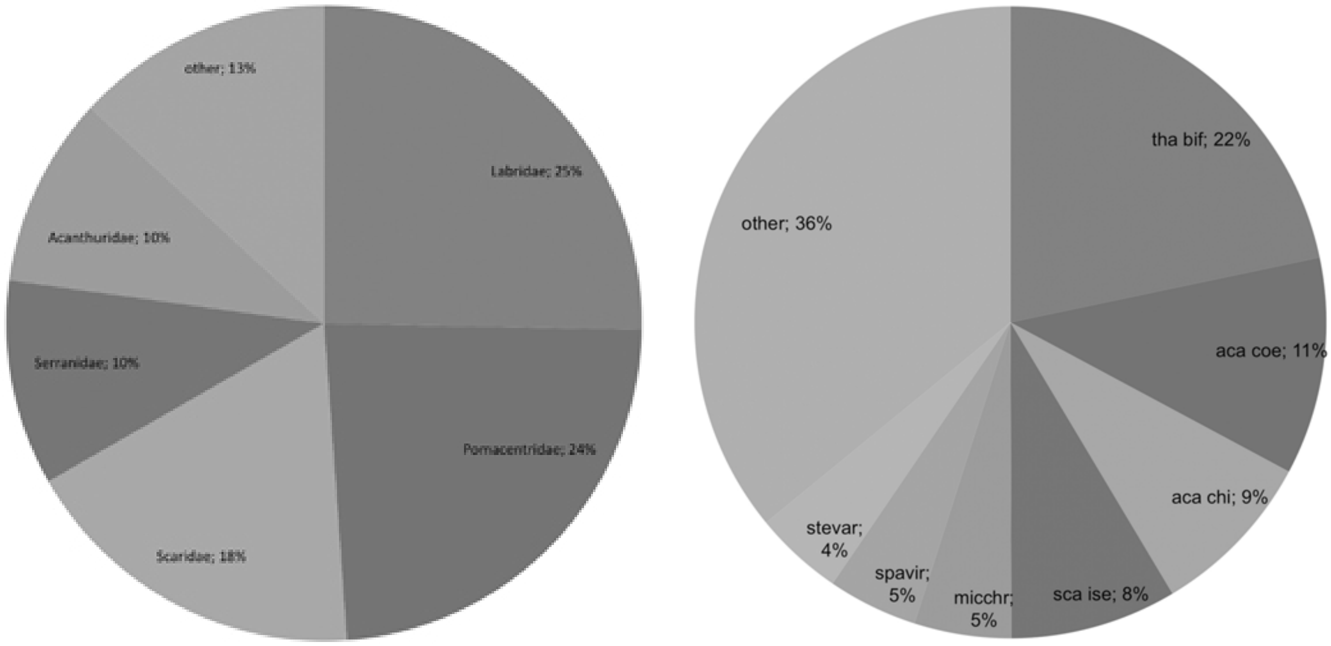

Figure 4 a,b. Relative abundance of reef fish Families and fish species in Montecristi. Values in percentage

sity Predmap and the reef habitat map, in order to establish potential sites. Along with the results of the MDS analysis, a spatial analysis was performed on the satellite imagery, extracting and measuring the areas of fringing mangrove and the distance of each potential site to the closest mangrove area.

The final areas for the proposed no-take zones were also selected taking into account the distance to human-population centers, the local extent of the habitat to which the station belongs, the local water-circulation and the park zonation originally proposed in the management plan. The water-circulation was established by visual assessment of sediment plumes on the reef area, using Landsat 7 ETM+ (2002), SPOT 2 (2005), and Ikonos (2002) satellite imagery. All the scenes represent a different time of the year and the patterns in the sediment plumes remain constant.

RESULTS

Geomorphology

The geomorphology of the reef was characterized using extraction of features from geo-referenced Landsat ETM+ satellite imagery and +150,000 depth points recorded. These data were merged in X,Y,Z matrices in order to obtain a digital bathymetric model (DBM) at the same horizontal resolution of the Landsat imagery (28x28 m/pixel) using simple kriging in Surfer v6.0 (Golden Software Inc.). The DBM was imported to GIS as a layer (grid), to obtain a generalized surface that reflected the bathymetric trends and the distribution of the reef zones along the system, and to highlight the most prominent geomorphologic features (i.e. reef lagoon, reef crest, reef front, reef platforms), Figure 2.

Reef Communities Assessment

The information extracted from the field surveys (150 stations) was used to define the condition of the coral and the fish communities.

Coral Communities

The coral communities of Montecristi, in general, are in good condition, 37 species of hard corals were recorded in total, and 10 of them represent some 80% of the total coral cover (Figure 3). Eight of these dominant species are true reef builders; among this list is *Acropora palmata* (5% of the recorded corals), having patchy but healthy distribution in different reef zones from the crest to the outer banks.

Coral diseases (yellow blotch, black band and white band) were observed in some sites, but in very low occurrence. Recently dead coral tissue was also observed in normal amounts (1.4 % ± 2.5 S.D. of total transect cover), mainly associated to sites with presence of coral diseases, or in coral patches with heavy sedimentation. Macroalgae (Brown algae) are dominant in most of the reef habitats with an approximate coral-brown algae ratio of 1:2.

Fish Communities

The reef fish communities of Montecristi are composed by 67 species (recorded on the surveys), belonging to 23 families (Figure 4a). The five dominant families (87% of the recorded individuals) are Labridae, Pomacentridae, Scaridae, Serranidae and Acanthuridae. The five dominant species (55%, Figure 4b) are *Thalassoma*

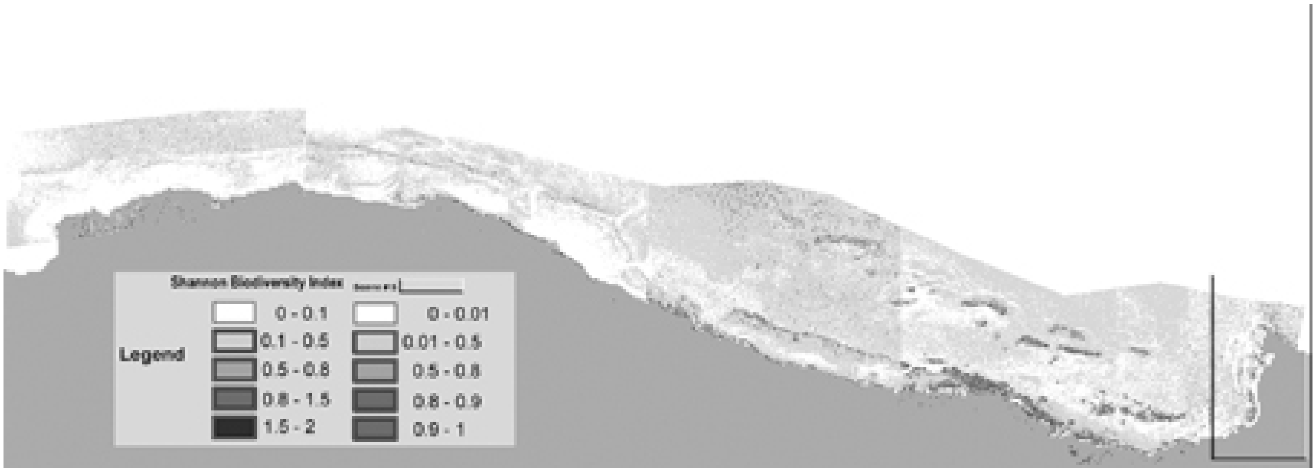

Figure 5. Predictive map of reef fish and hard coral species biodiversity (Shannon Index).

bifasciatum, Acanthurus coerulus, Acanthurus chirurgus, Scarus iserti and *Microspathodon chrisurus.*

In contrast grouper species are represented by *Ephinephelus guttatus* (Red Hind), *Cephalopholis fulvus* (Coney) and *Cephalopholis cruentata* (Graysby), adding to less than 5% of the individuals. Other commercially important fishes were in very low abundances, we only recorded 20 snappers (*Lutjanus apodus*), and big carnivores were scarce, we only recorded two barracudas (*Sphiraena barracuda*).

Condition Assessment.

From the analysis of the coral and reef fish communities' information and the estimation of rugosity (topographic complexity) in the field, the overall condition of the Montecristi Reef is defined as: at risk and prone to degradation.

There are a number of extraordinary sites with very high coral cover (> 35%), for the current standards in the Caribbean, but the vast majority of the surveyed sites in most of the reef habitats were dominated by macroalgae. The structure of the fish assemblages is depleted of economically important species, and the high-trophic level predators are almost non-existent. The sites with better condition were used for the proposal of the No-Take zones.

Prediction of Biodiversity Hot-spots

The Predmap of biodiversity was obtained using GRASP (Figure 5); the highest biodiversity areas correspond to the reef front and to the bank habitats, while the sand channels and sediment beds had the lowest biodiversity. A spatial query was performed in the Predmap in order to extract the pixels with the highest biodiversity values and this map was used to define the proposed no-take zones.

Selection of Sites for Monitoring Network and No-Take Zones

The proposed monitoring network is depicted on Figure 9, and the baseline information (Table 2) is constituted by the values of cover that must be used to compare against, when the results of the proposed monitoring effort are available. The proposed no-take zones, are also represented on Figure 6. The no-take zones baseline information (cover, species richness, biodiversity, etc) is included in Table 2. A visual estimation of the water-flow (Figure 6) from satellite imagery was also used to establish the proposed no-take zones, taking into account the possible connectivity between the different essential habitats for fish: Keys and reefs from the western portion of the Montecristi National Park, fringing mangrove forests, seagrass beds, coral patches and reef front. The proposed no-take zones would constitute fishing exclusion areas, enforced by park officials and delimited by markers. These areas constitute 20.5 km^2 from the 200 km^2 of the study area, roughly a 10% of it.

DISCUSSION

The Montecristi Reef System has been exposed to the same natural stressors as the rest of the Caribbean coral reefs. In addition the System has been exposed to anthropogenic perturbations even before Columbus set foot on Hispaniola. It is likely that the condition of the coral communities in Montecristi has followed the same decline trends as the vast majority of the reefs in the Caribbean (Wilkinson *et al*. 2004, Lang *et al.* 2004). The Montecristi System has the special resource of an extensive fringing mangrove forest (2,517.37 ha) associated with shallow seagrass beds (1,247.68 ha), in a reef lagoon along ~ 35 km of coastline. The association of these coastal environments with adjacent coral reefs has elsewhere proven a significant benefit for the reef fish communities by enhancing biomass and providing essential habitats for nursery, feeding grounds and refuge (Nagelkerken *et al.* 2000, 2002, Dorenbosch *et al.* 2004, Nagelkerken and van der Velde 2004 a,b, Mumby *et al.* 2004, Renan *et.al.* 2006, among others).

The effectiveness of No-Take zones or fishing-

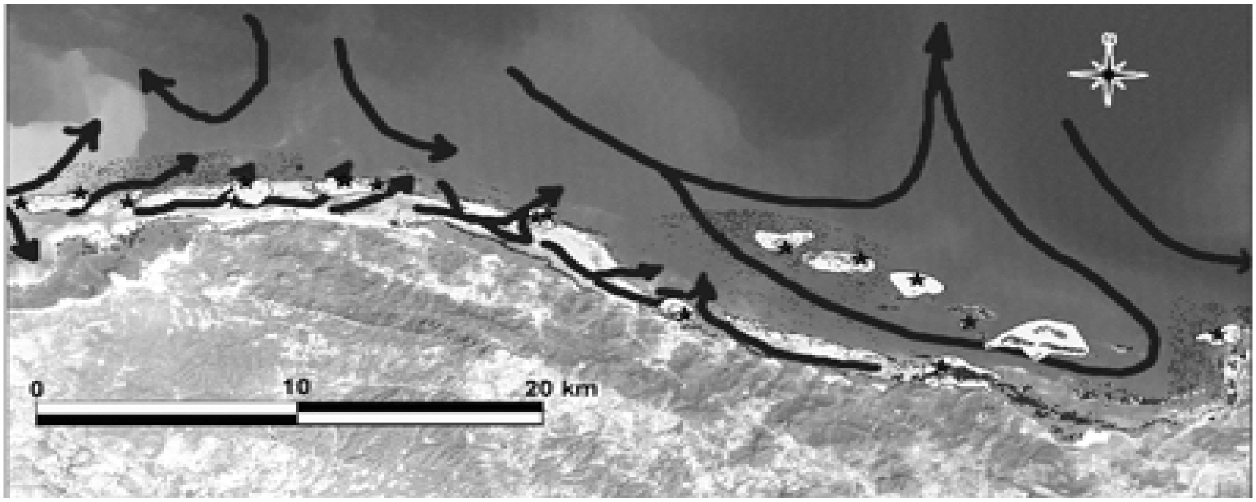

Figure 6. Highest biodiversity areas (dotted area), proposed monitoring network (stars), proposed no-take zones (clear polygons) and estimated coastal currents (arrows).

exclusion zones has also been proven, obtaining significant increases in number of individuals, size ranges, biomass and species richness in relative short periods (from 2 to 10 years) (Burke *et al.* 2004, Schmidt *et al.* 2004)

Montecristi reef has the added bonus of being a Natural Park in a relatively-low populated area, which minimizes the anthropogenic stressors on the adjacent coastal systems and on the reef. Coastal development has been associated with deleterious conditions on fringing coral reefs, and the effects are noticeable in a very short time-span (Arias-Gonzalez *et al.* In prep.). Reefs at risk that otherwise have shown resilience to natural impacts and even to fishing activities, suddenly have suffered phase-shifts from coral dominated to algae dominated when anthropogenic stressors related to coastal development act in synergy with the natural impacts.

Recommendations

The commendable efforts of the Dominican Government and officials to preserve the natural resources of the Dominican Republic must be supported and encouraged through the decision support. Our contribution is to provide additional scientific knowledge for a sustainable management. After assessing the coral and fish communities of the fringing reef system at Montecristi National Park, the following recommendations are proposed:

Concerning the enforcement of the protection of the Park, we have noticed a significant commitment from the park officials and park rangers; we suggest an increase in the support, gear, personnel and benefits available to the Park. These increases shall build a strong bond between the people and the resources they are guarding. They also encourage a better work performance and the associated preservation of the natural resources.

Concerning the land portion of the Park, we have noted an increase in the fragmenting of coastal land parcels for urban, residential and tourism development. Although these parcels represent a high economic value, and this value increases with the placement of services infrastructure, the ecological value for the reef system is greater. This coastal land acts as a buffer and filter from all the run-offs from inland sources. We strongly suggest keeping at the minimum level possible this habitat fragmentation and the coastal development inside the Park.

In the same context of the point above, we strongly suggest to preserve the fringing mangrove forests at any cost, since they play a very important ecological role in the structure-function of the fish communities. Any decrease in mangrove cover will only translate in a decrease in the condition of the reef and its associated fish communities.

Concerning the marine portion of the Park, we suggest the adoption of the proposed network of permanent reef monitoring sites and the implementation of the suggested monitoring methodologies. A baseline has been generated and the trends of the important components of the reef will establish the appropriateness of the management measures, allowing for corrective and preventive actions.

Concerning the reef system components, we urge the preservation of the seagrass habitats at any cost. The seagrass beds are also an important part of the structure-function of the Montecristi Reef System. Every anthropogenic modification to these habitats (by dredging or removal) will be detrimental to the condition of the reef and its associated fish communities.

On the marine portion of the park zonation, we suggest to modify the regulations and create a new type of use, a strict and enforced No-Take zone, where no activities of any kind are allowed, with the exception of the monitoring efforts to assess the appropriateness of this measure. And we respectfully request the current zonation to be adopted, and our proposed No-Take zones to be incorporated to this new use-category.

CONCLUSION

The reef fish communities of Montecristi are significantly depleted of major predators; the amount of big predators is one of the main indicators of a healthy condition of these communities. Also the reef fish communities in general are heavily over-fished; the standard biomass of reef fish indicator species (carnivores and herbivores only) included in the AGRRA list is 4.5 kg/100 sq. m. Our field surveys accounted for an average of 0.49 kg/100 sq. m. including all the observed reef fish species.

The coral communities of Montecristi have the same average condition of the wider Caribbean region, with recent coral mortality of ~4% of the total coverage. Montecristi still has areas with very high coral cover, up to ~50% of live coral cover, and also preserves the 3-D structural complexity (rugosity) needed as a essential ingredient for a flourishing fish community.

This study provides additional scientific information for decision support, regarding the current condition of Montecristi and proposes three direct actions: The first is to implement a network of No-Take zones, in order to make available the necessary conditions to replenish, or at least, enhance the structure of the reef fish communities in Montecristi. The second is to implement a permanent monitoring sites network to gauge the ecological trends in the reef communities, and to evaluate the usefulness of the network of No-Take zones. The third is to manage the adjacent land to maintain the coastal zone modification to a minimum, taking special care of preserving the fringing mangrove forests.

Fishing activities and impending coastal development are the main threats to the perpetuation of Montecristi reef as we have known it. While local and regional management does not have any way to prevent natural impacts as hurricanes, storms, El Niño and massive bleaching events, it must have the capacity to preserve the natural resources through a sustainable development plan.

LITERATURE CITED

Burke J.S., M.L. Burton, C.A. Currin, D.W. Field, M.S. Fonseca, J.A. Hare, W.J. Kenworthy, and A.V. Uhrin. 2004. Biogeographic Analysis of the Tortugas Ecological Reserve: Examining the Refuge Effect Following Reserve Establishment, NOAA Laboratory, Beaufort, North Carolina USA.

Cawsey EM, M.P.Austin, and B.L. Baker. 2002. Regional vegetation mapping in Australia: a case study in the practical use of statistical modelling. *Biodiversity and Conservation* **11**:2239-2274

Chiappone, M. 2001. Fisheries investigations and management implications in marine protected areas of the Caribbean. A case of study of Parque Nacional del Este D.R. Part 1 of 3, The Nature Conservancy. 105 pp.

Clarke, K.R. and R.M. Warwick. 2001. Change in marine communities. An approach to statistical analysis and interpretation. Primer-E Ltd. Plymouth Marine Laboratory, Plymouth, Massachusetts USA.

Clarkson, B.R, L.A. Schipper, and A. Lehmann. 2004. Vegetation and peat characteristics in the development of lowland restiad peat bogs, North Island, New Zealand. *Wetlands* **24**(1).

ERDAS Field Guide. 2003. *Leica Geosystems GIS & Mapping, LLC, 7th edition*. 689 pp.

ESRI. 1992. *Understanding GIS*. The ARC Info Method. Environmental Systems Research Institute Inc. Redlands CA. USA.

Garza-Pérez, J.R., A. Lehmann, and J.E. Arias-González. 2004. Spatial Prediction of Coral Reef Hábitats: Integrating Ecology with Spatial Modeling and Remote Sensing. *Marine Ecology Progress Series* **269**:141-152.

Geister, J. 1977. The influence of wave exposure on the ecological zonation of Caribbean coral reefs. Pages 23-30 in: *Proceedings of the 3rd International Coral Reef Symposium*.

Geraldes, F.X., M. Vega, E. Pugibet, H. Rimirez, G. Rosado, C. Mateo, T. Montilla, and S. Hernandez. 1997. Informe tecnico final caracterizacion marina, mapas de comunidades y reportes de la biodiversidad del litoral de montecristi, R.D. 48 pp..

Geraldes, F.X. 2003. The coral reef of the Dominican Republic. Pages 77-110 in: J. Cortes (ed.) *Latin American Coral Reefs*. Elsevier Science B.V.

Green, E.P., P.J. Mumby, J.E. Alasdair, C.D. Clark. 2000. *Remote Sensing Handbook for Tropical Coastal Management* UNESCO publishing, Paris, France.

Hastie, T. and R. Tibishirani. 1990. *Generalized Additive Models*. Chapman Hall, London, England.

Lang, J.C. 2003. Status of Coral Reefs in the Western Atlantic: Results of Inicial Surveys, Atlantic and Gulf Rapid Reef Assesment (AGRRA) Program. *Atoll Research Bulletin* **496**. 630 pp.

Lehmann, A, J.M.C. Overton, and J.R. Leathwick. 2002a. GRASP: Generalized Regression Analysis and Spatial Predictions. *Ecological Modelling* **157**:189-207

Lehmann, A., J.R. Leathwick, and J.M.C. Overton. 2002b. Assessing New Zealand fern diversity from spatial predictions of species assemblages. Biodiversity and Conservation **11**:2217-2238

Lehmann, A., J.M.C. Overton, and M.P. Austin. 2002c. Regression models for spatial prediction: their role for biodiversity and conservation. *Biodiversity and Conservation* **11**:2085-2092

Maggini, R., A. Lehmann, N.E. Zimmermann, and A. Guisan. 2006. Improving generalized regression analysis for the spatial prediction of forest communities. *Journal of Biogeography* **33**(10):1729-1749.

MAMMA. 1994. Proyecto inventario y elaboración del plan de manejo del parque submarino de La Caleta, D.N.

MAMMA. 1995. Reporte sobre evaluaciones ecologicas en los ambientes arrecifales y zona costero-marina de Las Terrenas, El Portillo, Puerto Escondido y cabo Cabron, Penisnula de Samana R.D.

Mumby, P.J., J.E. Alasdair, L. Arias-Gonzalez, C. Kenyon, P.G. Blackwell, A. Gall, M.I. Gorczynska, A.R. Harborne, C.L. Pescod, H. Renken, C.C.C. Wabnitz, and G. Llewellyn. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature* **427**:533-536.

Nagelkerken, I., M., Dorenbosch, W.C.E.P. Verberk, E. Cocheret de la Morinière, and G. van der Velde. 2000. Importance of shallow-water biotopes of a Caribbean bay for juvenile coral reef fishes: patterns in biotope association, community structure and spatial distribution. *Marine Ecology Progress Series* **202**:175–192

Nagelkerken, I. and G. van der Velde. 2004. Are Caribbean mangroves important feeding grounds for juvenile reef fish from adjacent seagrass beds? *Marine Ecology Progress Series* **274**:143–151

Nagelkerken, I. and G. van der Velde. 2004. Relative importance of interlinked mangroves seagrass beds as feeding habitats for fish on a Caribbean island. *Marine Ecology Progress Series* **274**:153–159.

Ray N, Lehmann A, Joly P (2002) Modeling spatial distribution of amphibian populations: a GIS approach based on habitat matrix permeability. Biodiversity and Conservation 11:2143-2165.

Renán, X., T. Brulé, and R. Lecomte-Finiger. 2006. First evidence of a nursery habitat for juvenile gag at the Southern Gulf of Mexico. *Transactions of the American Fisheries Society* **135**:595-603.

Schmidt, T.W., J.S. Ault, J.A. Bohnsack, J. Luo, S.G. Smith, D.Hl.Harper, G.A. Meester, and N. Zurcher. 2004. Site Characterization for the Dry Tortugas Region: Fisheries and Essential Habitats. NOAA Technical Memorandum NMFS-SEFSC-000, 123 pp.

Silva, R. and O. Battle. 1994. Rapid ecological assessment and reef characterization, Punta Cana R.D. Report to Fundacion Ecologica de punta Cana.

Vega, M, M. Chiappone, G.A. Delgado, R. Wright, and K.M. Sullivan. 1997. Evaluacion ecologica integral del Parque Nacional del Este R.D. Tomo 2 Recursos Marinos. The Nature Conservancy. 93 pp.
Wilkinson, C. (ed.). 2004. *Status of Coral Reefs of the World: 2004. Volume 2*. Australian Institute of Marine Science. 264 pp.
Yee, T.W. and N.D. Mitchell. 1991. Generalized additive models in plant ecology. *Journal of Vegetation Science* **2**:587-602
Zaniewski, A.E., A. Lehmann, and J.M.C. Overton. 2002. Predicting species distribution using presence-only data: A case study of native New Zealand fern. *Ecological Modelling* **157**:261-280

Table 1 . Habitats of Montecristi Fringing Reef System. All biotic components and bottom types are expressed in percentage of cover: 1) Coral Structures –spur & grooves, reef walls, reef plateaus-; 2) Coral Patches; 3) and 4) Hardground (shallow and deep, optically different) –hard bottom coral communities-; 5) Sediment Platform –shallow beds of bare compacted calcareous sediment-; 6) Dense Seagrass Beds; 7) Sand Plains - loose sand-; 8) Back Reef –shallow/ protected coral communities-; 9) Reef Crest; 10) Fringing Calcareous Platform –shallow calcareous pavement with abundant small coral colonies, dominated by brown algae-; 11) and 12) Shallow MIxed Vegetation Praires (optically different) 13) Mixed Segrass Beds (sparse segrass mixed with calcareous articulated algae, w/ scattered small corals and sponges); 14) Deep Algae Praire – deep bottom dominated by brown algae.- Shannon Biodiversity Index and Eveness was

Feature/ Habitat	1	2	3-4	5	6	7	8	9	10	11-12	13	14
Hard Coral	23.94	31.88	12.92	0.00	0.20	0.00	14.04	14.23	24.23	3.27	2.31	3.00
Octocoral	14.07	10.42	11.14	0.00	0.08	0.30	6.99	4.17	3.85	0.00	0.00	5.00
BrownAlgae	29.29	15.62	37.96	0.00	3.13	0.00	39.04	27.44	11.54	12.50	3.00	15.00
GreenAlgae	0.79	0.12	8.97	0.00	5.94	2.00	6.79	3.59	0.00	6.92	0.00	3.00
CalcArtAlgae	9.94	7.50	5.94	0.00	8.52	0.00	1.09	7.76	14.23	0.19	6.00	5.00
Sponges	3.89	1.77	6.67	0.00	5.79	2.00	1.22	3.78	8.65	0.00	8.00	5.00
Seagrass	0.00	2.00	0.00	0.00	59.70	3.00	3.33	0.77	0.00	21.35	32.69	0.00
Zoanth/Tunic	0.08	0.31	0.32	0.00	0.00	0.00	0.00	0.26	0.19	0.00	0.00	0.00
Sand	0.85	4.19	0.36	0.00	6.92	86.60	4.94	0.71	1.35	17.12	48.00	50.00
Sediment	0.54	0.12	0.87	100.00	7.44	0.00	0.51	0.00	0.00	0.00	0.00	0.00
Rubble	1.31	8.73	2.59	0.00	0.93	6.00	6.99	1.54	0.00	10.19	0.00	0.00
Rock/CalcPAv	13.03	13.19	16.96	0.00	0.58	0.00	13.78	34.68	35.58	28.46	0.00	5.00
RecentDead Coral	2.21	4.19	1.60	0.00	0.00	0.00	1.28	1.03	0.38	0.00	0.00	0.00
RedCalcAlgae	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon biodiv Index	0.83	0.65	0.65	0.00	0.41	0.00	0.54	0.52	0.38	0.54	0.47	0.00
Evenness	0.75	0.69	0.74	0.00	0.74	0.00	0.60	0.60	0.40	0.75	0.86	0.00
Fish Spp. Richness	13.10	9.60	8.65	0.00	4.44	0.00	8.83	8.89	6.63	6.50	3.75	0.00
Fish biomass (gr/sq.m)	756.70	574.73	425.72	0.00	125.68	0.00	521.70	637.74	610.60	335.79	39.43	0.00

Table 2 Monitoring network baseline information. Coordinates are in UTM Z19N, WGS-84. Values of biotic components and bottom types are of percent cover

StationID	a1	a2	a3	b2	b3	b7	b8	b10	c1	c2	d1	d2	d3	e5	f1	f2	L1
Northing	224591	226684	228428	232640	232310	228137	226039	223006	234113	236136	236245	237384	238465	239497	243067	243514	259417
Easting	2204078	2204507	2204098	2204972	2204114	2203803	2203802	2202381	2205066	2205067	2205071	2204864	2205040	2204121	2203448	2203554	2199598
Hard Coral	25.38	26.15	42.50	31.54	22.31	29.04	51.54	24.23	37.69	21.92	12.88	29.62	22.12	24.23	34.42	18.65	7.12
Octocoral	15.38	31.35	11.54	16.15	1.92	19.62	6.92	3.85	9.42	23.65	25.00	17.31	21.54	7.31	19.42	22.50	4.81
Brown Algae	32.50	15.38	9.23	21.54	50.19	16.92	2.12	11.54	21.92	26.35	40.77	17.31	29.62	35.77	29.04	33.46	37.12
Green Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.19	3.85	0.00	0.00	0.00	9.62
Calc/Art Algae	10.58	11.35	11.54	18.08	4.42	3.65	10.58	14.23	15.00	6.15	9.42	16.73	4.62	0.00	2.50	3.27	4.23
Sponges	4.42	3.65	2.31	5.19	1.92	3.27	1.54	8.65	2.69	5.19	6.73	8.08	2.31	0.00	3.65	9.23	5.58
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.65	0.00	0.00	0.00
Zoanth/Tunic	0.77	0.00	0.00	0.00	0.38	0.19	0.19	0.19	0.00	0.77	0.00	0.00	0.58	0.00	0.19	0.00	0.00
Sand	3.08	0.38	1.15	0.00	0.00	2.69	1.15	1.35	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.58
Sediment	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rubble	0.00	0.19	1.15	0.00	0.00	10.00	0.96	0.00	0.00	0.77	0.00	0.00	0.00	10.58	0.00	0.96	5.00
Calc.Pavement/Rock	7.50	9.62	13.85	5.19	15.38	9.62	16.35	35.58	3.08	7.12	2.50	9.04	14.62	18.46	10.19	11.15	25.96
Recent Dead Coral	0.38	1.92	6.73	2.31	3.46	4.42	8.65	0.38	10.19	7.69	0.77	1.73	0.77	0.00	0.58	0.58	0.00
Fish Biomass	14.76	7.96	11.73	21.11	19.51	18.66	2.22	4.15	21.84	18.28	18.82	21.89	18.16	5.65	9.96	6.14	2.08
Fish Spp richness	15	11	12	12	13	11	6	7	14	16	19	17	11	8	19	15	6
Fish Families Richness	7	5	7	5	6	5	4	4	9	7	9	5	5	5	8	9	4