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Use of Mixed-gas Rebreathers to Access Fish Assemblages in Mesophotic Coral Ecosystems (MCE) off La Parguera Shelf-Edge, Puerto Rico

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ABSTRACT

Diver-based visual census is commonly used to evaluate reef fish communities for ecological and fisheries purposes but depth limits to conventional scuba (~30 m) could bias the data. Fishes from Mesophotic Coral Ecosystems (MCEs) are important to scientists and managers because it is thought that these assemblages (1) contain the lower distribution of many shallow species, (2) contain additional commercially important species limited to these depths, and (3) are difficult to assess using other technologies due to the extreme geomorphology of slope environments. This study surveyed the fishes associated to six MCE sites off La Parguera from 50 to 85m depth, using rebreather trimix technical diving. Seventy-five fish species were identified in 64 transects and 30 species in 60 roving surveys. This rich ichthyofauna includes both common inhabitants of shallow reefs and species confined to deep habitats. MCEs are dominated by zooplanktivores (one-third of species; 63% of abundance) while herbivores dominate shallow reefs. Surveys found a higher abundance of fishery commercial species compared to shallow reefs, suggesting that MCEs serve as refugia for heavily exploited fishes. Depth and topographic complexity could shape MCEs assemblages; there is a greater abundance of zooplantivores and fishery-exploited species at more rugose sites. Research and monitoring of MCE fish assemblages are critical to enhance our knowledge on species composition and to compare ecological processes with shallow reefs.

KEY WORDS: Fish Assemblage, mesophotic coral ecosystems (MCE), rebreather, commercially exploited fishes, deep refugia.

El Uso de Rebreathers de Mezcla de Gases para evaluar las Comunidades de Peces de los Ecosistemas Coralinos Mesofoticos (MCE) del Veril de La Parguera, Puerto Rico

Los censos visuales realizados con técnicas de buceo se utilizan para evaluar las comunidades de peces arrecifales con fines ecológicos y pesqueros. Sin embargo, los límites de profundidad del buceo convencional (~ 30 m) podrían sesgar los datos. Los peces de ecosistemas coralinos mesofoticos (MCE) son importantes para los científicos y manejadores porque se cree que estas comunidades (1) contienen la distribución mas profunda de muchas especies de aguas someras (2) contienen especies comerciales adicionales importantes limitadas a estas profundidades, y (3) son difíciles de evaluar utilizando otras tecnologías dada la extrema geomorfología de los ambientes localizados en el veril. Este estudio evalúo los peces asociados a seis sitios de La Parguera entre 50 y 85m de profundidad, utilizando buceo técnico con rebreather y mezcla de aire trimix. Se identificaron 65 especies de peces en 64 transectos y 30 especies en 60 censos de búsqueda activa. Esta rica ictiofauna incluye tanto habitantes comunes de arrecifes de aguas someras como especies confinadas a hábitats profundos. Los MCEs están dominados por zooplanctivoros (un tercio de las especies; 63% de la abundancia) mientras los herbívoros dominan los arrecifes someros. Se encontró una mayor abundancia de especies de importancia comercial en comparación con los arrecifes someros, lo cual sugiere que los MCEs sirven de refugio a especies de peces explotadas extensivamente. La profundidad y complejidad topográfica podrían estar moldeando las comunidades de los MCEs; existe una mayor abundancia de zooplanctivoros y especies de explotación pesquera en los sitios más rugosos. La investigación y el monitoreo de las comunidades de peces que habitan en los MCEs es critico para mejorar nuestro conocimiento de la composición de especies y para comparar los procesos ecológicos con los de arrecifes someros.

PALABRAS CLAVE: Comunidad de peces, ecosistemas coralinos mesofoticos (MCE), rebreather, peces de explotación comercial, refugio profundo

L'usage des Recycleurs à Mélange Gazeux pour l'évaluation des Communautés de Poissons des Écosystèmes Coralliens Mésophotiques (ECM) à Veril de La Parguera, Puerto Rico

Les recensements visuels faits avec des techniques de plongée sont utilisés pour évaluer les communautés de poissons de récif et de la pêche à des fins écologiques. Toutefois, les limites de la profondeur de plongée classique (~ 30 m) pourraient biaiser les données. Les poissons des Écosystèmes Coralliens Mésophotiques (ECM) sont importants pour les scientifiques et les gestionnaires, car on croit que ces communautés (1) contiennent la distribution la plus profonde de nombreuses espèces d'eau peu profonde ; (2) contiennent d'autres espèces commerciales importantes limitées à ces profondeurs, et (3) sont difficiles à évaluer à l'aide d'autres technologies en raison de la géomorphologie des environnements extrêmes sur la crête. Cette étude a évalué aux poissons attirés de six sites à La Parguera, à des profondeurs entre 50 et 85 mètres, en utilisant la plongée technique avec recycleur (<<*rebreather*>>) et un mélange à l'air trimix. Nous avons identifié 65 espèces de poissons dans 64 transects et 30 espèces dans 60 quêtes à la recherche active. Cette riche faune de poissons est composée par des poissons communs aux récifs d'eaux superficielles, mais aussi par des poissons habitant des milieux des récifs peu profonds et même aussi par des espèces confinées à la profondeur. Les ECM sont dominées par zooplanctonophages (un tiers des espèces, soit le 63 % de l'abondance), tandis que les herbivores dominent le récif peu profond. On a trouvé une plus grande abondance d'espèces commercialement importantes par rapport aux récifs peu profonds, ce qui suggère que les ECM sont un abri pour les espèces de poissons exploitées de façon intensive. La complexité topographique et la profondeur pourraient être en train de façonner les communautés des ECNs, il y a une plus grande abondance de zooplanctonophages et d'espèces exploitées par la pêche dans la plupart des endroits les plus fripés et accidentés. La recherche et la surveillance des communautés de poissons habitant aux ECM est essentielle pour améliorer notre compréhension de la composition des espèces et afin de comparer les processus écologiques avec ceux des récifs peu profonds.

MOTS CLÉS: Comnauté de poissons, écosystèmes coralliens mésophotiques (ECM), recycleurs, poissons exploités, abri profound

INTRODUCTION

Reef fishes have been widely studied worldwide thanks to the invention and development of SCUBA diving techniques. Given that fish communities are commonly surveyed using diver-based visual censuses performed by conventional scuba, there is a relatively good understanding of the composition and ecology of these communities for the top 30 m depth of the reef (Thresher and Colin 1986, Itzikowitz et al. 1991, Pyle 2000). However, coral ecosystems can extend to depths of 100 m or more, thus about two thirds of the entire reef ecosystem is scarcely known due to limitations of the diving techniques. Advances in technology have allowed surpassing depth limitations using submersibles, robots and mixed gas diving. These technologies are adequate for broad observations (Pyle 2000) and have successfully revealed the existence of complex and diverse ecosystems occurring between 30 - 150 m, known as mesophotic coral ecosystems (MCE). Fish assemblages at MCEs are of great interest to scientists and managers because they differ in taxonomic structure and abundance from that of shallower reefs (García-Sais et al. 2004, Brokovich et al. 2008, Fetoiza et al. 2005, Colin 1976, Colin 1974). Nevertheless, little is known on this fauna composition and ecology.

At present, closed circuit trimix rebreather diving is considered the ideal technique to study fishes at MCEs. The main advantage of this technique is that provides reasonable bottom time at mesophotic depths to perform censuses, take photographs, collect cryptic species, and effectively approach organisms at cracks or crevices. In addition, fish behavior at the presence of divers is more natural because bubbles are not released. Nevertheless, the applicability of this technology can be limited because it is expensive and requires an extensive training.

Preliminary observations of deep-water fish habitats and abundance using the Johnson-Sea-Link II submersible in La Parguera, Southwest Puerto Rico, at depths ranging from about 100 - 450 m (Nelson and Appeldoorn 1985) suggested the presence of MCEs at the shelf edge. Thus the main goals of this study were to:

i) Identify and characterize fishes associated with MCEs,
ii) Contrast fish assemblages between MCEs and shallow reefs, and
iii) Examine the refuge potential of MCEs for exploited populations.

METHODS

Study Area

This study has being performed during three years at six sites within MCEs located in La Parguera, in the southwest Puerto Rico (Figure 1). Off La Parguera shelf-edge slope, the coral ecosystem extends to waters deeper than 100 m. Its geomorphology was described in detail by Sherman et al. (2010). The upper slope is divided into two geomorphic zones separated by a break in slope gradient at approximately 90 m water depth. Well developed MCEs are mostly present in the shallower zone (above 90 m). Sites were selected using multibeam bathymetry images of the shelf-edge provided by the Biogeography Branch of NOAA's National Centers for Coastal Ocean Science (Battista and Stecher 2006).

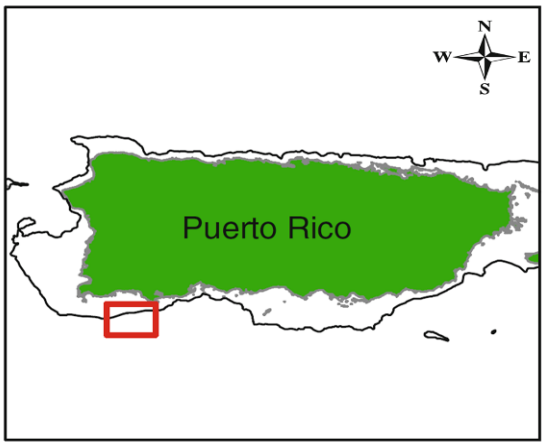

Figure 1. Study area. La Parguera shelf-edge, Southwest Puerto Rico.

Sampling and Data Analysis

MCEs were surveyed using trimix rebreather diving along a depth gradient from 50 to 85 m. Fishes were identified and counted in belt transects 10 m long by 3 m wide (30 m^2). Each transect was surveyed for 15 minutes. In addition, roving surveys were also performed to quantify target species observed outside of the transects but within the area. Fish composition (presence/absence of species) and abundance was compared with shallower ichthyofauna (less than 30 m depth) reported for the same areas by The Reef Environmental Education Foundation (REEF) (http://www.reef.org). The potential refuge function of MCEs was evaluated comparing the percent sighting frequency (% dives species encountered) between MCEs and shallower reefs.

RESULTS AND DISCUSSION

MCEs surveyed in La Parguera possess a rich fish fauna. Seventy-five species were identified within transects and 30 species in roving surveys. This ichthyofauna comprises many species commonly seen on shallow reefs, which appear to find their lower distribution at mesophotic depths. However, there is a group of species that were restricted to MCEs. Of these, *Chromis insolata* (sunshine fish), *Chromis scotti* (purple reeffish) and *Lutjanus buccanella* (blackfin snapper) were frequently observed and usually in large numbers. There is also a group of species that are common in MCEs but rare on shallow reefs (e.g. *Xanthichthys ringens* (sargassum triggerfish), *Centropyge argi* (cherubfish), and *Liopropoma sp.* (basslets). Other species like *Serranus chionaraia*

(snow basslet) and *Lipogramma klayi* (bicolor basslet) were observed only below 50 m. A similar mixed fish assemblage of shallow reef and true ''deep-reef'' species was first described by Colin (1974, 1976) at 90 and 305 m depth off Jamaica, Belize, the Bahamas, and in Puerto Rico by Garcia-Sais (2010).

In terms of trophic groups, MCEs between 50 and 85 m depth in La Parguera are strongly dominated by zooplanktivore fishes, which represent one third (32%) of all fish species and account for a 63% of all the fishes surveyed (Table 1). Plankton is believed to be a main source of energy for mesophotic fishes (Kahng et al. 2010). In contrast, herbivores are dominant at shallow reefs (less than 30 m depth) (Table 1). The proportion of trophic groups of the ichthyofauna found at MCEs differs from that of shallower reefs. Piscivores and zooplanktivores are proportionally more abundant at MCEs, both in species number and fish density. Instead the other categories, especially herbivores, become less representative at MCEs (Table 1). Because several abiotic factors such as light, turbidity, temperature, sediments, and/or nutrients vary with depth, resource availability, and likewise fish assemblage structure differs among zones. The exponential reduction of light with depth limits photosynthesis and affects primary producers, such as algae. Thus, variations in algal community structure with depth (Ballantine 2011) may influence changes in the composition and abundance of herbivorous fishes.

Table 1. Proportion of trophic groups composition of the ichthyofauna found at MCE's and shallow reefs (less than 30 m depth), in terms of fish density and species richness.

	Density (%)		Species richness (%)	
	MCEs	Shallow	MCEs	Shallow
Zooplanktivore	**63**	25	**32**	10
Mobile invertebrate feeders	17	24	30	39
Herbivore	12	**47**	18	**42**
Piscivore	6	2	15	3
Sessile invertebrate feeders	2	2	5	6

Topographic complexity was found to be an additional factor shaping fishes at MCEs. High rugosity sites had higher overall fish densities and higher sighting frequencies of large bodied groupers and snappers. Zooplantivorous fishes also exhibited higher overall densities at high rugosity sites, but this pattern varied at the species level. On the contrary, low rugosity sites were dominated by herbivorous fishes. Because a complex reef structure has the potential to affect water flow and lead to higher concentrations of plankton and nutrient retention in the area (Choat and Bellwood, 1991), higher planktivore densities found at more complex sites could result from higher plankton and nutrient availability in more complex reefs.

Fishery target species were observed in surveys within MCEs; seven in transects and 15 in roving surveys (Table 2). Of these, *Cephalopolis cruentata* (graysby) was the most common and abundant in transects and *Lutjanus jocu* (dog snapper) in roving surveys. In contrast with shallower reefs, MCEs possessed a higher abundance of fishery commercial species (Figure 2). Because these species were once common inhabitants of shallower reefs, but have become rare because of historical fishing pressure and habitat destruction, MCEs might serve as refuge for heavily exploited fishes, thus management measures should include these important ecosystems to protect the

Table 2. Percent of transects and/or roving surveys where fishery exploited species were encountered in MCEs (% sighting frequency).

	Transects	Roving
Balistes vetula	0	2
Canthidermis sufflamen	0	7
Cephalopolis cruentata	**57**	2
Cephalopolis fulva	4	5
Elagatis bipinnulata	0	3
Lachnolaimus maximus	0	4
Lutjanus analis	4	12
Lutjanus apodus	18	23
Lutjanus buccanella	16	10
Lutjanus cyanopterus	0	15
Lutjanus jocu	0	**55**
Lutjanus mahogoni	19	10
Mycteroperca bonaci	0	15
Ocyurus chrysurus	11	16
Scomberomorus sp.	0	7

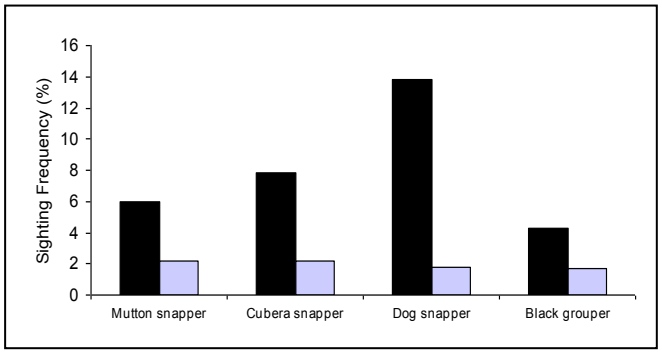

Figure 2. Comparison of percent of sighting frequency of the most commonly fishery exploited species observed at MCEs. Black bars are frequencies at MCEs, gray bars are frequencies at shallower reefs (above 30 m).

remaining spawning stock. Research and monitoring of MCE fish assemblages are critical to enhance our knowledge of species composition and to compare ecological processes with shallow reefs.

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