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The Health of Coral Reef Ecosystems in Southwestern Puerto Rico: A Local Ecological Knowledge Perspective from the Diving Community

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Abstract: As the conditions of coral reefs deteriorate worldwide, there is an urgent need for more effective management. But, establishing management strategies is a complex task. It has been acknowledged that the incorporation of community members and stakeholders can improve the decision making process. In this study, we identified recreational SCUBA divers as a key group that can share their knowledge and experience to help in assessing the status and health of coral reefs from the northwest to the southwest region of Puerto Rico. A total of 13 dive masters and instructors, the majority being dive operators, were interviewed and 24 coral reef sites were mentioned as the top three sites they visited the most. Two of the top three ranked sites are part of Marine Protected Areas (MPA) of the Commonwealth of Puerto Rico. Reefs at or closer to the shelf-edge and offshore islands had a higher ranking than those sites closer to the coastline, establishing a possible trend of deterioration near the coast that has also been reported by many scientists. The majority of the data obtained in this study is consistent with scientific documentation, suggesting that local ecological knowledge (LEK) should be given equal significance and value in decision-making processes. The incorporation of different forms of knowledge in management plans increases the chance of success and obtains more far-reaching support. This study also exposed some key issues that should be addressed in the future, such as the need for baseline data on SCUBA diving activities in Puerto Rico and the need to educate the public about the importance of marine ecosystems.

Keywords: Coral reefs, Local Ecological Knowledge, Marine Protected Areas, SCUBA divers.

Resumen: A medida que la condición de los arrecifes de coral se va deteriorando alrededor del mundo, surge la necesidad de un manejo más efectivo. Pero, el establecimiento de estrategias de manejo efectivas es una tarea bastante compleja. Se ha reconocido a la incorporación de la comunidad y de “*stakeholders*” o grupos o personas interesadas como una manera de adquirir mejores resultados en los procesos de toma de decisiones. En este trabajo incorporamos a los buzos recreativos como un grupo clave que puede proveer mucho de su conocimiento y experiencia para ayudar a evaluar la situación y la salud de los arrecifes de coral que se encuentran desde el noroeste hasta la región suroeste de Puerto Rico. En total 13 “dive masters” e instructores, en su mayoría operadores de tiendas de buceo fueron entrevistados personalmente y un total de 24 arrecifes fueron mencionados por los buzos como los 3 arrecifes más visitados. Dos de los 3 arrecifes de mayor rango resultaron ser Áreas Marinas Protegidas (AMP) del Estado Libre Asociado de Puerto Rico. Los arrecifes que se encuentran más cercanos o en el borde de la plataforma y las islas mar afuera tuvieron una mayor puntuación o rango que los arrecifes más cercanos a la costa. Esto establece una posible tendencia de deterioro hacia la costa, lo cual también ha sido reportado por científicos. La mayoría de los datos recopilados en este estudio son consistentes con la documentación científica, sugiriendo que al conocimiento ecológico local (LEK, por sus siglas en inglés) se le puede dar un alto valor e importancia en los procesos de toma de decisiones. La incorporación de distintas formas de conocimiento tiene mejor oportunidad de éxito y apoyo al momento de establecer política pública. Este trabajo también trajo a relucir unos asuntos claves que deben ser atendidos en el futuro, como lo son: la falta de información base sobre las actividades de buceo en Puerto Rico y la falta de educación al público sobre la importancia de los ecosistemas marinos.

Palabras claves: Arrecifes de coral, Conocimiento Ecológico Local, Áreas Marinas Protegidas, buzos recreativos.

Introduction

Coral reef ecosystems are recognized as the most diverse of all marine ecosystems and as extremely valuable resources. They possess the highest biological productivity of tropical marine ecosystems (Kelleher, 1997, Spalding, 2004, Wafar, 1997) and provide a great number of benefits such as: protection to coastal communities from incoming waves and atmospheric events, abundant resources, economical revenues from tourism and commercial fishing, and raw material for future medical research (Spalding, 2004). Nevertheless, the condition of this resource has been deteriorating worldwide for the last few decades due to a variety of biological and anthropogenic factors. Coastal development, with its impacts such as sedimentation and eutrophication, has caused the loss or damage of nearly 50% of inshore coral reefs (Torres, et al., 2000) in Puerto Rico. Coral disease, epizootics, coral bleaching, overfishing and a number of recreational activities are also contributing to coral reef deterioration (Morelock et al. 2001).

There is an urgent need for marine ecosystem management to prevent further loss of coral reefs. Due to the diverse nature of the sources affecting coral reefs, and lack of enforcement, management strategies are a complex task. However, regardless of the type of management, key stakeholders as well as interest groups in coastal areas must be incorporated in the process. One of the key groups that could represent an important source of knowledge and should be included in management processes is recreational SCUBA divers (Valdés-Pizzini, 2002). Through their work, dive operators have acquired unparalleled knowledge and experience. They can provide long term monitoring and recognize spatiotemporal changes at sites they frequently visit and have been visiting for many years. In addition, they can also educate and transfer their knowledge about resources to clients and other community members. Their experience has given them the capability to determine the best dive sites to take clients, which makes this industry highly dependent on the condition and health of coral reefs. This makes them excellent participants in stewardship because they have a vested interest. The knowledge gained by dive operators, also known as local ecological knowledge (LEK), is acquired by resource users through observations and experiences with their surrounding ecosystems (Yli-Pelkonen & Kohl, 2005). Despite the significance and value of LEK, it has usually been ignored or underestimated in resource management decisions and other

socioeconomic agreements. By integrating LEK from key stakeholders and all the parties involved, suitable information will be generated for the management and conservation of coral reef ecosystems. One mechanism for requesting this knowledge is through social research that explores resource users' knowledge, opinions and recommendations for management.

The Coral Reef Ecosystems Studies (CRES) is a multidisciplinary research project focused on understanding coral reef dynamics and processes, and providing tools and options for coral reef management. This project, based in three sites: La Parguera and Culebra, Puerto Rico, and St. John, US Virgin Islands, incorporates a socio-economic component with the purpose of integrating social concerns and perspectives into management decisions. In this study, we bring in SCUBA divers, and more specifically dive-masters and instructors as a key group who should be included in this process because of their LEK. The objectives of the study are to assess coral reefs located from the northwest to the southwest of the insular shelf of Puerto Rico based on users' perspectives and site selection; to determine from divers' perspective and experience the perceived reduction of coral species and their locations, and the probable cause for destruction; and finally, to compare divers' LEK to scientific documentation.

Materials and Methods

Study area.

Our study area is comprised of the coastal municipalities from the northwest to the southwest of the island of Puerto Rico: from Isabela (north coast) to Guánica (south coast). This region of the island is highly valued for its coastal and marine resources and where many recreational activities, especially SCUBA diving, take place. The islands of Desecheo, Mona and Monito, located off the western coast were also included in our study. These are oceanic uninhabited islands which are seldom subject to land-based impacts.

Methodology.

Although there is no documentation available on the historical development of recreational SCUBA diving in the Caribbean, by the year 2001 there were a total of 65 diving operations in Puerto Rico and an estimated 196,664 dives per year (García-Moliner, et al., 2001). All the dive shops from the northwest to the southwest of Puerto Rico were contacted personally with the aim of interviewing

the person responsible for diving excursions as they were expected to have a high level of expertise and experience. Three eastern region dive shops were included in our survey because they also visit dive sites in the western region with their clients. Interviews were conducted using a questionnaire with open and scaled questions, and were done in-person (face-to-face interviews) at the dive shop locations. As a result, all dive shops in the western region participated in this study. A total of 13 dive masters and instructors were interviewed between November 2004 and February 2005. As a part of the interview process, divers were asked to circle on a NOAA nautical chart of the west coast of Puerto Rico (Reference #25671) the broad geographical areas they visit most often with their clients and to circle and name the three coral reefs they most frequently visit (see Figure 1 for a map of the areas visited the most). The geographical data was digitized and displayed on NOAA benthic maps using ArcMap© GIS. Respondents also described each site's characteristics, reason for being selected, accessibility and condition based on their experience and knowledge. The interview also inquired about the species of coral and marine organisms considered to be in critical condition.

One of the difficulties encountered in the data was that some respondents referred to different reefs at Desecheo Island as more than one site while others referred to the various and some referred to the various reefs at Desecheo Island as a single site. To avoid confusion, we considered Desecheo Island and all of its reefs as one site (Desecheo Island). Another difficulty was that some of the geographic areas preferred by the divers were outside the nautical chart provided. These selections were eliminated when digitizing the data, although the names of these sites remain in the ranking list.

The empirical knowledge these respondents provided is indeed invaluable information about marine resource conditions and spatiotemporal changes of coral reef sites. The data is reported here as a source for assessing reefs and substantiating the knowledge of resource users.

Results

A total of 24 coral reef sites were mentioned by the 13 divers interviewed as the top three sites they visited the most. [Table 1](#) presents a ranking of the sites based on the number of times the respondents mentioned them. Escollo El Negro, Tourmaline and Desecheo Island were the three most salient reef sites, and their condition was most frequently indicated as being “very good”. Few reefs with shore access were mentioned and their condition was described as “regular” by the majority of interviewees. It is imperative to note that two of the top three ranked sites are part of Marine Protected Areas (MPAs) of the Commonwealth of Puerto Rico. Desecheo Island is designated as a natural reserve (NR) and Tourmaline is a seasonal no-take zone (NTZ) (Aguilar-Perera, et al., 2005). Mona Island, ranked seventh, is also an MPA. These findings are consistent with Green and Donnelly (2003), which found MPAs in the Caribbean to be the most visited sites by recreational SCUBA divers. The top ranked sites are also distant from the coast, a datum consistent with the findings of Hernández-Delgado and Sabat (2000) on the health of coral reefs on the east coast of Puerto Rico.

Based on the divers’ experience, there are many coral species considered to have reduced in terms of coverage ([Table 2](#)). Among these, the four most salient were the brain coral, *Diploria strigosa*, ([Figure 2](#)), the elkhorn coral, *Acropora palmata*, ([Figure 3](#)), sea fans, *Gorgonia* sp., ([Figure 4](#)) and the staghorn coral (*Acropora cervicornis*). The cause of this reduction was mainly attributed to pollution (generally land based), indiscriminate anchoring, sedimentation, and coral diseases. Even though dive sites at La Parguera were not among the top ranked, it was significant to find consensus among divers about the location where different coral species coverage has been reduced and La Parguera was the top most-mentioned location ([Table 2](#)). By contrast, the majority of divers who mainly visit Desecheo Island believe that there are no species of coral being reduced at this site, and rather that they appear to be improving. In terms of other marine organisms like groupers, especially the Red Hind (*Epinephelus guttatus*) and the Nassau grouper (*Epinephelus striatus*), Spiny Lobster (*Panulirus argus*), Queen Conch (*Strombus gigas*) and Hogfish (*Lachnolaimus maximus*) were also considered to have reduced in terms of numbers in the different areas mentioned by the divers in this study.

Conclusions

This study provides knowledge on the areas being used by recreational SCUBA divers, the condition of the reefs and other marine organism populations at these sites, and data comparable to available scientific knowledge. The selection of the best sites is a business decision made by dive shop owners in order to fulfill tourist and clients expectations and needs. The reefs most visited by divers ought to have better attributes and be in better condition than others with lower saliency or otherwise not mentioned (see [Figure 1](#)). Reefs at or closer to the shelf-edge and the offshore islands of Desecheo and Mona had a higher ranking than those sites closer to the shoreline. These two islands are uninhabited and therefore are subjected less to land effects such as coastal run-off and recreational activities. Proximity to the shore implies higher exposure to sedimentation, water turbidity, direct and indirect human impacts (pollutants, solid waste, trampling, extraction, etc.), boat traffic, and other land effects and activities. Those activities contribute to diminishing the quality of the diving experience, which is based on species abundance, coral cover and water quality.

García-Sais et al. (2004) reported a trend of deterioration of the coral reefs near the coastline of Mayagüez Bay. Reefs off of Mayagüez Bay, such as Tourmaline, rank among the best developed in Puerto Rico with the highest coral cover of all the intermediate depth range (6–14 m) reefs. Dive sites at Desecheo Island show the highest coral cover (up to 70% in some sections) and fish abundance among deeper reefs (García-Sais et al., 2004). Morelock et al. (2001) also reported a difference between reefs near shore and those offshore at La Parguera. García-Moliner et al. (2001) found Desecheo and Mona Island to be the sites on the west coast most visited by divers, information consistent with our findings on the quality of the sites. Differences between the reefs near and those further from the shore were also reported by Hernández-Delgado and Sabat (2000) in reefs off the eastern end of the island with a higher degree of degradation reported on inshore reefs. In contrast, Morelock et al.'s (2001) study found reefs off La Parguera to be the ones with the highest abundance, diversity and cover of living coral. Although sites such as Mona, Desecheo Island and others mentioned in our study were not included in their survey, the comparison of these results could imply that the coral reefs off La Parguera have experienced rapid deterioration in the past few years.

It is evident that most of the scientific documentation coincides with the results obtained in this study in terms of site selection, reduction of coral species coverage and other organisms and the possible causes for these conditions. These results suggest that LEK should be given more value and be accounted for in decision-making and management processes in order to obtain the best outcome. Decisions and policies that incorporate different forms of knowledge, with coincidences and discrepancies, are more likely to succeed and obtain more support.

On the other hand, the fact that divers' top ranked sites are MPAs also raises concern as to how much damage recreational SCUBA diving can represent to these sites. Hawkins, et al., (1999) found differences between dive sites and reserves (closed to diving); these were mainly in the coral community structure. Another study found that 70% of divers come into direct physical contact with the benthos at the beginning of their dive, though differences in impact were found among genders and specialized divers (Rouphael, et al. 2001). Many management strategies are based on the establishment of an area's carrying capacity. However, studies have shown that divers' experience and behavior are better indicators of potential impact rather than the amount of people who frequent a site (Rouphael, et al., 1997). Little data is available on the impact of recreational activities on coral reefs in Puerto Rico. More baseline data on recreational SCUBA diving and other sub-aquatic activities needs to be compiled in order to establish proper management if necessary. With this data, we can determine if dive sites are being frequented above their carrying capacity and implement a plan of action based on education for particular groups. Management strategies must also be carefully analyzed to prevent the local economy, dependent on tourism, from being affected by undue restrictions but more importantly, weight should be placed on other sources of impact which certainly cause greater damage to marine ecosystems.

The majority of the divers interviewed in this study were optimistic about the future of sub-aquatic activities, and all coincided that this future relies on education of the public to the importance of marine ecosystems and what they can do to protect them. These are key areas that should be addressed in the near future by the Caribbean Coral Reefs Institute (CCRI) and the Sea Grant College Program.

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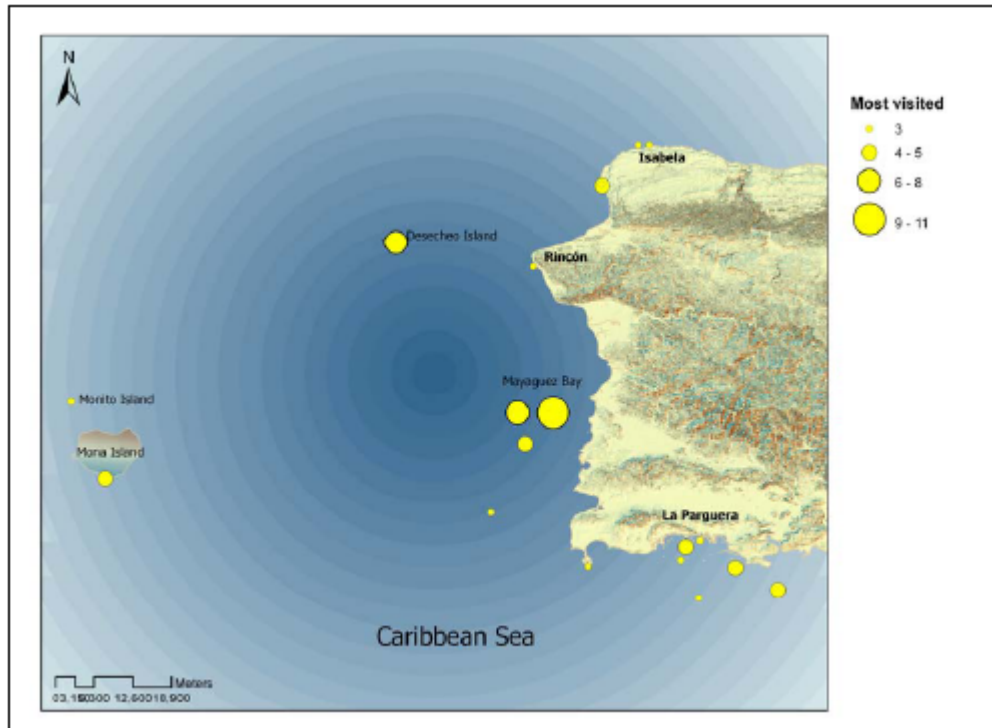
Table 1. Reef sites of the southwest region frequently visited by Puerto Rican SCUBA divers.

Reef site	%
Escollo El Negro	11
Tourmaline	8
Desecheo Island	8
El Ron	5
Fallen Rock	5
Turumote I	5
Mona Island	5
El Natural (Crashboat)	5
Cayo Enrique	5
Playa Bajuras	3
Playuela	3
Monito	3
North of Punta Ensenada (Rincón)	3
Caracoles	3
Media Luna	3
Bajo Gallardo	3
El Faro (Cabo Rojo)	3
Manchas Negras	3
Sector Las Cuevas	3
Quebrada de los Cedros	3
The Black Wall	3
The Hatchery	3
Los Pozos	3
Pablo	3

Table 2. Coral species reduced in coverage and the location.

Species	Common name	Location
<i>Diploria strigosa</i>	Brain coral (7)*	Cayo Ratones, Escollo El Negro, El Natural, La Parguera
<i>Acropora palmata</i>	Elkhorn coral (5)	Turrumote, Escollo El Negro, Desecheo Island, La Parguera
<i>Gorgonia</i> sp.	Sea fans (3)	El Natural and Desecheo Island
<i>Acropora cervicornis</i>	Staghorn coral (3)	La Parguera, Mona Island, Desecheo Island and Escollo El Negro
<i>Porites porites</i>	Finger coral (2)	Las Cuevas and Fajardo
<i>Acropora</i> spp. (Species not specified)	Staghorn and Elkhorn coral	Cayo Ratones and Escollo El Negro
<i>Antipathes</i> spp.	Black coral	Guánica to La Parguera
<i>Porites astreoides</i>	Mustard hill coral	La Parguera
<i>Montastrea cavernosa</i>	Great star coral	La Parguera
<i>Millepora complanata</i>	Fire coral	Las Cuevas and Crashboat

* Numbers in parentheses represent the number of respondents that mentioned the species.



**Figure 1. Sites visited the most by recreational SCUBA divers.
Maps by Idelfonso Ruíz Valentín.**



Figure 2. Coverage reduction of brain corals (*Diploria strigosa*) by location.

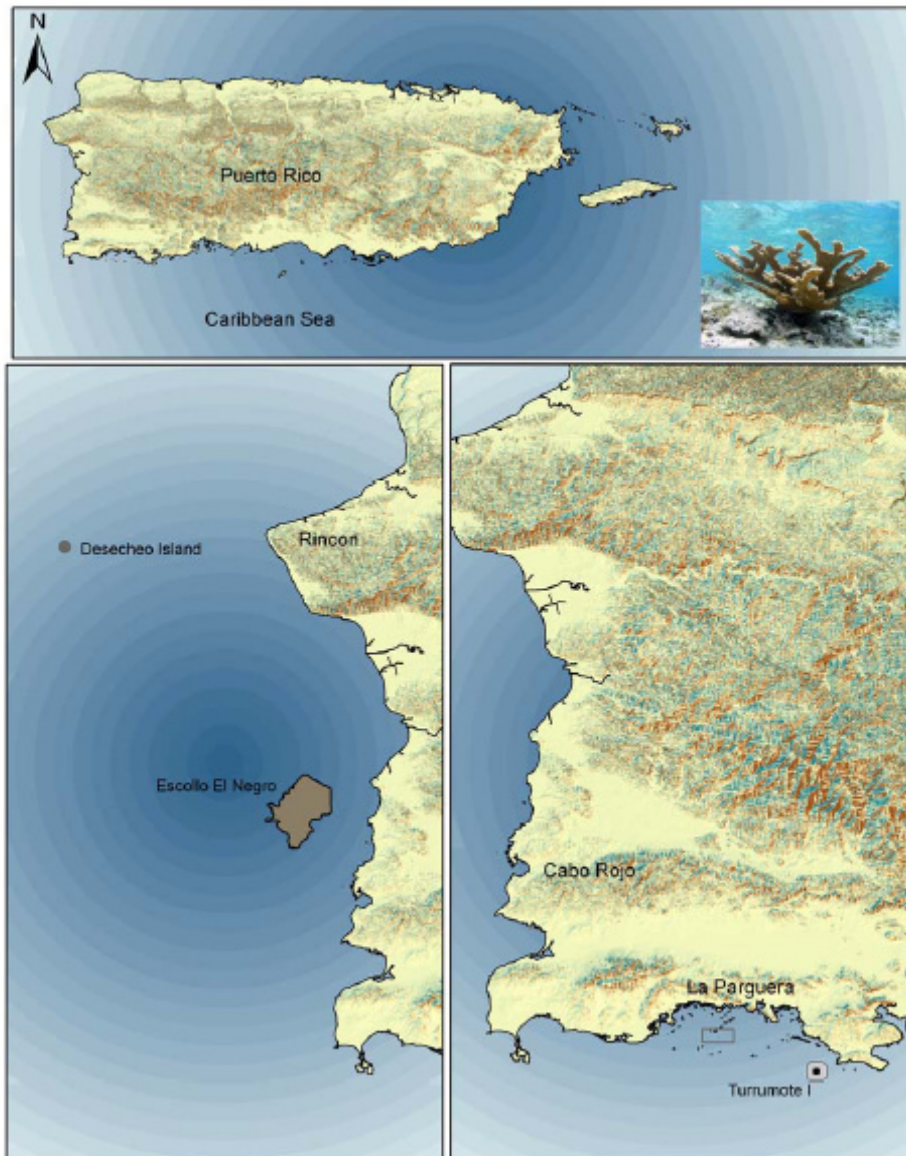


Figure 3. Coverage reduction of elkhorn coral (*Acropora palmata*) by location.



Figure 4. Coverage reduction of sea fans (*Gorgonia* sp.) by location.