Identification of Reef Fish Spawning Aggregation Sites in Los Roques Archipelago National Park, Venezuela

JUDSON P. BOOMHOWER[1], MARCO A. ROMERO[2], JUAN M. POSADA[2], SHINICHI KOBARA[3], and WILLIAM D. HEYMAN[3]
[1]*Fulbright Student Scholarship Program, Universidad Simon Bolivar, Apartado 89000, Caracas 1080A,Venezuela*
[2]*Departamento de Biología de Organismos, Universidad Simon Bolivar, Apartado 89000, Caracas 1080A,Venezuela*
[3]*Department of Geography, Texas A&M University, College Station, Texas 77843-3147 USA*

ABSTRACT

Despite some indications of their presence, spawning aggregations of reef fishes (among the most important events in marine ecosystems) have not been previously formally documented in the Los Roques Archipelago National Park in Venezuela. This study attempts to identify potential spawning aggregation sites and times in the archipelago. We interpreted satellite images and created bathymetric maps of the region in order to select three sites for monitoring, all located along the park's southern barrier reef. Thirty interviews with experienced local fishermen, taken January – March 2007, confirmed the choice of sites. Abundances and sizes of 27 species that form reproductive aggregations were monitored using underwater visual census for seven days after the full moon, February - August, 2007. Interviewed fishermen most frequently mentioned aggregations of mutton snapper, *Lutjanus analis,* at Cayo Sal. Fishermen described Groupers (*Epinephelus spp.* and *Mycteroperca spp.*) as uncommon. Descriptive statistics show an increase in density for some species, including *Lutjanus apodus*, in certain months although spawning events were not observed. While these results do not prove the existence or locations of spawning aggregations in the archipelago, they are a useful population baseline for the species studied. This work is a first step towards characterizing reef fish spawning aggregations in Los Roques Archipelago National Park for future research and protection.

KEY WORDS: Spawning aggregations, visual census, Los Roques

Identificación de Sitios de Agregaciones Reproductivas de Peces Arrecífales en el Parque Nacional Archipiélago Los Roques, Venezuela

Aunque existe alguna evidencia de su ocurrencia, las agregaciones reproductivas de peces (uno de los eventos más relevantes en ecosistemas marinos) no han sido formalmente descritas en el Parque Nacional Archipiélago Los Roques, Venezuela. Este estudio está orientado a identificar sitios y épocas de formación de dichas agregaciones en el archipiélago. Para ello se analizaron imágenes de satélite y se generaron mapas batimétricos, lo cual llevó a la selección de tres sitios de muestreo en la barrera sur del parque. Treinta pescadores experimentados fueron entrevistados entre enero y marzo de 2007, lo cual confirmó la pertinencia de los sitios escogidos. La mayoría de los entrevistados mencionó la existencia de agregaciones de *Lutjanus analis* en Cayo Sal, así como resaltaron que la presencia de meros (*Epinephelus spp.* y *Mycteroperca spp.*) es poco común en el archipiélago. Se realizaron censos visuales a lo largo de siete días, entre febrero y agosto de 2007, con miras a monitorear los cambios en las abundancias y tallas de 27 especies reconocidas por formar agregaciones reproductivas. Estadísticas descriptivas evidencian un incremento en la densidad de ciertas especies, como *Lutjanus apodus*, en meses diferentes, aunque no se observaron eventos de desove. Los presentes resultados no evidencian contundentemente la existencia de agregaciones reproductivas de peces en el archipiélago, pero constituyen una línea base poblacional muy relevante para las especies monitoreadas y es el primer paso hacia su caracterización.

PALABRAS CLAVES: Agregaciones reproductivas, censo visual, Los Roques

INTRODUCTION

Reproduction in spawning aggregations – congregations of dozens to thousands of individuals of a given species, reoccurring faithfully at the same locations and times – is a key phase in the life history of many tropical reef fishes. Because these predictable gatherings of fish are highly vulnerable to overfishing, which causes negative ecosystem and economic impacts, research has been, and is, currently focused on locating spawning aggregations of reef fish, understanding the biology behind their formation, and developing strategies for their management (Claydon 2004, Domeier and Colin 1997).

Fishing on spawning aggregations yields a very high catch per unit effort and quickly becomes unsustainable. Fishing on spawning aggregations beyond a limited subsistence scale can negatively impact the targeted aggregation as well as local/regional stocks of the targeted species (Sadovy and Domeier 2005). In the Caribbean, overfishing has reduced or eliminated reef fish spawning aggregations in many areas, particularly for groupers (Serranidae) (Sadovy 1994, Sala *et al.* 2001). About one-third of known Nassau grouper (*Epinephelus striatus*) and one-fourth of known Goliath grouper (*Epinephelus itajara*) spawning aggregations have been wiped out by fishing (Sadovy and Eklund 1999). Especially for transient aggregations that feature large numbers of individuals from a wide geographic area, the degradation or elimination of spawning aggregations contributes to region-wide population declines (Claydon 2004).

The importance and current peril of reef fish spawning aggregations in the Caribbean argue for management responses to protect spawning aggregations from overfishing. Possible management measures include seasonal fishing closures at known reproductive sites, prohibitions on the sale of relevant species during their peak reproductive periods, and inclusion of spawning aggregation sites in larger, permanent no-take marine reserves (Heyman *et al.* 2004a). While aggregations that have been completely eliminated are not thought to re-form in most cases (Claydon 2004, Sadovy and Eklund 1999), there is evidence that depleted but extant aggregations will recover their numbers if fishing pressure is removed (Burton *et al.* 2005, Nemeth 2005).

All of these management strategies require knowledge of the locations and/or time of spawning for the species to be managed. Identifying and characterizing individual spawning aggregations is an active area of research (for example, Claro and Lindeman 2003, Heyman *et al.* 2005, Matos-Caraballo *et al.* 2006, Nemeth *et al.* 2006, Whaylen *et al*. 2004). To learn aggregation sites and times, researchers either rely on information from fishermen or attempt to identify aggregations independently. The most common approach is to observe or interview fishermen in order to discern when and where they reliably catch larger than normal amounts of individual species (Heyman *et al*. 2004a). This approach is an example of the value of traditional ecological knowledge to conservation of marine resources (Drew 2005). In some areas, however, spawning aggregations are unfished and/or unknown. In these cases researchers must identify aggregation sites and times in fishery-independent ways, including based on hypothesized geomorphological characteristics of aggregation sites (S.K. and W.H.D., Unpubl. data, Heyman 2004b). Whether possible sites are identified using fishery-dependent or fishery-independent techniques, direct or indirect evidence of spawning is required to confirm the existence of a spawning aggregation. Direct evidence of spawning aggregations includes observations of spawning or the presence of hydrated oocytes within the gonads of females collected from the site (Heyman *et al*. 2004a). Indirect evidence of spawning can include increases in density, changes in color, spawning behaviors (biting, chasing, etc), swollen abdomens, and an increase in the gonadosomatic index (GSI) (Heyman *et al*. 2004a). A commonly used, though largely arbitrary, metric to indirectly determine the presence of a possible spawning aggregation of reef fish is whether the density of individuals at the site is at least three times greater than what would be expected at that site under "normal" conditions (Domeier and Colin 1997).

The science and management community is currently grappling with the best way to handle information gained by scientists about previously unknown aggregations (Sadovy *et al*. 2007). While some argue that research could expose these currently unfished sites to fishing pressure, others point out the likelihood that economic or ecological shifts (for example, the depletion of current fisheries), will eventually lead to their discovery and exploitation by fishermen in any case. A key challenge is achieving protections for spawning sites quickly after they are identified. This can be difficult given the often years-long duration of the fisheries policy process and the limited strength of institutions for environmental management in some countries.

This study investigated the presence and location/timing of reef fish spawning aggregations in the Los Roques Archipelago National Park in Venezuela. Specifically, the objective of this study was to evaluate the possible presence and timing of reef fish spawning aggregations at three sites (identified through fisherman interviews and geomorphological predictions) through repeated, quantitative characterization of the fish fauna at these sites. The Los Roques Archipelago is an insular reef platform located in the Southern Caribbean, 160 km north of the central Venezuelan coast (11° 44´-11°58´N latitude and 66°32-66°57´W longitude) (Figure 1). The Venezuelan government declared the area a national park in 1972. Since then, spearfishing has been prohibited throughout the archipelago. The use of nets was banned in 1992. Because of this history of protection and because of the area's innate high diversity, the Los Roques area is considered to be among the most intact coral reef environments in the Caribbean (Kramer 2003, Posada *et al*. 2003). The archipelago is isolated from the mainland coast and from nearby island groups, such as the Las Aves archipelago, by wide expanses of deep water (> 1,000 m), which suggests that migration between Los Roques and these nearby environments by reef fish may be rare or nonexistent.

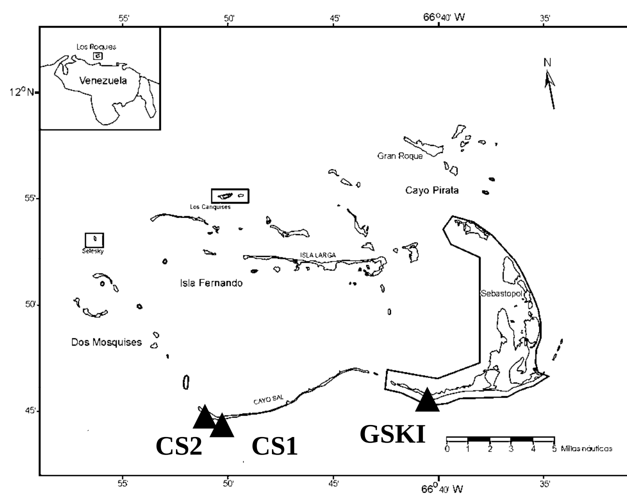

Figure 1. Map of Los Roques. Sites monitored with underwater visual surveys in this study are shown. CS1: Cayo Sal 1. CS2: Cayo sal 2. GSKI: Gresqui. Boxed areas on map represent areas of special protection, where additional rules (beyond those applicable to the entire park) further limit exploitation of marine resources.

Spawning aggregations in Los Roques have not been well-studied. One previous researcher observed hydrated oocytes and post-ovulatory follicles in gonads from female red hind (*Epinephelus guttatus*) collected at several sites in January and February, and an increase in their gonadosomatic index during the same period (Alvarez 2004). Additionally, one of the authors (J.P.) has observed large groups of schoolmaster snapper (*Lutjanus apodus*) displaying possible reproductive behaviors near Cayo Sal in September. Because of these observations, and because of the isolation of the archipelago, transient spawning aggregations of various species of reef fish that live in the archipelago are expected to occur here. However, since fishermen in the archipelago do not appear to actively fish spawning aggregations of reef fish, researchers have not been able to identify spawning aggregation sites by observing fishermen. The Los Roques fishery is focused on spiny lobster (*Panulirus argus*), which is abundant in the archipelago and highly demanded by purchasers for markets on the mainland. Buyers typically pay about 30,000 Bolivares (about US$14 at the official exchange rate) per kilogram of lobster, vs. about 15,000 Bolivares (about US$7) per kg of reef fish like snapper and grouper (J.B., pers. obs.). Because of the ecological importance of the archipelago and the relative lack of knowledge of spawning aggregation sites here, Los Roques is an important place to investigate reef fish reproductive patterns.

METHODS

Fishermen and Diver Interviews

To document community knowledge of spawning aggregations, interviews were conducted with 30 experienced local fishermen. Interviews took place at Isla Fernando, Caranero, Cayo Pirata, and Gran Roque. The average years of fishing experience in Los Roques of the fishermen interviewed was 34 years (minimum 15 years; maximum 61). The interviews consisted of both a questionnaire and an open-ended discussion portion and typically lasted between 30 and 90 minutes. All respondents were asked to identify sites and times during which they reliably caught higher amounts (two to three times greater or more) of a certain species than on an average day of fishing.

Recreational dive masters at each of the four dive shops on the island of Gran Roque were also interviewed. In these open-ended interviews operators were asked if they had noted regular gatherings of any species of fish in predictable places at given times of year. Simple data questionnaires were left for dive operators to fill out after dives, but participation in these surveys was low.

Monitoring Site Selection

At the beginning of the study, seven reef areas that displayed characteristics of potential reef fish spawning aggregation sites were identified based on physical characteristics seen at spawning aggregation sites in other parts of the Caribbean (S.K. and W.D.H., unpublished data; Heyman, 2004b). A LOWRANCE echosounder/GPS device was used to make detailed bathymetric maps of these sites (Heyman *et al*. 2007, Kvernevik *et al*. 2002). Exploratory SCUBA dives were also conducted at these sites to assess the bottom cover. Based on the detailed bathymetric mapping and the preliminary dives, as well as preliminary interviews with local fishermen, three sites were chosen for monitoring. All three sites were located on the southern barrier reef: Cayo Sal 1, Cayo Sal 2, and Gresqui (Figure 1). Cayo Sal 1 is a near-vertical wall extending from approximately 10 meters depth to the bottom at about 45 meters. Cayo Sal 2 is a similar wall with its top at about 12 meters and its bottom at about 50 meters. Gresqui is a less vertical slope covered with soft corals giving way to a flat sand bottom at about 45 meters. Given the ongoing dialogue among scientists and managers about how to deal with aggregation research, exact coordinates of these sites are not provided in this paper.

Visual Census

These three sites were monitored for seven days after each full moon from February through August 2007 using underwater visual census. The week after the full moon captured the most likely aggregation periods for most snapper and grouper species based on observations in other parts of the Caribbean (Heyman *et al*. 2004a). Funding constraints prevented the execution of more than seven days of visual surveys each month. Because the locations of potential aggregations at each site were unknown, a continuous, long transect was followed on each dive in order to maximize the reef area covered. A two-diver team, one at 20 m depth and the other at 25 m depth, swam continuous transects for 21 minutes at each site. Within a 10 m high by 10 m wide transect, the divers recorded the abundance and size of individuals from a list of 26 locally-occurring species known or suspected to form transient reproductive aggregations in other parts of the Caribbean (Table 1). Because the length of transects varied with current speed and other factors, the divers towed a Garmin handheld GPS device in a waterproof case attached to a surface buoy to record the dive track. The divers consistently covered the same areas, despite variability in total transect length (extreme values of about 150 – 500 m, but generally about 350 – 400 m). Cayo Sal 1 and Gresqui were monitored once every two days, while Cayo Sal 2 was monitored every day. Dive surveys were conducted in the afternoon (between 13:00 and 18:30 hours) because the majority of the species under study are thought to spawn near dusk, or later.

Table 1. Species counted in underwater visual surveys.

Common Name	Scientific Name
Black margate	*Anisostremus surinamensis*
Jolthead porgy	*Calamus bajonado*
Blue runner	*Caranx crysos*
Crevalle jack	*Caranx hippos*
Horse-eyed jack	*Caranx latus*
Bar jack	*Caranx ruber*
Red hind	*Epinephelus guttatus*
Goliath grouper	*Epinephelus itajara*
Red grouper	*Epinephelus morio*
Nassau grouper	*Epinephelus striatus*
White grunt	*Haemulon album*
Blue-striped grunt	*Haemulon sciurus*
Hogfish	*Lachnolaimus maximus*
Mutton snapper	*Lutjanus analis*
Schoolmaster snapper	*Lutjanus apodus*
Cubera snapper	*Lutjanus cyanopterus*
Grey snapper	*Lutjanus griseus*
Dog snapper	*Lutjanus jocu*
Mahogani snapper	*Lutjanus mahogani*
Lane snapper	*Lutjanus synagris*
Comb grouper	*Mycteroperca acutirostris*
Black grouper	*Mycteroperca bonaci*
Yellowmouth grouper	*Mycteroperca interstitialis*
Tiger grouper	*Mycteroperca tigris*
Yellowfin grouper	*Mycteroperca venenosa*
Yellowtail snapper	*Ocyurus chrysurus*

RESULTS

Interviews

About 67% of the fishermen interviewed indicated predictable large (two or more times normal) catches of mutton snapper (*Lutjanus analis*) along the southern barrier reef around the full moon in May (Figure 2). Almost 75% of the fishermen interviewed indicated elevated catches of red hind (*Epinephelus guttatus*) at several sites in January around the full moon (Figure 2). About 23% of responses also indicated that until approximately 15 years ago, high catches of Nassau grouper (*Epinephelus striatus*) occurred in the central-northern part of the archipelago around the full moon in January (Figure 2). None of the other species in the study were mentioned by more than 10% of fishermen as being abundant in any given month.

Visual Census

No spawning events were directly observed during the study. Several species showed elevated abundance during certain months at individual sites, though the magnitude of the differences varied. For example, schoolmaster snapper (*Lutjanus apodus*) showed elevated abundance at Cayo Sal 1in August (Figure 3). The mean density of schoolmaster observed at this site in August was 0.35 individuals per 100 m^2. The average of the mean densities observed in the other months of the study was 0.12 individuals per 100 m^2. The highest density of this species observed at this site in August was 0.66 individuals per 100 m^2, on the third day after the full moon at 25 m depth. The average of the highest observations from the other months of the study was 0.29 individuals per 100 m^2 (Fig 3). A single-factor ANOVA analysis for this species at this site rejected the null hypothesis of no difference between monthly mean densities with significance of p = 0.001. In August the animals were observed displaying chasing and biting behaviors.

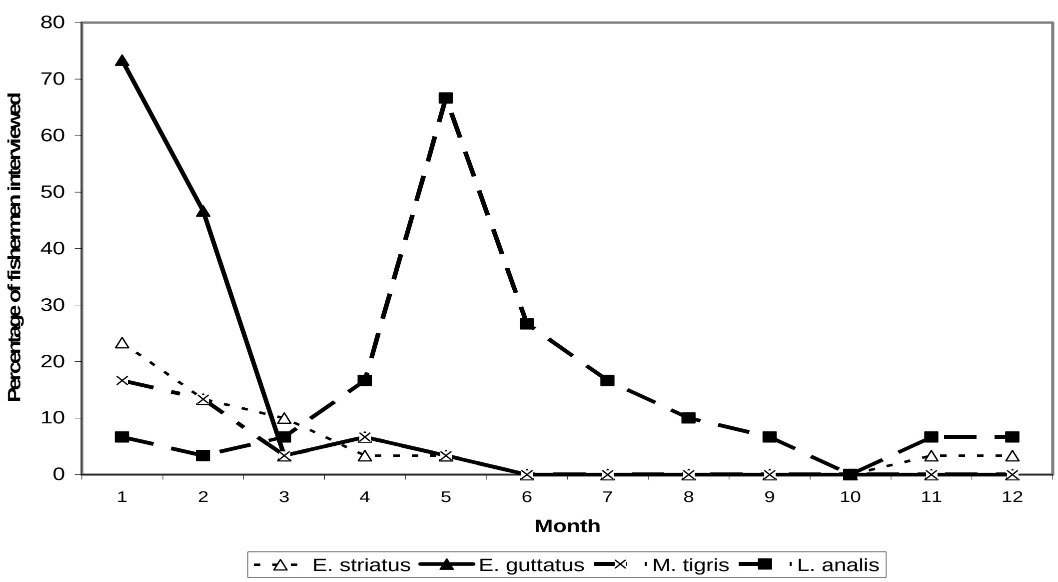

Figure 2. Periods of elevated catch (two or three times normal or more) for various species as reported in fishermen interviews (n = 30). None of the other species in table 1 were reported as abundant in any period by more than 10% of respondents.

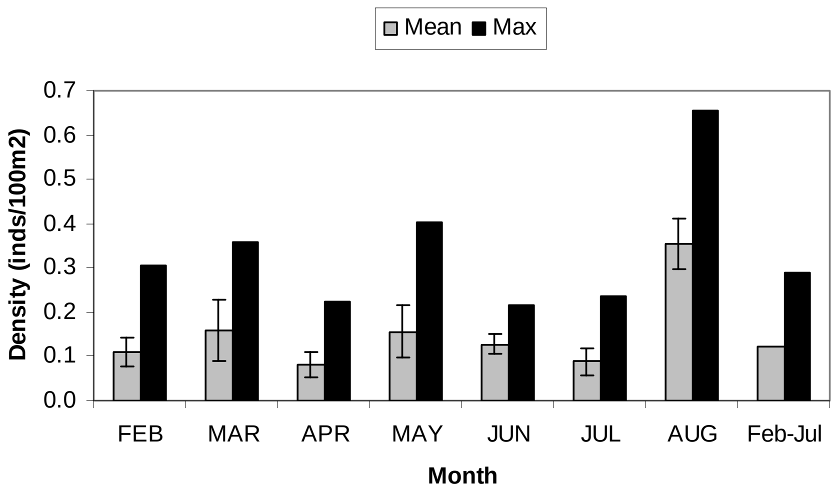

Figure 3. Mean and maximum monthly densities of schoolmaster snapper observed at Cayo Sal 1. Y error bars on average data represent +/- standard error. The total number (n) of dives (both 20 and 25 m transects) at this site is shown above each month's data.

DISCUSSION

These data are not sufficient to prove the existence of spawning aggregations at any site in Los Roques. However, the interviews and dive surveys provide initial indirect evidence of possible reproductive peaks for some species and areas. The fishermen interviews provide the strongest indirect evidence of possible spawning aggregations in the archipelago. Clear patterns in the epochs listed by fishermen for higher-than-normal catches of mutton snapper (*Lutjanus analis*) and red hind (*Epinephelus guttatus*) indicate that these species could be forming transient spawning aggregations at the sites mentioned by fishermen. About one-fourth of those interviewed described historical high catches of Nassau grouper (*Epinephelus striatus*) at various sites in the north-central archipelago around the full moon in January. All of them said that these catches declined and eventually stopped approximately 15 years ago. Many of these respondents were referencing stories told to them by their fathers or other older fishermen. The fishermen blame the decline on overfishing. It is possible that an annual spawning aggregation of Nassau grouper existed at this site and was eliminated by overfishing, as has occurred at other locations in the Caribbean (Sadovy and Eklund 1999). The smaller portion of fishermen who reported this aggregation compared to mutton snapper and red hind may be explained by decreasing knowledge of the extinct aggregation over time and/or by the fact that some of the fishermen interviewed may have limited their responses to their direct experience instead of relating stories told to them by older fishermen. It is possible that similar overfishing, perhaps especially before the declaration of the national park in 1972, also reduced populations and maybe aggregations of other grouper species, which were seen to have relatively low abundance in our dive surveys.

The visual census data suggest that several species may be forming spawning aggregations near the three monitoring sites during specific epochs, but do not provide conclusive evidence. Surprisingly, despite the strong evidence from fishermen interviews, spawning or even elevated abundance of mutton snapper (*Lutjanus analis*) was not observed in dive surveys at Cayo Sal in May or June. This aggregation may be forming in deeper water or over a different section of the reef.

The August increase in schoolmaster snapper abundance at Cayo Sal 1 suggests the possibility of a spawning aggregation of that species somewhere near that site in that month. The mean density of individuals observed at that site in August (0.35 inds./100 m^2) is roughly equal to three times the average of other monthly mean densities observed in the study (0.12 x 3 = 0.36 inds./100 m^2) (Figure 3). However, the maximum density observed on any single dive in August (0.66 inds/100 m^2, on the third day after the full moon at 25 m depth) is only slightly more than two times the average of the maximum densities observed in the other months of the study (0.29 inds./100 m^2). Hence, whether the data fulfill Domeier and Colin's subjective density-based definition of a spawning aggregation depends on which data (monthly average or monthly maximum) are used for the comparison. The highly significant difference between monthly mean densities at this site seen in the ANOVA analysis suggests that real differences in the abundance of schoolmaster snapper exist at this site, but does not prove that the variability is related to reproduction. Given the relatively low absolute abundance of schoolmaster snapper at this site even in

August, compared to observations of spawning aggregations elsewhere (Heyman *et al*. 2004a), a possible scenario is that a spawning aggregation of schoolmaster snapper occurs somewhere near, though not exactly at, this site. Since aggregations often occur in two successive months, an August spawning aggregation of schoolmaster snapper in this area would agree with informal observations of large, circling groups of these animals by one of the authors while diving in the area in September during the year previous to the study (J.P. Unpubl. data).

Similar to the situation with schoolmaster snapper, peak densities in our dataset are low for all of the species monitored with visual census (between about 0.5 and 1.5 inds./100 m^2). These abundances are too low in most cases to believe that spawning aggregations may have been happening directly at our monitoring sites. However, as suggested above for schoolmaster snapper, changes in the monthly abundance of a species around the full moon may be a sign of a spawning aggregation forming somewhere in the area of our study sites.

Another possibility is that the timing of spawning aggregations for some species with respect to the lunar calendar is different in Los Roques than in other areas (*i.e.* spawning does not occur or peak during the week after the full moon). In this case, aggregations could have occurred during the portions of the month during which we were not diving. While fishermen interviews suggest that at least some aggregative spawning occurs during the full moon, evidence from the literature shows that spawning can be spread throughout the lunar calendar. Brown-marbled groupers (*Epinephelus fuscoguttatus*) in the Pacific were observed to form aggregations during the full moon at one site and during the new moon at a nearby site (Rhodes and Sadovy 2002).

There is more work to be done to characterize spawning aggregations of reef fish in Los Roques. Future efforts should focus first on finding aggregation sites in an informal or *ad hoc* manner before beginning formal scientific monitoring of sites. It will be important to keep the Venezuelan government and the fishing community informed and involved as this project proceeds to maximize the chances for good management of these special areas in Los Roques.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support of the United Nations Environment Program/Caribbean Environment Program, the Los Roques Scientific Foundation (FCLR), and the US Fulbright Student Scholarship program (to JB). Humberto Camisotti provided invaluable aid, logistical assistance, and discussion. We are also grateful for the help of Denise Debrot, Pablo Mata, Moncho, Rodrigo Lazo, Eloy Cuevas, Lindsay Garbutt, Jeanette Pérez, Bladimir Rodriguez, and the benefactors of the FCLR.

LITERATURE CITED

Álvarez, B. 2004. Fecundidad y frecuencia de desove del mero tofía (*Epinephelus guttatus*), en el Parque Nacional Archipiélago Los Roques. Trabajo Especial de Grado. Universidad Central de Venezuela. Facultad de Ciencias. Escuela de Biología. 86 pp.

Burton, M.L., K.J.Brennan, R.C. Muñoz, R.O. Parker. 2005. Preliminary evidence of increased spawning aggregations of mutton snapper (*Lutjanus analis*) at Riley's Hump two years after establishment of the Tortugas South Ecological Reserve. *Fisheries Bulletin* **103**:404–410.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. *Gulf and Caribbean Research* **14**(2):91-106.

Claydon, J. 2004. Spawning aggregation of coral reef fishes: Characteristics, hypotheses, threats and management. *Oceanography and Marine Biology: An Annual Review* **42** 265-302.

Domeier, M.L. and P. Colin. 1997. Tropical reef fish spawning aggregations defined and reviewed. *Bulletin of Marine Science* **60**(3):698–726.

Drew, J.A. 2005. Use of traditional ecological knowledge in marine conservation. *Conservation Biology* **19**(4):1286-1293.

Heyman, W.D., J. Azueta, O. Lara, I. Majil, D. Neal, B. Luckhurst, M. Paz, I. Morrison, K.L. Bjorn, B. Wade and N. Requema. 2004a. Protocolo para el monitoreo de agregaciones reproductivas de peces arrecifales en el Arrecife Mesoamericano y el Gran Caribe. Versión 2.0. Meso–American Barrier Reef. System Project, Belize City, Belice. 57 pp.

Heyman, W.D. 2004b. Conservation of multi-species reef fish spawning aggregations. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:521-529.

Heyman, W.D., B. Kjerfve, R.T. Graham, K.L. Rhodes, and L. Garbutt. 2005. Spawning aggregations of *Lutjanus cyanopterus* (Cuvier) on the Belize Barrier Reef over six year period. *Journal of Fish Biology* **67**:83–101.

Heyman, W.D., J.L.B. Ecochard, and F. Biasi 2007. Low-Cost Bathymetric Mapping for Tropical Marine Conservation—A Focus on Reef Fish Spawning Aggregation Sites. *Marine Geodesy* **30**(1&2):37-50.

Kramer, P. 2003. Synthesis of coral reef health indicators for the western Atlantic: Results of the AGRRA Program (1997-2000). *Atoll Research Bulletin* **496**:1-58.

Kvernevik, T.I., M.Z.M. Akhir, and J. Studholme. 2002. A low-cost procedure for automatic seafloor mapping, with particular reference to coral reef conservation in developing nations. *Hydrobiologia* **474**:67-79.

Matos–Caraballo, D., J.M. Posada, and B.E. Luckhurst. 2006. Fishery-dependent evaluation of a spawning aggregation of tiger grouper (*Mycteroperca tigris*) at Vieques Island, Puerto Rico. *Bulletin of Marine Science* **79**(1):1-16.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Marine Ecology Progress Series* **286**:81–97.

Nemeth, R.S., E. Kadison, S. Herzlieb, J. Blondeau, and E.A. Whiteman. 2006. Status of a yellowfin grouper (*Mycteroperca venenosa*) spawning aggregation in the US Virgin Islands with notes on other species. *Proceedings of the Gulf and Caribbean Fisheries Institute* **57**:543-558.

Posada, J.M., E. Villamizar, and D. Alvarado. 2003. Rapid assessment of coral reefs in the Archipielago de los Roques National Park, Venezuela (Part 2: Fishes) *Atoll Research Bulletin* **496**:530-543.

Rhodes, K.L., and Y. Sadovy. 2002. Temporal and spatial trends in spawning aggregations of camouflage grouper, *Epinephelus polyphekadion*, in Pohnpei, Micronesia. *Environmental Biology of Fishes* **63** (1):27-39.

Sadovy, Y.M. 1994. Grouper stocks of the Western Central Atlantic: The need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:43-65.

Sadovy, Y.M. and A.M. Eklund. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1972), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Technical Memorandum NMFS 146, Pages 1 –65.

Sadovy, Y.M. and M. Domeier. 2005. Are aggregations fisheries sustainable? Reef fish fisheries as a case study. *Coral Reefs* **24**: 254–262.

Sadovy, Y.M., M. Domeier, K. Lindeman, B. Luckhurst, E. Sala, P. Colin, M. Russell, J. Gibson, M. Samoilys, R. Hamilton, T. Donaldson, and J. Robinson. 2007. Spawning Aggregations and Confidentiality: Balancing Research Products and Conservation Realities (Opinion Piece). Accessed Sept. 15 2007 at ww.scrfa.org.

Sala, E., E. Ballesteros, and R.M. Starr. 2001. Rapid Decline of Nassau Grouper Spawning Aggregation in Belize: Fishery Management and Conservation Needs. *Fisheries* **26**(10):23–30.

Whaylen, L., C.V. Pattengil – Semmens, B.X. Semmens, P.G. Bush and M.R. Boardman. 2004. Observations of a Nassau grouper, *Epinephelus striatus*, spawning aggregation site in Little Cayman, Cayman Islands, including multi–species spawning information. *Environmental Biology of Fishes* **70**(3):305–313.