Reef Fish Spawning Aggregations of the Puerto Rican Shelf

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ABSTRACT

Known spawning aggregation sites for commercial reef fishes from Puerto Rico consist only of several red hind (*Epinephelus guttatus*) sites and one each for rock hind (*Epinephelus adscensionis*), tiger grouper (*Mycteroperca tigris*) and mutton snapper (*Lutjanus analis*). Known non-commercial species spawning aggregation sites mentioned in the literature include: one each for the creole wrasse (*Clepticus Parrae*), stripped parrotfish (*Scarus iserti*), ocean surgeonfish (*Acanthurus bahianus*) and blue tang (*Acanthurus coeruleus*). In this study, we conducted an interview-based survey as a first step to identify additional potential sites throughout the entire Puerto Rican Archipelago including the islands of Mona, Desecheo, Culebra and Vieques. The survey targeted 50 key stakeholders consisting of commercial and sport fishers using skin-diving who were identified as knowledgeable, long-term users of local fisheries resources. Using charts and geographic information system (GIS) analysis, information was obtained about 27 past and 93 present "potential" (non-overlapping) spawning aggregation sites, spawning times, changes in species composition in time and space, spawning-site fidelity, as well as 76 sites supporting multiple spawning species. The information generated included a total of 61 species, though primarily snappers (12), groupers (11), jacks (8) and scombrids (4). In addition, a diverse and useful range of socio-economic and biological information was gathered, mainly from commercial fishers, which may prove useful in designating and managing potential MPAs.

KEY WORDS: spawning aggregations, reef fish, fishery, Puerto Rico, Caribbean.

Agregaciones Reproductivas de Peces de Arrecifes en la Plataforma de Puerto Rico

En Puerto Rico las áreas o sitios conocidos donde los peces de arrecifes de interés comercial se agregan para desovar consistían en sólo varios sitios para la cabrilla (*Epinephelus guttatus*) y un sitio para cada una de las siguientes especies el mero tigre (*Mycteroperca tigris*), la cabra mora (*Epinephelus adscensionis*) y otro para la sama (*Lutjanus analis*). Otros sitios de agregación reproductiva que se mencionan en la literatura, pero para especies no comerciales son: un sitio para cada una de las siguientes especies, creole wrasse (*Clepticus Parrae*), cotorro (*Scarus iserti*) y los médicos o cirujanos (*Acanthurus bahianus*) y (*Acanthurus coeruleus*). Se comenzó un estudio basado en entrevistas para obtener información de aquellos sitios que pudieran ser identificados como de agregaciones reproductivas "potenciales" en el archipiélago puertorriqueño, incluyendo a las islas territoriales de Mona, Desecheo, Culebra y Vieques. Durante el estudio se entrevistaron a 50 usuarios entre pescadores comerciales y recreativos que pescan a pulmón, identificados como conocedores y usuarios por mucho tiempo de los recursos pesqueros locales. Utilizando cartas náuticas y sistemas de información geográfica "GIS" se obtuvo información de 27 sitios de agregaciones reproductivas del pasado y 93 "potenciales" (no sobrelapadas) en el presente, época de desove, cambios de la composición de especies en el tiempo y en el espacio, fidelidad a los sitios de desove, y 76 sitios específicos de desove para múltiples especies. La información obtenida cubrió un total de 61 especies, principalmente pargos (12), meros (11), jureles (8) y escómbridos (4). En adición, diversos comentarios en un amplio marco socio-económico y biológico, fueron provistos principalmente por pescadores comerciales, que podrían ser muy útiles durante la designación y el manejo de áreas marinas con potencial a ser protegidas "MPAs".

PALABRAS CLAVES: agregaciones reproductivas, peces de arrecifes, Puerto Rico, Caribe.

INTRODUCTION

Puerto Rico, like many other Caribbean islands, has been experiencing a steady decline in catches of commercially important marine fishes (Appeldoorn 1992, Nemeth 2005). Most of these species, e.g., snappers and groupers, along with other fishes (e.g., Scaridae) have gregarious reproduction strategies (Claro and Lindeman 2003, Luckhurst 2003), restricting their spawning aggregations to highly predictable occurrences in space and time (Coleman *et al*. 1996). This reproduction strategy, coupled to life history traits of long life, slow growth, late maturation, large size and low natural mortality, makes them highly vulnerable to commercial and sport fishing pressure (Coleman *et al.* 2000). Spawning aggregations of coral reef fishes are well known to have biological and fishery importance (Domeier and Colin 1997, Domeier *et al*. 2002), but many aggregating species (e.g., Nassau grouper, *Epinephelus striatus* and goliath grouper, *E. itajara*) have been over fished, some to the point of commercial extinction (Sadovy and Eklund 1999, Colin *et al*. 2003). Nevertheless, if management/conservation intervention occurs before complete collapse, they have the potential to recover.

Declines in spawning aggregations (SPAGs) can impact commercial/recreational fisheries and produce a cascading effect on coral reefs. Given the key importance of SPAGs for population reproduction and fishery exploitation, knowledge of their location, time of occurrence and status are critical for sustainable management. Nevertheless, in Puerto Rico little has been documented on SPAG locations, occurrences, persistence and the species involved. Known spawning sites of aggregating commercial fishes from Puerto Rico are few (Table 1, Figure 1), consisting of several red hind (*Epinephelus guttatus*) sites along the southwest coast (Colin *et al.* 1987, Shapiro *et al*. 1993, Sadovy *et al*. 1994a), one for rock hind (*Epinephelus adscensionis*) (mentioned in Colin *et al*. 1987), one site in Vieques for the tiger grouper (*Mycteroperca tigris)* (Sadovy *et al*. 1994b, White *et al.* 2002) and one for mutton snapper (*Lutjanus analis*) on the southwest coast (Figuerola and Torres 2001). Another site located on the southwest coast off Guánica Bay was reported by Colin and Clavijo (1988), where spawning aggregations were documented for several non-commercial species: creole wrasse (*Clepticus Parrae*), stripped parrotfish (*Scarus iserti*), ocean surgeonfish (*Acanthurus bahianus*) and blue tang (*Acanthurus coeruleus*). Aggregations for Nassau grouper and jewfish occurred previously, but no longer exist (mentioned by Sadovy and Eklund 1999). This lack of critical information is an obvious gap in the management database, as evidenced by the few spawning aggregation sites documented in the "Environmental Impact Statement of the Caribbean Fisheries Management Council" (CFMC 2003) for Puerto Rican waters.

The main objectives of this work are to document "potential" spawning aggregation sites in the Puerto Rican Archipelago based on historical fishing activity by local artisanal commercial fishers (Colin *et al.* 1987) and more recently by some sport fishers who skin dive (Roberto Reyes and Jorge Rodriguez, "Apnea" Sport Fishing Group, and José Mario Cartagena, Puerto Rico Scuba, personal communications). Particular attention is given to snapper and grouper species with commercial importance. In addition, this work attempts to generate general public awareness of the importance of these aggregations and provide direct information to local and federal agencies to aid development of conservation and management initiatives.

METHODS

The survey was conducted through voluntary interviews with experienced fishery stakeholders. The selection of fishers was made by considering the fisher's experience, the type of fishing gear used, the coastal region of fishing activity and the certainty of a positive and voluntary collaboration. A total of 50 full interviews of commercial, sport fishermen (blue water skin divers), and displaced fishers were performed all around Puerto Rico including Vieques and Culebra islands. The interview tool was prepared following the "Fisher survey interview format general guidelines" from the Society for the Conservation of Reef Fish Aggregations (Sadovy 2003) and the "Reef Fish

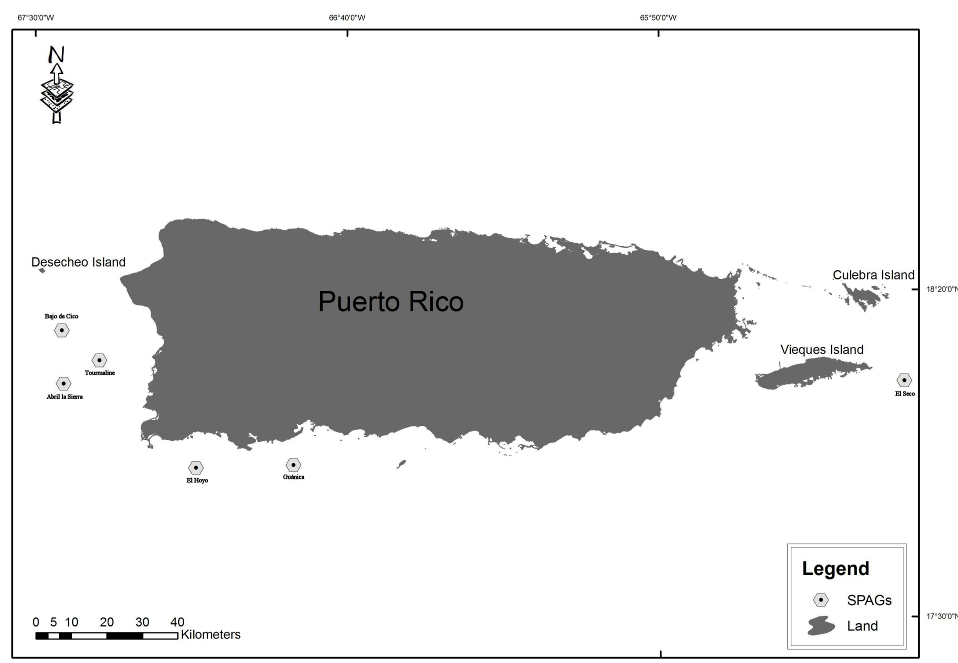

Figure 1. Known and verified spawning aggregations for Puerto Rico.

Spawning Aggregation Monitoring Protocol for the Wider Caribbean" (Heyman *et al*. 2002). Copies of nautical charts for each region were used to mark fishing and SPAGs sites during the interviews. A series of fish drawings, organized by families, were used to identify species, determine the different common names given to the same species in different coastal regions and collect additional information not mentioned in the other interview tools used.

A questionnaire with a set of 23 questions was prepared to obtain information on fisher characterization (age, fishing experience and source of fishing education, most frequent fishing areas, fishing gear used and fish species targeted), past and present known spawning aggregations with reference to bottom type, spawning times, spawning site fidelity, multispecies spawning sites, changes in species composition in time and space, factors governing SPAGs events, general comments as well as other valuable information.

To facilitate fisher selection, and in principle to have an even representation of fishers all around the insular shelf, the archipelago was subdivided into 12 artificially-delimited fishing zones. A total of four to six fishers were interviewed in each zone. For the north coast, where the island shelf is narrower and fisheries are more oriented to deep and pelagic species fishes, the number of fishermen interviewed was less than on the other coasts.

Historical landing records for main commercial species were obtained from the Fisheries Research Laboratory (FRL) of the Department of Natural and Environmental Resources (DNER) - Fishery Statistic Program (FSP) in order to document and compare commercial landings during species-specific reproduction seasons to data on the timing of reproductive aggregations obtained from the fishers. In addition, aerial surveys of fishing vessels concentrated in small areas for a limited time period during presumed red hind spawning peaks (Johnston *et al.* 2003, Nealson *et al.* 2004) were used to verify spatial data obtained in this study.

All fishing and SPAG data collected were first entered using electronic navigation charts, and were then converted to different geospatial layers using ArcView 9.1. Shapefiles were created for fishing aggregations, spawning aggregations, past spawning aggregations, sport fishermen fishing aggregation sites, and the observed boat positions during the 2002 and 2003 aerial censuses. For each site/area the type of species, fisher ID and bottom type reported by fishermen are available through the shapefiles. Due to the sensitive nature of this data and confidentiality between the fishers and the Principal Investigator, only general information will be disclosed. This will also protect identified sites from opportunistic fisheries, which was a condition for obtaining fishers' cooperation during interviews.

RESULTS

Characterization Fishers Surveyed:

The 50 fishers interviewed during this study averaged 52 years of age, ranging from 27 to 92 years, and the average 37 years of fishing experience, ranging from 10 to 78 years. The study reflected a strong tradition of passing historical fishing knowledge to the next generation. When fishers were asked about their source of fishing knowledge, multiple sources were given, but the majority of interviewees answered that they learned fishing from other close family members such as fathers, grandfathers, uncles and brothers. Some responded that they learned from friends, others on their own (through trial and error experiences) and others from older fishermen. When asked if they were fishing in the same fishing areas since they started fishing, 37 fishers answered that they haven't changed their general fishing areas, but that they usually rotate fishing grounds to let them recover. However, 21 included some additional new fishing grounds, mainly due to a change (decrease) in fish abundance close to shore. The preferred fishing gear

Table 1. Known spawning aggregations of commercially important species in Puerto Rico prior to this study and number of species now ascribed to these sites

Site	Location	Confirmed species	Number of species
El Hoyo	Southwest	*Epinephelus guttatus* *Epinephelus adscensionis*	9
Tourmaline	West	*Epinephelus guttatus*	9
Bajo de Sico	West	*Epinephelus guttatus*	6
Abril la Sierra	West	*Epinephelus guttatus* *Lutjanus analis*	10
El Seco	Vieques	*Mycteroperca tigris*	6

used by the fishers interviewed were (in order) fish traps and hook & line, followed by spearfishing (using scuba) and vertical drop-lines, in addition to other less frequently use gear. The highest number of fish species were captured using fishing traps.

The change of fishing grounds, usually deeper and closer to the shelf edge, were oriented to different target species, promoting a change in fishing gear to those that are more efficient and profitable, or in some specific cases, to less expensive gear. In other cases, some fish-trap fishers said they stopped using a gear due to declining catch rates and because their traps frequently were stolen. Different types of long-line fishing could, in the past, be used close to shore to target oceanic and coral reef species, but now fishermen using this type of gear need to travel near or beyond the shelf break, which increases their effort to make a living. The same has happened to fishers using fish traps, commercial spearfishing and hand collection methods. Today, all fishers must fish further from the coast and in deeper waters.

"Potential" Spawning Aggregation Sites:

Most fishers interviewed were aware that certain coral reef fish species aggregate at specific times and locations to reproduce. The majority acknowledged that they had personally fished spawning aggregations, which was generally evidenced by the fact that they consistently caught fish with ripe testes or ovaries and that the catch was comparatively large. In other instances, fishers identified all "fishing aggregations" as reproduction aggregations. This information was carefully evaluated in order to differentiate productive but non-reproductive fishing aggregation points or areas from spawning aggregations as the latter is frequently confused or assumed by commercial fishermen when fish are migrating to or are aggregated on foraging grounds.

Using fishers' testimonies and their marks on navigational charts, maps were drawn depicting information on 27 known past spawning aggregation areas, main sport and commercial fishing aggregation target areas, and 93 present "potential" spawning aggregation sites, where 76 sites were supporting multiple species spawning throughout the year. A site was considered a multispecies site when two or more species were reported utilizing the same area to reproduce. Curiously, some of the sites mentioned as past spawning areas by one fisher were mentioned by others as still active but on a lesser scale, e.g., El Hoyo, a site off of La Parguera, in southwest Puerto Rico. All well-known, documented and verified spawning sites for *E. guttatus, E. adscensionis, L. analis and M. tigris* in Puerto Rico were repeatedly mentioned during the interviews, but in addition, all these known sites were identified to be multispecies spawning sites (Table 1). A total of 61 species, primarily snappers (12), groupers (11), jacks (8) and scombrids (4) were reported by commercial fishermen as targets for fishing or "potential spawning" aggregations.

A total of 134 aggregations were reported, spread across 93 locations with no overlapping areas. These locations were, in the majority of cases, related to areas at or close to the shelf edge, although other numerous reports were spread over the shelf. The species characterized by the greatest number of fisher observations was *Ocyurus chrysurus* (yellowtail snapper). This species was followed closely by *Lutjanus synagris* (lane snapper) and *L. analis* (mutton snapper). There were only 9 observations for two species of deep-water snapper; *Etelis oculatus* (queen snapper) and *L. vivanus* (silk snapper) with a possible fishing-aggregation peaking period in April. In the general area of Desecheo Island, five fishermen reported sixteen (16) fish species, mostly groupers, reproducing in aggregations.

Timing of Spawning Aggregation:

There were 1,321 positive responses from fishermen in terms of the timing of spawning aggregations for the snapper-grouper complex (Table 2). Sixty-seven percent of the reported aggregations of groupers fell between December and February. The main exception was *Cephalopholis fulva* (Coney), which was more widely spread across months, although major peaks occurred from December to February. In contrast, 50% of observations for snappers were largely concentrated in the period from March to June. The remaining observations were more evenly distributed all year round, but principally for *L. apodus*, *L. griseus, L. jocu, L. campechanus, L. mahogani, L. synagris* and *O. chrysurus*.

In general, variations in monthly catch records from 1996 to 2002 (Figure 2) supported fishers' observations. Both the lane snapper (*L. apodus*) and yellowtail snapper (*O. chrysurus*) showed high variability in catch rates over the year, which matched fishers observations both in terms of variability and the suggested period of maximum spawning (Table 2, Figure 2). For the mutton snapper (*L. analis*), there were distinct peaks in catch that occurred from March to May, matching the limited spawning period reported. Similarly, the red hind showed peak catches in January and February, its limited period of spawning. However, this was not the case for Nassau grouper (*E. striatus*), where fishermen interviewed reported two spawning events: a major one during January-February and a minor one during August-September. Catch trends (Figure 2) show a peak only from July to September.

Of all fishers interviewed, 92% understood that the SPAGs are annually recurrent and show clear site fidelity. Very little displacement over time within an area was mentioned. This displacement was accounted for by different reasons but fundamentally due to yearly recurrent fishing pressure on the same area/site. Variability in spawning time, including the process of migration to their spawning grounds, is attributed by fishers to different reasons. In 90% of the interviews, fishers understood that the lunar phase is a critical factor determining the spawning process. Fishers also understood that other parameters might addi-

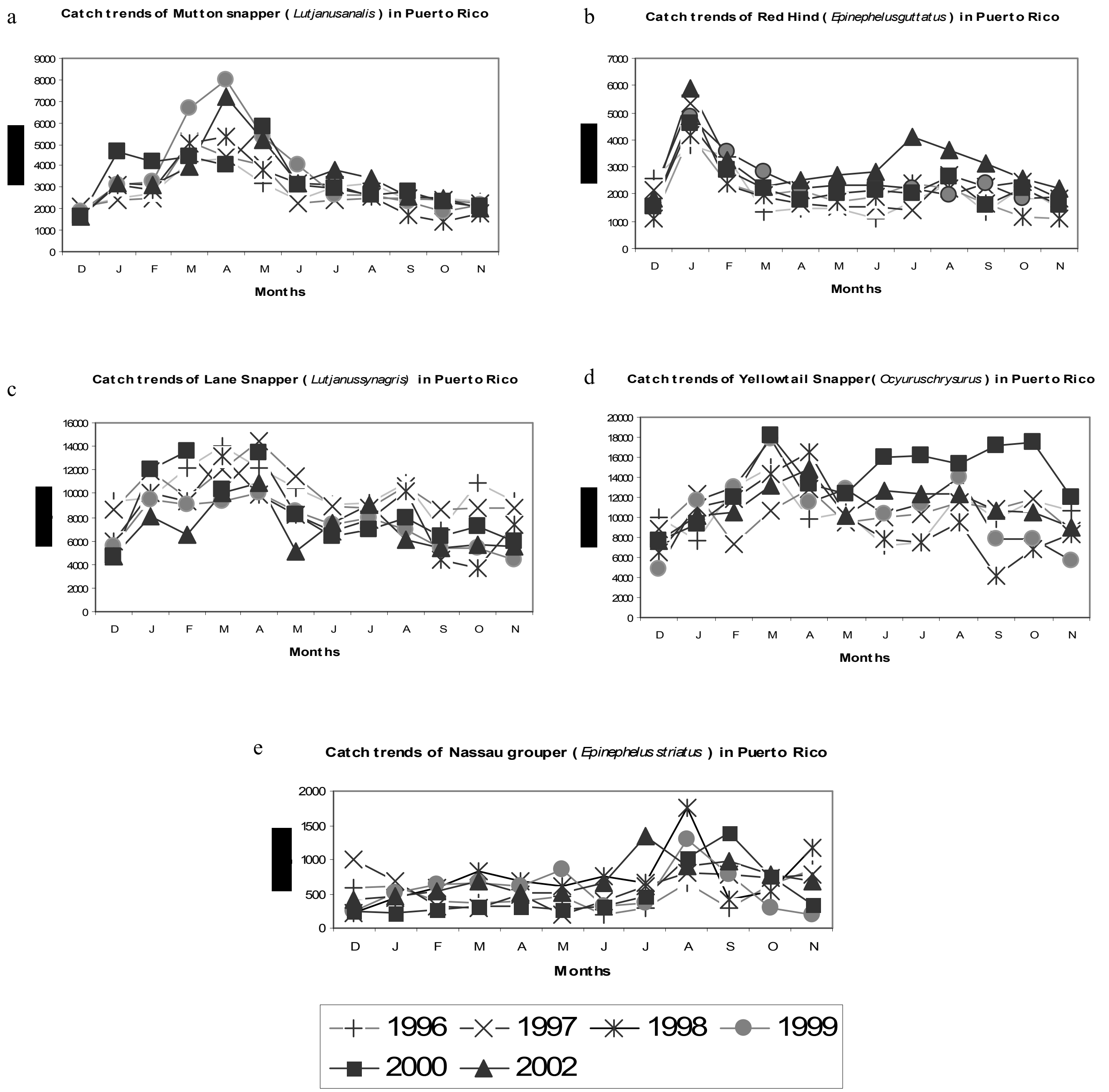

Figure 2. Catch trends of commercial landings (Kg) in Puerto Rico from 1996 to 2002 for: a) Mutton snapper (*L. analis)* b) Red hind (*E. guttatus*, c) Lane snapper (*L. synagris*), d) Yellowtail snapper (*O. crysurus)* and e) Nassau grouper (*E. striatus*).

A general observation is that experienced commercial scuba-divers (fishing with spearguns) were the ones giving the most complete information on species, related bottom type, and aggregation sightings.

When fishermen were asked if they had noted a change in the size of fish over time, 28 interviewees responded yes, 20 no, and two answered "do not know". The most common reasons given for these changes were due to overfishing, oil spills, and increase of sedimentation from runoff; however many responded that they didn't know the reason.

DISCUSSION

The locations of fishing boats determined from aerial surveys at the time of known red hind spawning events showed boats to be clustered at specific points, and that there was a close match between these points and the fishing aggregations reported by fishers. Most of the boats were located at or very near to the shelf edge, similar to the pattern found in this study. This shelf edge location of many aggregation sites has been validated in Puerto Rico for the red hind, the mutton snapper, the rock hind and the tiger grouper (Colin et al. 1987, Shapiro *et al*. 1993, Sadovy *et al*. 1994a, Figuerola and Torres 2001, White *et al*. 2002, Sadovy *et al*. 1994b), and by studies elsewhere, for example mutton snapper (Thompson and Munro 1974, Johannes 1978, Claro 1981). This spatial congruence and variations in mothly catch rates strongly suggest that fishers indeed target fishing spawning aggregations. While the results of this study support that of Heyman *et al.* (2002), indicating that many aggregations have strong site fidelity, as they occur in exactly the same location each year, other studies suggest that aggregations may shift from their traditional sites when heavy fishing pressure or disruption from divers occurs (Aguilar-Perera 2000, Heyman *et al.* 2002). The identification by fishers of 27 past SPAGs is a clear example the impact of extensive and unregulated fishing of aggregations has had in Puerto Rico, unfortunately a result that has occurred elsewhere throughout the tropics (Claydon 2004).

Usually the best means of obtaining information on spawning aggregations is compiling traditional knowledge from resource users (Heyman *et al.* 2002, Rhodes and Sadovy 2002). The main importance of this study is that it documents, for the first time, what areas are the most important for the commercial fisheries in Puerto Rico, and rescues the knowledge gained from the experiences of past and present local fisher generations on potential fish spawning aggregation sites including those that occurred in the past and where they continue to occur in the present. This critical information is urgently needed in order to preserve their persistence at a time when many stressors, such as sedimentation runoff, coastal contamination, climate change, natural hazards (e.g., hurricanes) and overfishing, are constantly affecting reef fish populations. Cornish (2005), mentioned that the SCRFA database has 557 records of spawning aggregations reported, comprising of 119 species from 18 families. However, many aggregations have yet to be validated. Therefore, the results of this work (61 fish species in 93 non-overlapping spawning sites) should be interpreted as preliminary information until field verification and characterization of the sites can be performed.

Given the potential importance of the spawning aggregations, management should incorporate the obtained into validation, monitoring and management regulations. The detailed shapefiles on fishing aggregations, spawning aggregations, past spawning aggregations, sport fishermen fishing aggregation sites, and the observed fishing boat positions during 2002 and 2003 for each site/area, including the type of species, fisher ID, bottom type and comments reported by fishermen will be available to management agencies. Both the Puerto Rico DNER and the federal Caribbean Fisheries Management Council, as well as appropriate NGOs and academic scientists are encouraged to use this information to develop conservation-based management strategies, e.g., the closure of aggregation sites during spawning times and the protection of sites as critical habitat. Furthermore, this information should be used in the process of selecting marine areas to be designated as MPAs.

Regardless of the management regime developed, it is imperative that fishers and other stakeholders are actively involved in planning and implementation. It was through the willing cooperation of fishers that the information from this study was obtained, and fishers can be additional sources of knowledge and strong partners in management if a relationship is properly cultivated.

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Table 2. Stakeholder observations of spawning aggregations by month for groupers and snappers. Shaded areas represent the obvious spawning peaks/fishing aggregations. Numbers represent the frequency of fishermen identifying spawning months at spawning sites by species identified.

Species	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Epinephelus adscensionis	8	7	5	1	1	1						2
Cephalopholis cruentata	2	5	4	1	1	1						1
Cephalopholis fulva	13	16	16	10	8	8	9	9	8	10	8	9
Epinephelus guttatus	22	38	32						1	1	2	
Epinephelus itajara	3	1							1	1		1
Epinephelus morio	3	3	2	2								1
Epinephelus striatus	4	9	6	1					3	3		2
Mycteroperca bonaci	2	3	1	2	3	2						1
Mycteroperca interstitialis	2	3	1	1	2	2						1
Mycteroperca tigris	7	9	7	1								
Mycteroperca venenosa	8	14	9	2	1	1						3
Lutjanus analis	3	4	4	28	34	32	9	3	3	1	2	2
Lutjanus apodus	5	5	4	4	7	5	4	6	8	7	5	4
Lutjanus campechanus	1	1	1	2	2	1	3	3	2	2	2	1
Lutjanus cyanopterus		1	1	2	3	2	2	3	3			
Lutjanus griseus	2	4	4	3	4	4	4	5	5	1	1	2
Lutjanus jocu	2	2	2	4	4	4	6	6	5	2	2	2
Lutjanus mahogani	10	10	10	16	17	18	11	11	10	7	9	9
Lutjanus synagris	11	11	11	19	21	21	13	12	11	9	11	11
Lutjanus vivanus & bucanella				2	2	1						
Ocyurus chrysurus	17	17	24	38	42	35	29	22	19	22	25	22
Etelis oculatus				1	2	1						