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Status Report on Fish Spawning Aggregations in the Mesoamerican Reef

2020

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The document authors (Araceli Acevedo, José Estrada, Jacobo Caamal and Stuart Fulton) would like to thank all the people of contributed to the reports, through the workshop, online questionnaire, and presential interviews. Cover photo: Alfredo Barroso.

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Executive summary

Scientific reports, and concerns about overfishing, on Fish Spawning Aggregations (FSA) in the Mesoamerican Reef (MAR) now date back over 70 years. Widespread conservation efforts, beginning in Belize, are now entering their fourth decade. The scientific literature is clear that protecting fish during spawning periods is critical to maintaining fish stocks. Through 21 online surveys, 15 interviews with key stakeholders and managers in Mexico, Belize, Guatemala, and Honduras, and extensive revisions of scientific publications and grey literature, we reviewed the status of 36 FSA sites. Despite significant past efforts, there is still a lot of work to be done to recover fish stocks to levels seen even a few decades ago. Managers, decision-makers, and researchers should be aware of a potential *shifting baseline* regarding knowledge transmission in and between institutions that manage FSAs. Several interviewees reported the current low abundances of spawning fish as having "*unknown*" tendencies in abundance, despite publications from the early 2000´s or before showing much higher numbers of fish. Uncertainty still exists about some potential FSAs that are yet to be visually validated, particularly in Honduras. Traditional ecological knowledge of fishers, or landings data suggest the presence of spawning fish, but visually verification will be need to geolocate the FSA site before spatial management tools can be applied. Interviewees highlighted the need to increase enforcement and ensure regular monitoring at the FSAs. Increased coordinated regional efforts across the four MAR countries is critical for the management of these transboundary species. Adaptative management to respond the climate change must begin to be implemented, and improved data management and sharing across the MAR are needed to ensure continuity.

Key recommendations

1. *Regional coordination*: Fish spawning aggregations are cross-boundary resources. They must be managed as such, through international collaborations and effective dialogue and decision-making between governments, academics, fishers, and civil society.
2. *Effective data management*: Data and knowledge loss has occurred over the previous decades due to personnel changes, siloed information, and poor data management. Regional digital ecosystems and repositories will reduce data loss.
3. *Standardized and systematic monitoring*: Simple, robust, and systematic indicators for each spawning site should be available, while sensitive data should be protected to prevent overfishing. Standardized monitoring protocols and a regional database, information hub and dashboards should be made available.
4. *Scientific principles and local knowledge*: Management tools should be based on the best scientific information available, effective design principles and always consider the traditional ecological knowledge of the local fishers.
5. *Encourage participation*: Concerns in the conservation community about fishers "discovering spawning sites" must be overcome. Fishers already know the sites. Participatory processes encourage best practices and in the long-term help fill the void left by underfunded and overstretched managing agencies.
6. *Adaptive management*: Climate change brings uncertainty. Management tools need to be continually reviewed over the coming decades.

Resumen ejecutivo

Los informes científicos y las preocupaciones por la sobrepesca en las Agregaciones Reproductivas de Peces (ARP) en el Sistema Arrecifal Mesoamericano (SAM), ahora se remontan a más de 70 años. Los esfuerzos de conservación, que comenzaron en Belice, ahora están entrando en su cuarta década. La literatura científica es clara y para mantener a las poblaciones de peces, es fundamental protegerlos durante sus períodos de desove. A través de 21 encuestas en línea, 15 entrevistas con actores claves en México, Belice, Guatemala y Honduras, y extensas revisiones de publicaciones científicas y literatura gris, revisamos el estado de 36 sitios ARP. A pesar de los importantes esfuerzos realizados en el pasado, aún queda mucho trabajo por hacer para recuperar las poblaciones de peces a los niveles vistos hace unas décadas atrás. Los manejadores y tomadores de decisiones deben reconocer una posible línea base cambiante con respecto a la transmisión de conocimiento dentro y entre las instituciones que administran las ARP. Varios entrevistados informaron que las bajas abundancias actuales de peces reproductores tienen tendencias "desconocidas" en abundancia, a pesar de que publicaciones de principios de los años 2000 o antes, mostraban un número mucho mayor de peces. Todavía existe incertidumbre acerca de algunas potenciales ARP que aún no se han validado visualmente, particularmente en Honduras. El conocimiento ecológico tradicional de los pescadores y los datos de desembarque sugieren la presencia de peces reproductores, sin embargo, es necesaria una verificación visual para geolocalizar el sitio de ARP antes de que se puedan aplicar las herramientas de gestión espacial. Los entrevistados destacaron la necesidad de aumentar la vigilancia y garantizar un monitoreo regular en las ARP. Incrementar los esfuerzos regionales coordinados en los cuatro países del SAM es fundamental para el manejo de estas especies transfronterizas. La gestión adaptativa para responder al cambio climático debe implementarse, y se necesita mejorar la gestión y el intercambio de datos en toda la región del SAM para garantizar la continuidad.

Recomendaciones claves

1. *Coordinación regional*: Las ARP son recursos transfronterizos. Para el manejo de éstos se requiere de colaboraciones internacionales, diálogos efectivos y la participación del gobierno, academia, pescadores y sociedad civil en la toma de decisiones.
2. *Manejo de datos efectivo*: La pérdida de datos y conocimiento ha ocurrido en décadas anteriores por diversas razones. Ecosistemas y repositorios digitales ayudarán a reducir la pérdida de información.
3. *Monitoreo estandarizado:* Los protocolos para un monitoreo estandarizado, bases de datos regionales y repositorios de información deben de ser accesibles al igual que indicadores simples, robustos y sistematizados para cada sitio de agregaciones. Los datos sensibles se tienen que proteger para evitar la sobre pesca.
4. *Principios científicos y conocimiento local:* Las herramientas de manejo deben basarse en la mejor información científica disponible, principios de diseño efectivos y en el conocimiento ecológico local.
5. *Fomentar la participación:* Procesos participativos promueven mejores prácticas y en el largo plazo contribuyen a llenar el vacío dejado por agencias de manejo con fondos insuficientes y sobredimensionados.
6. *Manejo adaptativo:* El cambio climático conlleva incertidumbre. Durante las próximas décadas, se deben de revisar arduamente estrategias de manejo.

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List of acronyms

COBI	Comunidad y Biodiversidad A.C.
CONANP	National Commission of Natural Protected Areas (Mexico)
CONAPESCA	National Commission of Aquaculture and Fisheries (Mexico)
CPUE	Catch per unit effort
CSO	Civil society organization
DIGEPESCA	Department of Fisheries and Aquaculture (Honduras)
DIPESCA	Department of Fisheries and Aquaculture (Guatemala)
ERI	University of Belize – Environmental Research Institute
FSA	Fish spawning aggregation
GDP	Gross domestic product
HRI	Healthy Reefs Initiative
ICF	National Institute for Conservation and Forestry (Honduras)
MAR	Mesoamerican Reef
NGO	Non-governmental organization
PA	Protected area
PROLANSATE	Foundation for the Protection of Lancetilla, Punta Sal and Texiguat (Honduras)
SEA	Southern Environmental Association
TASA	Turneffe Atoll Sustainability Association
TEK	Traditional ecological knowledge
TIDE	Toledo Institute for Development and Environment
WCS	Wildlife Conservation Society

Introduction

Fish Spawning Aggregations (FSA) are large, temporary gatherings of fish that meet for reproduction (Sadovy de Mitcheson & Colin 2012). On coral reefs, FSA occur at specific sites and periods of the year (Heyman & Kjerfve 2008, Colin 2012, Erisman et al. 2018). Sites can be multispecific, hosting a range of different species at different times of the year (Heyman & Kjerfve 2008). Individual fish can travel long distances to specific FSA sites, and the majority of a species´ reproductive output is concentrated on specific sites at specific times of year. FSA´s are critical life-cycle events for many commercial fish species, including groupers (Epinephelidae) and snappers (Lutjanidae) (Erisman et al. 2018). FSA´s can be found in all marine ecosystems - they have been documented in all five oceans - and, to date, 53 countries. While coral reef FSA´s are the most studied, overall, 52% of FSA´s have not been assessed by scientist and managers, and of those that have, 53% are in decline, and 15% have disappeared (Erisman et al. 2018).

Fishing FSAs is not considered sustainable (Sadovy & Domeier 2005), nor economically optimal (as the market receives an oversupply of a single species at a specific time, and prices are driven down - Sadovy and Domeier 2005). Large quantities of fish can be caught quickly, with minimum effort, and as the site remains the same over time, fishers can predict the arrival of the fish with accuracy. Fishing at FSA can appear stable, due to a concept known as hyperstability (Erisman et al. 2011). Hyperstability occurs when catch per unit effort (CPUE) remains high, even while the fish population declines. This scenario is particularly common in data-poor fisheries, such as fisheries found on many FSAs. As fish must come to FSA sites to spawn, fishing at FSAs means the fishers always see the peak abundance of the fish and continue to catch in abundance. At the same time, surrounding reefs are slowly depopulated, but fish continue to return to spawn at the FSA. The most famous example of an aggregating spawning species that suffered from hyperstability is the Atlantic cod (*Gadus morhua*), where catches remained high until massive population collapse (Rose and Kulka 1999).

The Mesoamerican Reef (MAR) is a Caribbean coral reef system that extents over 1,000 km from Cabo Catoche, Quintana Roo, Mexico to the Bay Islands, Honduras. The MAR ecoregion covers 457,536 km^2, and includes portions of Mexico, Belize, Guatemala and Honduras. The MAR is considered to be an area of high biodiversity. The coastal zone is home to 65 species of stony coral, more than 500 species of fish, including many emblematic marine species such as the Whaleshark (*Rhincodon typus*), five species of turtle, West Indian Manatee (*Trichechus manatus*), and the Goliath Grouper (*Epinephelus itajara*). Fishing is an important economic driver in the region, providing employment, income and food security to thousands of people. In Belize, fisheries contribute 5% of GDP and employs 2,400 fishers and more than 15,000 people involved in processing and export. Guatemala, with only 70 km of Caribbean coast, has more than 3,400 fishers. In Mexico, around 2,200 fishers operate from 25 fishing cooperatives, and although the annual catches include high value species like lobster, fishing contributes less than 0.1% of GDP in Quintana Roo due to the importance of tourism. In Honduras, fisheries contribute 6.2% of GDP, and about 10,000 small-scale fishers operate on the Caribbean coast (Green et al. 2017).

This is the first MAR-wide FSA status report, but it draws heavily on previous valuable research. Table 1 includes a summary of the most important documents on FSA distribution or status, and other key information.

Table 1 A summary of key documents about FSA distribution and status in the MAR

Title	Author	Year	Description
Agregaciones reproductivas de peces en el Sistema Arrecifal Mesoamericano: Consultoría Nacional –Mexico	Sosa-Cordero et al.	2002	Interviews and traditional ecological knowledge to identify possible FSA sites in Quintana Roo, Mexico
Status of Multi-Species Spawning Aggregations in Belize	Heyman & Requena	2002	Evaluation of Belizean FSA sites.
The Nassau Grouper Spawning Aggregation at Caye Glory, Belize: a Brief History	Paz & Truly	2007	A very thorough history of the best documented FSA in the MAR – Caye Glory, Belize (aka Emily).
Situación actual del mero de Nassau, *Epinephelus striatus*, en el Arrecife Mesoamericano	Aguilar-Perera et al.	2009	A summary report on Nassau grouper populations, fishing and FSA in the MAR.
Reporte de Agregación Reproductiva de Peces en Roatan Bank, Mariposales, La Grupera y Punta Pelicano, Cayos Cochinos, Honduras	Aronne	2009	Descriptive report of the FSA sites in the Bay Islands.
Brief History of Management and Conservation of Nassau grouper and their Spawning Aggregations in Belize: A Collaborative Approach	Burns-Perez, & Tewfik	2016	A summary of the work of the Belize Spawning Aggregation Working Group since 2001.
Reporte técnico y resultados de validación y monitoreo de los sitios de agregación reproductiva de pargos y meros en el centro y sur de Quintana Roo	Fulton, Caamal, Marcos, & Nalesso	2016	A report on the visual validation of the sites reported in Sosa-Cordero et al. (2002)
Plan for a network of Replenishment Zones (RZs) in northern Honduras	Chollett	2017	A plan for a network of fish replenishment zones, that includes an extensive literature review of known and presumed FSA in the Honduran Caribbean.
Mesoamerican Reef Report Card 2020	McField et al.	2020	The MAR report card includes a summary of FSA information for each country.

Historical information can play a key role understanding changes at FSA sites. Our scientific knowledge about FSAs has been collected over a limited timescale. Until the advent of SCUBA in the 1940s, FSA sites were only really known about because of the abundant catches fishers reported in certain months of the year. SCUBA allowed researchers to begin visual surveys of FSA sites, but by the time researchers in the MAR were diving on FSAs in the 1990´s, populations were already severely depleted. At present, a FSA with just 1,000 fish is considered a “large” or “unique” site, by both scientists and younger fishers, but we should recognize that today’s “normal” is potentially a significant decrease from the population of 50 to 100 years ago. This “shifting baseline” (Pauly 1995) has been reported for the same species in other regions (Saenz-Arroyo et al. 2005, Bravo-Calderon et al. 2020), and describes a situation in which it is currently hard to recognize past abundances as we only have current reference points with which to compare. From historical literature we see quotes such as the following, that seem unimaginable today:

“*According the fishermen, a grouper fishery… operated during December and January at Mahahual. In 1965, fishermen told [the interviewer] that they took 20 to 30 tons of grouper during this [time]*” (in: Miller 1982)

"The groupers congregate here in almost countless numbers in late December or early January; it is reported that they are so closely packed as to hide the white sand bottom" (Thompson 1944 - Caye Glory, Belize)

Catches in Caye Glory[1] were such that an experienced crew could catch 1,200 – 1,800 Nassau grouper per season (Craig 1966), and 300 boats headed to the site each during this time. Craig (1969) estimates that 90 metric tons of grouper could be caught in a season[2], but overfishing had already begun decades earlier. Jacques Cousteau, exploring Caye Glory, Belize in 1976, commented "*I think it would be very important to protect this area against any [fishery] improvement as a way to protect the [livelihoods] of these fishermen for years to come… The area to protect is tiny, but it would be enough"* (Cousteau 1976). What Cousteau discussed with the fisheries minister in 1976 still applies 45 years later. Small protected areas are recognized as an effective management tool for protecting spawning fishes (Erisman et al. 2017), and while any fishing on FSAs is not recommended, any increases in effort should be greatly discouraged.

This status report focuses on transient migrants[3] – fish which migrate long distances to spawn in the MAR. In this region, transient migrants including commercially important fish such as groupers (Epinephelidae) and snappers (Lutjanidae). These species form large FSAs and should be considered a transboundary resource. Nassau grouper can migrate more than 300 km to a FSA site (Bolden 2000), equivalent to a fish swimming from Guatemala to Mexico to spawn. While population movements between spawning sites are poorly understood, fish abundances at FSAs in the MAR continue to decline due to fishing pressure outside of spawning season, during migrations to spawning sites and due to legal or illegal fishing directly at the FSA sites. This transboundary nature highlights the importance of understanding the status of all the FSA in the MAR. Answering questions such as: what are the current and historic population levels? How are abundances changing? How much enforcement is needed and how effective is it? Where should overstretched resources for monitoring and enforcement be prioritized?

While groupers and snappers are present throughout the Caribbean, it is likely the MAR has significant self-recruitment that maintains local populations as Nassau groupers in the MAR are genetically distinct to those in the Eastern Caribbean and Bahamas (Jackson et al. 2014). This means that the actions we take in the MAR have direct impacts on the health of our fish stocks. However, it also means that the impacts of actions taken in just one of the MAR countries can be limited. This status report covers all of the known FSA sites in the MAR region, focusing principally on those that have been visually verified by SCUBA divers.

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[1] Today more commonly known as Emily.
[2] Considering that Nassau grouper reach maturity at approximately 48 cm (aprox. 1.9 kg – Fishbase) and average size at a US Virgin Island FSA was 60 cm (Nemeth et al. 2006) (aprox. 3.8 kg – Fishbase), this could represent between 23,873 and 47,750 individual fish being caught during the 1966 spawning season.
[3] Spawning of local residents, fish which spawn more frequently within their home range, also play an important role in reef health but are not included in this document. These fish tend to be smaller and are found at lower trophic levels (e.g. wrasse, parrotfish, and surgeonfish).

Methodology

Regional workshop

The workshop "*Fish Spawning Aggregation Monitoring in the MARFish Network*" was held in Cancun on the 21st and 22nd of November 2019. The goal of the workshop was to validate a common FSA strategy, prioritize the validation and monitoring of FSA sites, develop a common monitoring protocol and discuss FSA data sharing across the MAR. Twenty-eight people (13 women, 15 men) from 20 MAR organizations took part, representing civil society, fishing communities, resource managers and research organizations (see Annex 1 for the full list).

During the workshop, six plenary talks, and five group exercises and discussions were held, on topics such as traditional ecological knowledge, underwater censuses, and the use of new technologies such as passive acoustic monitoring, tagging, fishery monitoring, and eDNA.

A standardization in data collection was agreed, taking as a reference the work carried out in Belize, but incorporating new elements such as the measurement of sizes with laser devices. The development of a data sharing agreement for FSAs was begun, maintaining a certain level of privacy on key aspects such as the coordinates of the sites. The workshop allowed us to generate a preliminary list of FSA sites in the MAR, as well as an extensive list of contacts with whom we could follow up with for more specific information.

Survey and interviews

We published a survey in Google Forms (Annex 2) in English and Spanish, which was directed at workshop participants or people identified in the workshop who had information about FSAs in the MAR. The survey objective was to generate standardized information about visually verified FSAs, including components on geomorphological, ecological, geographic, and oceanographic particularities for each site, tendencies in fish abundance, and recommendations for improving management.

Twenty-one surveys were completed in Google Forms. The information was then used to arrange 14 face-to-face interviews in Belize and Honduras and one by videoconference in Guatemala. COBI personnel, supported by two partners from the Punta Allen community, travelled to Belize and Honduras, conducting 14 interviews with 16 managers. Interviews were carried out between 10-13th March in Belmopan and Belize City (Belize), and La Ceiba, Roatán and Tela (Honduras). Interviews were conducted in English and Spanish. Interviews were used to validate, and compliment information collected through Google Forms. In person interviews for the Mexican sites were no conducted as the interview team was based in Mexico and sufficient information was provided by the Google Forms surveys.

Data analysis

Replies from the Google Forms and in-person interviews about the FSA sites were stored digitally in an Excel database. Responses were categorized and used for analysis to characterize key components of the FSA sites. For this report, information from the interviews was compared and contrasted with previously published literature.

Status report

Information was collected on 36 FSA sites: eight in Mexico, 16 in Belize, one in Guatemala and 11 in Honduras. The numbers differ from previous studies. For example: Belize (13 FSAs - Paz & Grimshaw 2001, McField 2020) or Honduras (6 FSAs sites - McField et al. 2020; 13 FSAs – Hasbun et al. 2011; 21 potential FSAs - Chollet 2017). Discussion and uncertainty occur around what actually consists a FSA site (Chollett et al. 2020). However, here we report all the information from the interviews conducted with stakeholders in March 2020, and from the November 2019 workshop "*Fish Spawning Aggregation Monitoring in the MARFish Network*". We then contrast and compare this information with previous studies and publications.

<u>Protection status</u>

94% of the sites are within Protected Areas (PA) (Figure 1). These PA´s are generally zoned for multiple uses and being inside a PA does not mean that fishing is prohibited at the FSA sites. Similarly, The Belizean spawning aggregation marine reserves (statutory instruments SI-162 and SI-49) used to protect FSAs can be declared outside of PA´s (e.g. Gladden Spit and Emily). In total, 22 FSAs are fully protected year-round for grouper and snapper fishing (MEX:5, BZE:16, GUA:1, HON:0), but only 15 of these sites have been visually verified by divers to have spawning fish (Annex 3). Honduras has six verified FSA zones that are temporally closed during spawning season.

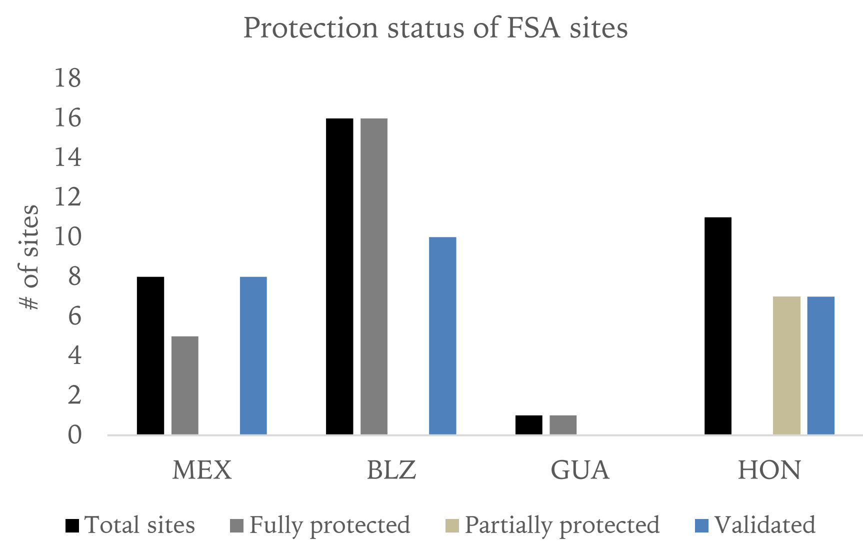

Figure 1 - Protection status of FSAs reported by interviewees

<u>Geophysical characteristics</u>

The majority of the sites (58%) are found at depths between 20 and 35 m. Shallow (less than 20m) FSAs are uncommon (3%), and 14% are at depths greater than 35 m. A quarter of the sites do not have depth information (Figure 2). Seafloor geomorphology is consistent with previous publications (Kobara et al. 2013) with 56% of FSAs occurring on reef promontories, and 36% on reefs with slight slopes (Figure 2). 58% of the sites are near deep water (> 500m)[4], 49% are near

[4] 11% did not have this information

a shallow lagoon (including mangroves or atolls), and 40% of the sites are in areas of convergent currents[5].

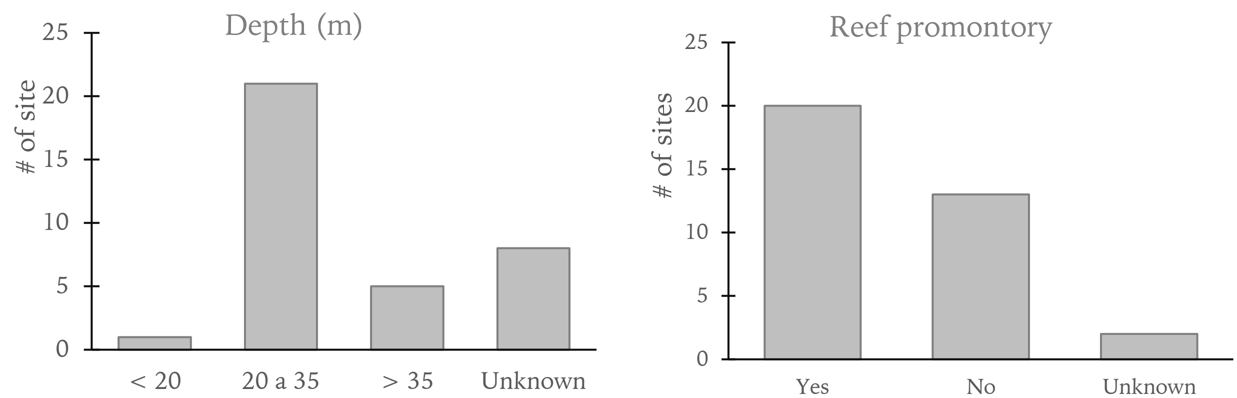

Figure 2 - Geophysical characterization of the FSA sites

<u>Management and monitoring</u>

Government agencies play a very important role in the management and surveillance of FSA sites in the MAR. 47% of the sites are managed by the government of their respective country, 19% are managed by the government in conjunction with NGOs / CSOs and 19% are managed only by CSOs. Government agencies, or with co-managers are responsible for enforcement at 58% of the sites. In just 8% of the sites, fishers participate in enforcement in coordination with government agencies. CSOs dominate monitoring, either independently or in collaboration with research institutions, government or fishing organizations.

Figure 3 - Stakeholder involved in management, enforcement and monitoring

[5] 36% lack sufficient data to confirm

Threats

The main threats reported for the 36 FSA sites are illegal fishing, overfishing, fishing by fishers from outside the community, the use of illegal fishing gear (pots, nets and lines), the presence of larger boats (some of them industrial fishing vessels), pollution (fertilizers and solid waste dumped into the sea), climate change, lack of enforcement and increasing tourism (Figure 4).

Figure 4 - Multilingual word cloud of the most mentioned words in the interviews

Enforcement

The ease of enforcement varies significantly, mostly related to distance from the organization´s base or prevailing weather conditions at the site. Interviewees consider enforcement at FSA sites to be relatively difficult or difficult (33%), moderate (28%) and easy or relatively easy (31%). The remaining sites did not have information or were reported as “unknown”.

Management recommendations

Most interviewees made management recommendations that can be grouped in to the four categories found in Table 2.

Table 2 - Management recommendations made by the interviewees

Enforcement	Significant improvements in enforcement need to be made, particularly during grouper and snapper spawning periods, and ideally involving members of the community or fishing organizations. New technologies should be implemented to improve enforcement.
Monitoring	Site validation needs to be conducted at possible FSA sites to visually verify whether spawning fish are present. Continuous biological monitoring efforts should be made, complemented with oceanographic monitoring, new technologies (e.g. acoustic sensors), standardized trainings for survey divers and improved database management.
Site protection	Protected areas should be created on FSA sites that are not currently protected. Spawning species should also be protected with other management tools such as closed seasons or moratoriums. Coordinated efforts between agencies should be improved for more effective management and enforcement.
Citizen science	Environmental awareness campaigns targeted at fishers and the general public should be launched. Fishers and their families should be involved in generating information to manage and protected FSAs.

Figure 5 – Map of FSA sites included in this study

[please contact the document authors for an image of the map. The exact location and coordinates of each spawning site is not included in this report to protect the sites against additional fishing pressure]

Mexico FSA site summary

Site name	Cayo Lobos			Blanquizal			Mahahual		
Inside protected area	Banco Chinchorro Biosphere Reserve			Arrecifes de Xcalak National Park			Caribe Mexicano Biosphere Reserve		
Protected from fishing	No			No			No		
Type of spatial protection	NA			NA			NA		
Protected Area manager	CONANP			CONANP			CONANP		
Organization responsible for enforcement	CONANP			CONANP			CONANP		
Organization responsible for monitoring	No organization currently monitors the site			Instituto Tecnologico de Chetumal			No organization currently monitors the site		
Fishing pressure at site	Moderate			Unknown			Unknown		
Ease of enforcement	Difficult			Easy			Relatively easy		
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency
Epinephelus striatus	ND	No (TEK)[6]	Unknown	2000-5000	Yes	Increasing	1000	Yes	Extinct
Epinephelus guttatus				50-100	No (TEK)	Unknown	1-50	Yes	Unknown
Mycteroperca bonaci				50-100	Yes	Increasing			
Mycteroperca venenosa									
Mycteroperca tigris				250-1000	Yes	Increasing			
Lutjanus jocu									
Lutjanus analis	3000	Yes	Unknown						
Lutjanus cyanopterus				100-250	No (TEK)	Unknown			
Lutjanus griseus									
Lutjanus synagris									
Ocyurus chrysurus	ND	No (TEK)	Unknown						
Notes	The large school of snappers has been observed once (2013). Spawning of *Balistes capriscus* has also been visually verified. Other FSAs are reported by the fishers in Banco Chinchorro, but have yet to be visually verified. Fishers from three cooperatives fish this site for snapper each year. CONANP has monitored the FSA fishery in the past.			Large aggregations of grouper were first documented in 2001. Monitoring has occurred on and off since then.			The FSA was the first to be documented in the Mexican Caribbean (1998). FSA was reported extinct in 2013. Subsequent expeditions have not found spawning fish. Historically, this was a very productive fishing spot with reports of landings of 24 tons per season in the 1950´s.		
Citations	Heyman et al. 2014, Castro-Perez et al. 2011			Medina-Quej et al. 2004			Aguilar-Perera 1994, Aguilar-Perera & Aguilar-Dávila 1996, Aguilar-Perera 2006, Aguilar-Perera 2013		

[6] Traditional Ecological Knowledge

Site name	Maya Ha			Niche Habin (Punta Allen)			El Faro (Punta Herrero)		
Inside protected area	Caribe Mexicano Biosphere Reserve			Sian Ka´an Biosphere Reserve and Arrecifes de Sian Ka´an Biosphere Reserve			Sian Ka´an Biosphere Reserve		
Protected from fishing	Yes			Yes			Yes		
Type of spatial protection	Public use Subzone Riviera Maya and Mahahual			Fish refuge zone			Fish refuge zone		
Protected Area manager	CONANP			CONANP/CONAPESCA			CONANP/CONAPESCA		
Organization responsible for enforcement	CONANP			CONAPESCA			CONAPESCA		
Organization responsible for monitoring	No organization currently monitors the site			SCPP Pescadores de Vigía Chico/COBI			SCPP José María Azcorra/COBI		
Fishing pressure at site	Low			None			None		
Ease of enforcement	Moderate			Moderate			Easy		
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency
Epinephelus striatus				1000-2000	Yes	Increasing	100-250	Yes	Decreasing
Epinephelus guttatus									
Mycteroperca bonaci	1-50	Yes	Unknown	1-50	Yes	Unknown	1-50	Yes	Unknown
Mycteroperca venenosa							1-50	Yes	Unknown
Mycteroperca tigris									
Lutjanus jocu							100-250	Yes	Stable
Lutjanus analis							250-1000	Yes	Stable
Lutjanus cyanopterus	1-50	Yes	Unknown				100-250	Yes	Unknown
Lutjanus griseus									
Lutjanus synagris									
Ocyurus chrysurus	1-50	Yes	Unknown						
Notes	No spawning was observed (2014). Spawning indicators were colour changes, aggregating fish and behaviour. The site has not been revisited. The subzone only permits lobster and catch and release sport fishing.			Spawning has been observed on several occasions. First documented 2005. Protected for five years in 2016.			Documented for first time in 2009. Protected 2012 (expires 2024). No spawning has been observed. Spawning indicators include colour changes, aggregating fish and behaviour		
Citations	Fulton et al. 2016			Franquesa-Rinos & Loreto-Viruel 2006, ASK & COBI 2010, Fulton et al. 2016, Fulton et al. 2018			Franquesa-Rinos & Loreto-Viruel 2006, ASK & COBI 2010, Fulton et al. 2016, Fulton et al. 2018		

Site name	San Juan			Xahuayxol		
Inside protected area	Sian Ka´an Biosphere Reserve and Arrecifes de Sian Ka´an Biosphere Reserve			Arrecifes de Xcalak National Park/Caribe Mexicano Biosphere Reserve		
Protected from fishing	Yes			Yes		
Type of spatial protection	Fish refuge zone			Core zone of Arrecifes de Xcalak National Park		
Protected Area manager	CONANP/CONAPESCA			CONANP		
Organization responsible for enforcement	CONAPESCA			CONANP		
Organization responsible for monitoring	SCPP Pescadores de Vigía Chico/COBI			Instituto Tecnologico de Chetumal		
Fishing pressure at site	Unknown			Unknown		
Ease of enforcement	Relatively difficult			Difficult		
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency
Epinephelus striatus	200	Yes	Decreasing	250-1000	Yes	Unknown
Epinephelus guttatus						
Mycteroperca bonaci	100	Yes	Decreasing			
Mycteroperca venenosa	1-50	Yes	Decreasing			
Mycteroperca tigris						
Lutjanus jocu						
Lutjanus analis						
Lutjanus cyanopterus						
Lutjanus griseus						
Lutjanus synagris						
Ocyurus chrysurus						
Notes	First documented 2005. Protected for five years in 2016. No spawning has been observed. Spawning indicators include colour changes, aggregating fish and behaviour. Maximum abundances were seen in 2010, current abundances are much lower <50 fish)			This site has been poorly documented. The FSA is suspected to be on the boundary of PN Arrecifes de Xcalak and RB Caribe Mexicano. Both areas do not allow finfish fishing so the site is protected.		
Citations	Franquesa-Rinos & Loreto-Viruel 2006, ASK & COBI 2010, Fulton et al. 2016, Fulton et al. 2018			Aguilar-Perera, Gonzalez-Salas & Villegas-Hernandez 2008		

Belize FSA site summary

Site name	Caye Bokel			Dog Flea Caye	Emily (Caye Glory)		
Inside protected area	Turneffe Atoll			Turneffe Atoll	No		
Protected from fishing	Yes			Site is protected but the aggregation location needs to be recharacterized.	Yes		
Type of spatial protection	Marine reserve[7]			Marine reserve	Marine Reserve		
Protected Area manager	TASA			TASA	Belize Fisheries Department		
Organization responsible for enforcement	TASA			TASA	Belize Fisheries Department		
Organization responsible for monitoring	University of Belize – Environmental Research Institute (ERI)			University of Belize – Environmental Research Institute (ERI)	Belize Fisheries Department		
Fishing pressure at site	High for snappers			ND	Low		
Ease of enforcement	Relatively difficult			ND	Moderate		
Species	**Max. abundance**	**Visually verified?**	**Abundance tendency**	**Information that suggests the site is a FSA**	**Max. abundance**	**Visually verified?**	**Abundance tendency**
Epinephelus striatus				No fish have been sighted at this site since 2015. Managers report that the FSA may have moved. Data on species presence and abundances were not available.	238	Yes	Unknown
Epinephelus guttatus							
Mycteroperca bonaci					1-50	Yes	Unknown
Mycteroperca venenosa					1-50	Yes	Unknown
Mycteroperca tigris					1-50	Yes	Unknown
Lutjanus jocu	1-50	Yes	Decreasing		1000-2000	Yes	Unknown
Lutjanus analis	1-50	Yes	Decreasing		1-50	Yes	Unknown
Lutjanus cyanopterus	1-50	Yes	Decreasing				
Lutjanus griseus							
Lutjanus synagris							
Ocyurus chrysurus	1-50	Yes	Decreasing		23	Yes	Unknown
Notes	Other species reported - *Trachinotus falcatus, Caranx ruber, C. latus, C. hippos*. <15 *E. striatus* were reported in 2000, along with 500 *L. jocu,* 300 *L. analis*, and 23 *M. bonaci*. Green Reef monitored the site in 2002. UB-ERI has monitored the site since 2015. Numbers are low and decreasing. Researchers believe fishing may have moved the site deeper.			Was surveyed in 2000. 100 *E. striatus* were reported, including colour changes. Green Reef monitored the site in 2002. The site was reported to have two species of spawning fish. Monitoring in 2011-2013 reported no fish. Managers believe some fishers know the new location of the FSA. ROV and fish finder searches in 2020 did not locate the site.	Data from 1999 report 3,000 *E. striatus*, declining to new zero in 2001-2002, before increasing to approximately 250 in 2005. Divers reported 2,000 fish in 2014, falling to 238 in 2019.		
Citations	Paz & Grimshaw 2001, Heyman & Requena 2002			Paz & Grimshaw 2001, Heyman & Requena 2002, Burns-Perez & Tewfik 2015	Paz & Grimshaw 2001, Heyman & Wade 2007, Burns-Perez & Tewfik 2015, Cho-Ricketts 2019		

[7] "Marine reserve" refers to sites protected by the 2003 (SI-162) and 2009 (SI-49) statutory instruments. For more information consult: http://www.spagbelize.org/Legislation.aspx

Site name	Gladden Spit			Half Moon Caye Elbow			Mauger Caye		
Inside protected area	Gladden Spit Silk Cayes Marine Reserve			Half Moon Caye Natural Monument			Turneffe Atoll		
Protected from fishing	Seasonal Protection			Yes			Yes		
Type of spatial protection	Marine Reserve			Natural Monument			Marine Reserve		
Protected Area manager	SEA			Belize Audubon Society/Belize Forest Department			TASA		
Organization responsible for enforcement	SEA			Belize Audubon Society			TASA		
Organization responsible for monitoring	SEA			Belize Audubon Society			University of Belize – Environmental Research Institute (ERI)		
Fishing pressure at site	Moderate			Zero			Low		
Ease of enforcement	Difficult			Moderate			Moderate		
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency
Epinephelus striatus	1-50	Yes	Decreasing	11	Yes	Unknown	400-500	Yes	Increasing
Epinephelus guttatus	1-50	Yes	Unknown						
Mycteroperca bonaci	1-50	Yes	Unknown				10-15	Yes	Unknown
Mycteroperca venenosa	1-50	Yes	Unknown				1-50	Yes	Unknown
Mycteroperca tigris	1-50	Yes	Unknown				<10	Yes	Unknown
Lutjanus jocu	5000	Yes	Stable	1800	Yes	Decreasing	1-50	Yes	Unknown
Lutjanus analis	2000-4000	Yes	Unknown						
Lutjanus cyanopterus	250-2000	Yes	Stable						
Lutjanus griseus									
Lutjanus synagris									
Ocyurus chrysurus	1-50	Yes	Unknown	1-50	Yes	Unknown			
Notes	Was surveyed in 2000, having 100 *E. striatus*. Friends of Nature monitored the site in 2002, the site had 350 *E. striatus*. Data from 2012-2015 show less than 200 *E. striatus*. 6,000 *L. analis* were seen 2017. Special permits are available for traditional fishers to fish mutton snapper (*L. analis*) between March and June.			Was surveyed in 2000 and had, 25 *M. bonaci*, 200 *L. jocu*, but no *E. striatus*. TNC monitored the site in 2002. It had 10 *E. striatus*. Only one *E. striatus* was recorded in 2006 (BAS data). *Lachnolaimus maximums* and *Caranx latus* also mentioned as potentially spawning at the site. It is defined as being important as a multi-species spawning aggregation site, with twenty species being recorded using the location over the course of the year.			Managers report that the aggregation has moved deeper. *Caranx* sp. also reported. 657 *E. striatus* reported in 2019. Monitored annual since 2013.		
Citations	Paz & Grimshaw 2001, Heyman & Requena 2002, Burns-Perez & Tewfik 2015, Cho-Ricketts 2019			Paz & Grimshaw 2001, Heyman & Requena 2002			Burns-Perez & Tewfik 2015, Cho-Ricketts 2019		

Site name	Nicholas Caye			Northeast Point (Northern Glovers)			Rise and Fall Bank
Inside protected area	Sapodilla Cayes Marine Reserve			Glovers Reef Atoll			Sapodilla Cayes Marine Reserve
Protected from fishing	Yes			Yes			Yes
Type of spatial protection	Marine Reserve			Marine Reserve			Marine Reserve
Protected Area manager	Belize Fisheries Department			Belize Fisheries Department			Belize Fisheries Department
Organization responsible for enforcement	Belize Fisheries Department			Belize Fisheries Department			Belize Fisheries Department
Organization responsible for monitoring	Belize Fisheries Department			WCS			Belize Fisheries Department
Fishing pressure at site	Low			Low			Low
Ease of enforcement	Easy			Difficult			Easy
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency	Information that suggests the site is a FSA
Epinephelus striatus	300	Yes	Stable	2000	Yes	Decreasing	No data exists about species found at the aggregation site
Epinephelus guttatus							
Mycteroperca bonaci	40	Yes	Unknown	1-50	Yes	Unknown	
Mycteroperca venenosa				1-50	Yes	Stable	
Mycteroperca tigris				1-50	Yes	Stable	
Lutjanus jocu							
Lutjanus analis							
Lutjanus cyanopterus							
Lutjanus griseus							
Lutjanus synagris							
Ocyurus chrysurus							
Notes	TIDE monitored the site in 2002. 100-200 *E. striatus* were reported 2014-2015, but only 107 were seen in 2018.			Other species reported include *Caranx ruber, Carangoides bartholmaei, Elagatis bipinnulata.* Monitoring in 1999 reported peaks of 3000 *E. striatus*. WCS monitored the site in 2002. It was reported to have 4,600 *E. striatus*. This had declined to 2,400 by 2005 and less than 500 by 2015. Anecdotally, 15,000 E. *striatus* were reported in the 1970´s. 900 *E. striatus* were reported in 2018, and 330 in 2019.			Six *E.striatus* were seen in 2001. Few other species were reported, TIDE monitored the site in 2002.
Citations	Heyman & Requena 2002, Burns-Perez &Tewfik 2015, Cho-Ricketts 2019			Sala et al. 2001, Heyman & Requena 2002, Heyman & Wade 2007, Burns-Perez & Tewfik 2015, Tewfik et al. 2019			Paz & Grimshaw 2001, Heyman & Requena 2002

Site name	Rocky Point	Sandbore			Seal Caye
Inside protected area	Bacalar Chico Marine Reserve	Lighthouse Reef Atoll			Sapodilla Cayes Marine Reserve
Protected from fishing	Yes	Yes			Yes
Type of spatial protection	Marine Reserve	Marine Reserve			Marine Reserve
Protected Area manager	Belize Fisheries Department	Belize Fisheries Department			Belize Fisheries Department
Organization responsible for enforcement	Belize Fisheries Department	Belize Audubon Society			Belize Fisheries Department
Organization responsible for monitoring	Belize Fisheries Department	Belize Audubon Society			Belize Fisheries Department
Fishing pressure at site	Low	Low			Low
Ease of enforcement	Moderate	Difficult			Easy
Species	**Information that suggests the site is a FSA**	**Max. abundance**	**Visually verified?**	**Abundance tendency**	**Information that suggests the site is a FSA**
Epinephelus striatus	Belize Fisheries Department report that there is an aggregation at the site, but the exact location has not been found.	2000-5000	Yes	Stable	Abundance and species information for this site was not provided
Epinephelus guttatus					
Mycteroperca bonaci		1-50	Yes	Decreasing	
Mycteroperca venenosa		1-50	Yes	Unknown	
Mycteroperca tigris		Unknown	Yes	Unknown	
Lutjanus jocu					
Lutjanus analis					
Lutjanus cyanopterus					
Lutjanus griseus					
Lutjanus synagris					
Ocyurus chrysurus		Unknown	Yes	Unknown	
Notes	No *E. striatus* seen in 2000. Bacalar Chico Marine Reserve monitored the site in 2002. Only three *E. striatus* were seen. Very low numbers also reported 2012-2015. Staff from Bacalar Chico Marine Reserve conducted monitoring in January 2019 and saw 300 *Haemulon album*, 600 *Lutjanus jocu*, 500 *Caranx ruber*, 800 *Caranx latus*, 100 *C. crysos* and 90 *Trachinotus falcatus* were reported. Eight *Mycteroperca bonaci* were seen in February 2018. More fish were seen deeper but were not visually identified.	*E. striatus* was reported as the most abundant species, but a maximum abundance estimate was not provided. *Trachinotus falcatus* and *Caranx* sp. were also reported for the site. Data from 2000 report >4,*000 E. striatus*, declining to 2,000 in 2005. TNC monitored the site in 2002. Divers reported 450 *E. striatus*. Data from 2016-2018 show between 3,000 - 4,000.			TIDE reportedly monitored the site in 2002 but the site has not been monitored recently.
Citations	Paz & Grimshaw 2001, Heyman & Requena 2002, Burns-Perez & Tewfik 2015	Paz & Grimshaw 2001, Heyman & Requena 2002, Burns-Perez & Tewfik 2015, Heyman & Wade 2007, Belize Audubon Society 2019			Heyman & Requena 2002

Site name	Southpoint			Soldier Caye	Tiger Bank		
Inside protected area	No			Turneffe Atoll	Glovers Reef Atoll		
Protected from fishing	Yes			Yes	Yes		
Type of spatial protection	Marine Reserve			Conservation Zone	Conservation Zone		
Protected Area manager	Belize Fisheries Department			TASA	Belize Fisheries Department		
Organization responsible for enforcement	Belize Audubon Society			TASA	Belize Fisheries Department		
Organization responsible for monitoring	Belize Audubon Society			No organization currently monitors the site	WCS		
Fishing pressure at site	Moderate			Unknown	Moderate		
Ease of enforcement	Moderate			Unknown	Easy		
Species	**Max. abundance**	**Visually verified?**	**Abundance tendency**	**Information that suggests the site is a FSA**	**Max. abundance**	**Visually verified?**	**Abundance tendency**
Epinephelus striatus							
Epinephelus guttatus							
Mycteroperca bonaci							
Mycteroperca venenosa							
Mycteroperca tigris	Unknown	Yes	Unknown	The site was last monitored in 2013-2014. No information about species abundance was provided.	1-50	Yes	Stable
Lutjanus jocu	762	Yes	Increasing				
Lutjanus analis	3000	Yes	Unknown				
Lutjanus cyanopterus	3500	Yes	Increasing				
Lutjanus griseus							
Lutjanus synagris							
Ocyurus chrysurus	4500	Yes	Increasing				
Notes	*Carangoides bartholomaei, T. falcatus, Caranx sp. L. apodus.* were seen in 2016. *Caranx sp, M. bonaci, M. tigris, E. striatus, O. chrysurus* and *Lutjanus jocu* were seen in 2002.			Green Reef monitored the site in 2002. Only six *E. striatus* were seen. A small number of *M. bonaci* were seen in 2002. UB-ERI monitored the site in 2013.	First documented in 2003-2004. WCS began monitoring the site in 2015 50 *M. tigris* seen in 2019		
Citations	Heyman & Requena 2002			Heyman & Requena 2002	Starr et al. 2018, Tewfik et al. 2019		

Site name	**Northern Two Cayes**
Inside protected area	Lighthouse Reef Atoll
Protected from fishing	Yes
Type of spatial protection	Marine Reserve
Protected Area manager	Belize Fisheries Department/Belize Audubon Society
Organization responsible for enforcement	Belize Audubon Society
Organization responsible for monitoring	Belize Audubon Society
Fishing pressure at site	Unknown
Ease of enforcement	Unknown
Species	**Information that suggests the site is a FSA**
Epinephelus striatus	This site supported a Nassau grouper fishery in the past, but has not been monitored recently
Epinephelus guttatus	
Mycteroperca bonaci	
Mycteroperca venenosa	
Mycteroperca tigris	
Lutjanus jocu	
Lutjanus analis	
Lutjanus cyanopterus	
Lutjanus griseus	
Lutjanus synagris	
Ocyurus chrysurus	
Notes	Statutory Instrument 162 of 2003 lists this site as being fished for Nassau Grouper based on a special license. However, this practice is now discontinued. SI-49 of 2008 legally protects this site. No monitoring has been conducted.
Citations	

Guatemala FSA site summary

Site name	Corona Caiman		
Inside protected area	No		
Protected from fishing	Yes		
Type of spatial protection	Temporal Spatial Closure (10 years) Ministerial Agreement 85-2020		
Year first documented as FSA	Spawning not yet visually verified		
Protected Area manager	DIPESCA		
Organization responsible for enforcement	DIPESCA		
Organization responsible for monitoring	Healthy Reefs Initiative and TIDE		
Fishing pressure at site	Moderate		
Ease of enforcement	Moderate		
Species	**Max. abundance**	**Visually verified?**	**Abundance tendency**
Epinephelus striatus			
Epinephelus guttatus	1-50	Yes	Unknown
Mycteroperca bonaci	1-50	Yes	Unknown
Mycteroperca venenosa			
Mycteroperca tigris			
Lutjanus jocu	50-100	Yes	Unknown
Lutjanus analis	50-100	Yes	Unknown
Lutjanus cyanopterus			
Lutjanus griseus			
Lutjanus synagris			
Ocyurus chrysurus	50-100	Yes	Unknown
Notes	Reproductive behaviour has been seen at the site, but no spawning has been observed to date. As well as the above-mentioned species, reproductive behaviour for species including *Hypoplectrus gemma, Canthidermis sufflamen, Caranx hippos* have also been reported. The site is protected for 10 years (2020-2030). The site has been declared as a temporary spatial closure by Ministerial Agreement 85-2020, published in the Federal Register on the 22nd May 2020.		
Citations	Pérez-Murcia 2020		

Honduras FSA site summary

Site name	Banco Capiro[8]	Cordelia Banks			Izopo
Inside protected area	Refugio de Vida Silvestre Marino Bahía de Tela	Islas de la Bahía National Marine Park			Parque Nacional Punta Izopo
Protected from fishing	Partially (only hook and line allowed)	During spawning season			Partially (only hook and line allowed)
Type of spatial protection	Recovery Zone	Temporary closed zone			Recovery Zone
Protected Area manager	ICF/Municipality/AMATELA/Tela Marine Research Center	Roatan Marine Park/Comité Técnico/ICF			Municipio de Tela/Arizona y Esparta/ PROLANSATE/ICF
Organization responsible for enforcement	PROLANSATE/Fuerza Naval/DIGEPESCA/AMATELA	Roatan Marine Park			PROLANSATE/Fuerza Naval/DIGEPESCA
Organization responsible for monitoring	CORAL/Healthy Reefs Initiative/Tela Marine Research Center	Healthy Reefs Initiative, CORAL, Roatan Marine Park, BICA, ZOLITUR			CORAL/Healthy Reefs Initiative
Fishing pressure at site	High	High			High
Ease of enforcement	Moderate	Difficult			Difficult
Species	**Information that suggests the site is a FSA**	**Max. abundance**	**Visually verified?**	**Abundance tendency**	**Information that suggests the site is a FSA**
Epinephelus striatus	Fisheries landing information and TEK suggests that *Lutjanus synagris* spawns at this site	100-250	Yes	Decreasing	Fisheries landing information suggests that *Epinephelus guttatus, Lutjanus jocu, L. analis, L. synagris* and *L. vivanus* spawn at this site
Epinephelus guttatus		1-50	No (TEK)	Decreasing	
Mycteroperca bonaci		100-250	Yes	Decreasing	
Mycteroperca venenosa		100-250	Yes	Decreasing	
Mycteroperca tigris		100-250	Yes	Decreasing	
Lutjanus jocu		100-250	Yes	Decreasing	
Lutjanus analis		50-100	No (TEK)	Decreasing	
Lutjanus cyanopterus		100-250	Yes	Decreasing	
Lutjanus griseus		50-100	No (TEK)	Decreasing	
Lutjanus synagris					
Ocyurus chrysurus		100-250	Yes	Decreasing	
Notes	Heyman & Requena (2003) mention that the site could be a FSA due to high landings.	Despite the high number of species and abundances at this site, complementary information, articles or grey literature could not be found to further support the interview information.			
Citations	Heyman & Requena 2003, Chollett 2017	Chollett 2017			Chollett 2017

[8] A second site in the Refugio de Vida Silvestre Marino Bahía de Tela was reported (Vietnam) but was not included in this table as it did not have reports of the target species. Landings data suggests *Lutjanus vivanus* spawns here.

Site name	La Grupera	Mariposales			North East Bank (aka Barbareta)
Inside protected area	Monumento Natural Marino Archipiélago Cayos Cochinos	Monumento Natural Marino Archipiélago Cayos Cochinos			Islas de la Bahía National Marine Park
Protected from fishing	During spawning season for snapper	During spawning season			During spawning season
Type of spatial protection	Temporary closed zone	Temporary closed zone			Temporary closed zone
Protected Area manager	Fundación Cayos Cochinos/Municipalidad Roatán/ICF	Fundación Cayos Cochinos/Municipalidad Roatán/ICF			Roatan Marine Park/Technical Committee/ICF
Organization responsible for enforcement	Fundación Cayo Cochinos/Fuerza Naval Honduras	Fundación Cayo Cochinos/Fuerza Naval Honduras			Roatan Marina Park/BICA
Organization responsible for monitoring	Fundación Cayos Cochinos	Fundación Cayos Cochinos			BICA
Fishing pressure at site	Low	Moderate			High
Ease of enforcement	Easy	Relatively easy			Difficult
Species	**Information that suggests the site is a FSA**	**Max. abundance**	**Visually verified?**	**Abundance tendency**	**Information that suggests the site is a FSA**
Epinephelus striatus	None of these species were reported to spawn at this site				Fisheries landing information suggests that *Epinephelus guttatus* and *Mycteroperca venenosa* spawn at this site, however the exact location is unknown.
Epinephelus guttatus					
Mycteroperca bonaci		50-100	Yes	Unknown	
Mycteroperca venenosa		50-100	Yes	Unknown	
Mycteroperca tigris		50-100	Yes	Unknown	
Lutjanus jocu					
Lutjanus analis					
Lutjanus cyanopterus					
Lutjanus griseus					
Lutjanus synagris					
Ocyurus chrysurus		100-250	Yes	Unknown	
Notes	High abundances of other snappers (*Lutjanus apodus* >5000, *L. mahogoni* 250-1000) and chub (*Kyphosus* sp. 2000-5000) observed in 2007, including spawning.	"Reproductive characteristics" were reported for fish seen between 2006-2009. Spawning not observed.			
Citations	Aronne 2009, Chollett 2017	Aronne 2009, Chollett 2017			Box & Bonilla 2008, Chollett 2017

Site name	Punta Pelicanos			Roatan Bank			Punta Sal
Inside protected area	Monumento Natural Marino Archipiélago Cayos Cochinos			Monumento Natural Marino Archipiélago Cayos Cochinos			Blanca Janeth Kawas Fernandez National Park
Protected from fishing	During spawning season			During spawning season			Partially (only hook and line allowed)
Type of spatial protection	Zona de Pesca Temporal			Zona de Pesca Temporal			Recovery Zone
Protected Area manager	Fundación Cayos Cochinos/Municipalidad Roatán/ICF			Fundación Cayos Cochinos/Municipalidad Roatán/ICF			PROLANSATE/ICF/Municipalidad de Tela
Organization responsible for enforcement	Fundación Cayo Cochinos/Fuerza Naval Honduras			Fundación Cayo Cochinos/Fuerza Naval Honduras			PROLANSATE/Fuerza Naval/ DIGEPESCA
Organization responsible for monitoring	Fundación Cayos Cochinos			Fundación Cayos Cochinos			CORAL/Healthy Reefs Initiative/Tela Marine Research Center
Fishing pressure at site	Moderate			Moderate			High
Ease of enforcement	Relatively easy			Difficult			Difficult
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency	Information that suggests the site is a FSA
Epinephelus striatus							Fisheries landing information and TEK suggests that *Lutjanus vivanus* and groupers spawn at this site
Epinephelus guttatus							
Mycteroperca bonaci	50-100	Yes	Decreasing	50-100	Yes	Unknown	
Mycteroperca venenosa	50-100	Yes	Decreasing	50-100	Yes	Unknown	
Mycteroperca tigris	100-250	Yes	Stable				
Lutjanus jocu	Unknown	Yes	Unknown				
Lutjanus analis							
Lutjanus cyanopterus							
Lutjanus griseus							
Lutjanus synagris							
Ocyurus chrysurus	Unknown	Yes	Stable				
Notes	Possible multispecific spawning site. Spawning not observed. First reported 2005.			"Reproductive characteristics" were reported for fish seen between 2005-2009. Spawning not observed.			Heyman and Requena (2003) mention that the site could be a FSA due to high landings.
Citations	Aronne 2009, Chollett 2017			Aronne 2009, Chollett 2017			Heyman & Requena 2003, Chollett 2017

Site name	Power Point (Lawson Rock-Sandy Bay)			Western Bank (Texas – West End)		
Inside protected area	Islas de la Bahía National Marine Park			Islas de la Bahía National Marine Park		
Protected from fishing	During spawning season			During spawning season		
Type of spatial protection	Zona de Pesca Temporal			Zona de Pesca Temporal		
Protected Area manager	Roatan Marine Park/Comité Técnico/ICF			Roatan Marine Park/Comité Técnico/ICF		
Organization responsible for enforcement	Roatan Marine Park			Roatan Marine Park		
Organization responsible for monitoring	Roatan Marine Park			Roatan Marine Park/Healthy Reefs Initiative		
Fishing pressure at site	Low			High		
Ease of enforcement	Easy			Moderate		
Species	Max. abundance	Visually verified?	Abundance tendency	Max. abundance	Visually verified?	Abundance tendency
Epinephelus striatus				250-1000	Yes	Decreasing
Epinephelus guttatus				Unknown	No (TEK)	Decreasing
Mycteroperca bonaci	1-50	Yes	Unknown	250-1000	Yes	Decreasing
Mycteroperca venenosa				100-250	Yes	Decreasing
Mycteroperca tigris	250-1000	Yes	Unknown	250-1000	Yes	Decreasing
Lutjanus jocu				100-250	Yes	Decreasing
Lutjanus analis				1-50	No (TEK)	Decreasing
Lutjanus cyanopterus				250-1000	Yes	Decreasing
Lutjanus griseus				50-100	Yes	Decreasing
Lutjanus synagris				1-50	Unknown	Decreasing
Ocyurus chrysurus				250-1000	Yes	Decreasing
Notes						
Citations	Chollett 2017			Chollett 2017		

Discussion

The discussion is divided into subsections, each considering a theme derived from the results. We draw on information provided by the interviewees and existing literature on FSAs, both from the MAR and worldwide. Concerted FSA conservation in the MAR is entering its fourth decade. To date, the impacts of the actions taken appear to be limited. Overall, fish abundances at FSA sites continue to decline, or insufficient information is apparently available to make informed management decisions. This suggests that the mechanisms for FSA conservation implemented to date have not been the correct ones, or they have been poorly implemented. Each subsection has short title and descriptive paragraph. The text is not written in order of priority or importance.

How do we define a FSA? - One area of discussion that must be resolved to allow progress to be measured and activities prioritised is how we define an active FSA site. How do we *know* there are fish there and that the FSA is found at these exact coordinates? The term "spawning aggregation" was first formally defined in 1997 (Domeier 2012), and other definitions have been suggested since then. The current recommended definition is:

"Spawning Aggregation is a repeated concentration of conspecific marine animals, gathered for the purpose of spawning, that is predictable in time and space. The density/number of individuals participating in a spawning aggregation is at least four times that found outside the aggregation. The spawning aggregation results in a mass point source of offspring" (Domeier 2012).

The most common method for verifying this information in the MAR is through visual censuses, as visual confirmation of spawning fish is the most accurate way to geolocate gamete release. Indirect indicators (colour change, increased abundance etc.) are likely indicators that the site is a FSA, but the divers may have seen migratory fish. However, combining these biological indicators with geomorphological features (Kobara et al. 2013) can increase the likelihood that a location is an active FSA.

As Domeier (2011) mentions both the scientific and grey literature include examples of poorly documented FSAs that lack rigorous information to document their existence. Colin et al. (2003) and Domeier (2011) published four criteria that directly verify spawning: 1) visual verification of gamete release, 2) females with hydrated eggs, 3) post-ovulatory follicles in the ovaries of females and 4) very early stage eggs and larvae in the water column. It is likely that some of the FSAs reported in this document do not meet these criteria and as such can only be considered "probable" or "likely" FSA sites. For example, above normal abundances of black grouper aggregating on an underwater promontory in the days after the January full moon were seen at the Maya-Ha FSA in Mexico. It is likely that this site is an FSA, but no spawning was seen, and the site is yet to be revisited to create long time series data and confirm spawning. Similarly, several of the Honduran FSA sites have limited evidence at this stage to support their classification as a FSA site.

The need for a regional database – the information about FSAs in the MAR can be confusing. The following situations were identified:

- Different scientific reports have different numbers of FSAs.

- What may be the same FSA is named differently, or the name changes over time.
- Two FSA sites that are only 200 or 300 m apart are counted as separate FSAs.
- Some "FSAs" are counted as "visually verified" when the evidence for spawning is sparse (see above).

Considering these examples, creating a regional digital database and repository that contains clear information to characterize each site (spatial, biological and governance characteristics) that is updated annually by designated people in each MAR country would go a long way towards avoiding these problems in the future.

Beware of hyperstability - Two interviewees mentioned that FSA sites had moved, and it is common to read in the grey literature over the past two decades (e.g. Paz & Truly 2007). This seems unlikely and is not well supported in the scientific literature where most fish show high site fidelity with FSAs occurring at specific geomorphological features repeatedly over time (e.g. Heyman & Kjerfve 2008, Starr et al. 2007). The more likely scenarios are: 1) that the original sighting was not the actual FSA, but perhaps a grouping of non-spawning fish or a migratory route, 2) the site was poorly georeferenced and was not found again (divers have limited bottom times), 3) dispersed fragments of previously larger aggregations may exist, as was reported for Caye Glory (Paz & Truly 2007) or 4) the site has been fished out (similar to the commonly reported by fishers: "*there are less fish now, they have gone deeper*"). An alternative scenario for the sudden disappearance of a FSA is hyperstability, as mentioned earlier. Due to the aggregation dynamics of the species, fishers can continue to have high catches until one day, the fish are gone.

Counting fish is easy, effective conservation and management of FSAs is not – Despite this, the survey results suggest that little has changed about how we monitor or manage our FSAs over the last two decades. Research teams continue to visit the sites periodically (when funding allows, and not to all FSAs because the fish spawn at the same time at each site) to SCUBA dive, count fish and estimate sizes. This information has been used to propose marine reserves, but cases of using this information for wider fisheries policy are limited. This overreliance on visual census monitoring to detect change, combined with significant data gaps, failures to capture the maximum abundance, and limited fishery dependent data at the species level away from FSA sites and over long time periods is a limiting factor for better understanding fishery dynamics. Cooperative research programs, involving local fishers (e.g. effective catch reporting, biological sampling, or video sampling) or complementing monitoring with new technologies (hydrophones, acoustic telemetry or laser callipers for more effective size estimates) should be considered (Chollett et al. 2020, Pittman & Heyman 2020).

Recovery will take time - Conservation actions must also be considered in context. Even in Belize, the MAR country that continues to lead the region in investigation and protection of FSAs, actions to protect FSA´s have come late. Despite warnings from the 1960´s onwards, sites were only protected in the early 2000´s. Figure 5 shows us that by this time, some aggregations had all but disappeared. Protecting depleted FSAs should have a positive impact and is likely to help rebuild fisheries (Chollett et al. 2020), but after >100 years of heavy exploitation and depletion, we should not expect recovery to occur at a faster rate, considering the slow life history of the target species and the fact that the regional population is severely depleted, not just the population of one FSA.

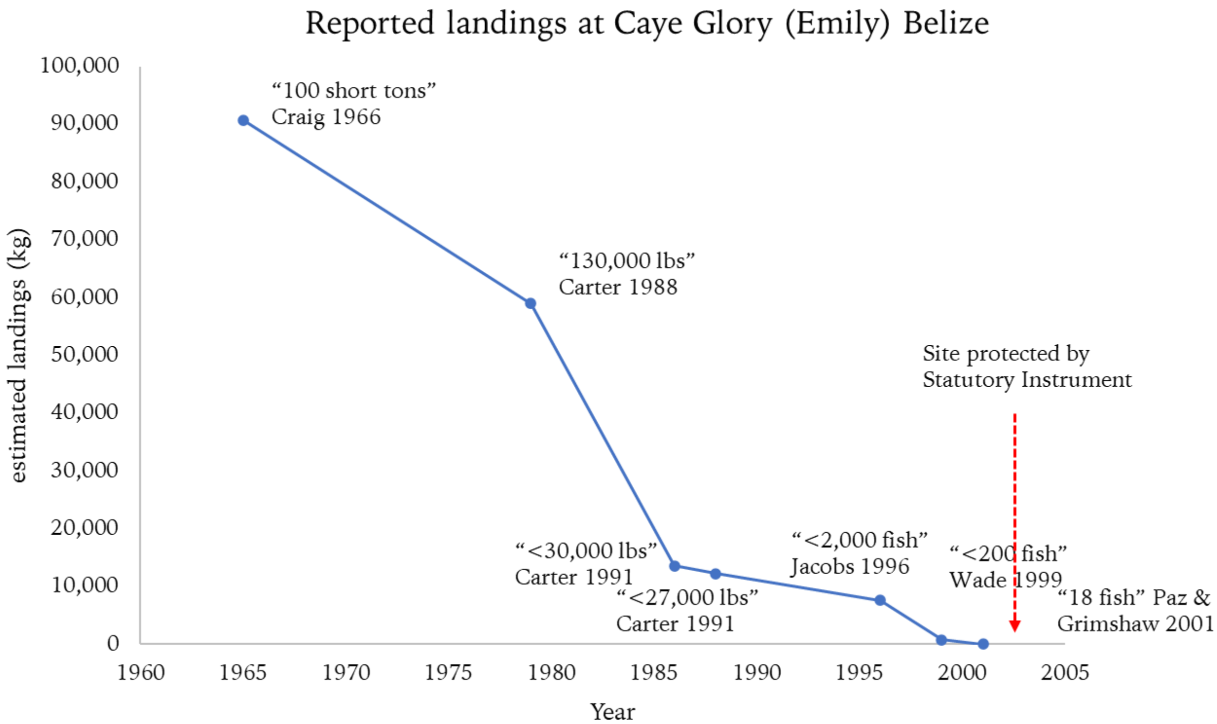

Figure 6 - Reconstructed and estimated landings at Caye Glory (Emily), principally based on Table 4 of Paz & Truly (2007). Number of fish converted to landing weight using 3.8 kg per fish average (Nemeth et al. 2006)

Organizational and information continuity is important, and lacking – when asked "in what year was the FSA first documented or monitored?" many interviewees answered with a year in the last decade or two. Examples included the Sian Ka´an sites in Mexico (with answers of early 2010´s) and several Belizean FSAs (early 2000´s). However, the literature shows that these sites were documented often decades previously (Franquesa-Rinos & Loreto-Viruel 2006, Paz & Grimshaw 2001). This shows a lack of information continuity and clarity, and also contributes to the shifting baseline effect.

During the many decades of FSA work in Belize, dozens of organizations, and 100´s of people have been involved. As staff change, information and knowledge are lost. Whilst the Belize SPAG group has tried to maintain this continuity, and has a core group of long-time members, this has not been enough to prevent FSA knowledge loss over time. This can be seen in the replies of the interviewees regarding the tendencies in abundance at the FSA sites. Tendencies for 44 species abundances[9] at 10 Belizean FSA where reported, 54% of the tendencies were reported as "*Unknown*". Considering that many of these sites have been monitored on and off for over 20 years, it seems unlikely that this is not known. It is more probably an artefact of institutional knowledge loss over time.

The other MAR countries have generated less information, so have less to lose, but knowledge is also dependent on people rather than institutions. At present, Mexico has benefited from the

[9] Replicate species, as the same species may spawn at many sites

continuity of three researchers[10] who have worked in the region for decades, and two CSO[11] staff who have conducted most of the site validations. Similarly, two key stakeholders in Honduras have significant information about FSAs there[12]. However, mechanisms must be put in place to ensure that information passes through institutions rather than people. People move, their roles change, or they retire. The institution must ensure knowledge continuity. Alliances and data sharing agreements with international groups such as SCRFA (*Science and Conservation of Fish Spawning Aggregations*) or FishBase could help this continuity.

Continued monitoring is key to measure change but has its limitations – continually monitoring a population allows researchers and managers to detect changes over time. Long time series data is particularly important for slow life history species such as grouper, where population increases at protected sites may be hard to detect. Standardized monitoring protocols should be implemented where possible (Acevedo, Caamal & Fulton 2020) and monitoring should be prioritized to catch the maximum abundance of fish[13]. Often, due to limited resources (financial and human), and the fact that the same species will spawn at different sites at the same time, it is not possible to collect continuous data at all FSA sites. However, with maximum abundance being the most reported indicator, efforts should be made to capture this important data. Similarly, technology can help provide solutions to improve data quality. Hydrophones can detect grouper activity over long time periods, which can be used to guide visual surveys. Laser calliper use during visual censuses can help collect size structure data which can provide information about recruitment, an important indicator for population recovery.

Enforcement will always be limited – conservation planners and managers should not set their hopes on effective surveillance eliminating illegal fishing at FSA sites in the MAR. This is an unrealistic scenario for countries with low budgets for natural resource management, high levels of corruption and a range of human wellbeing needs that are prioritized over marine conservation. Considering this, enforcement should be prioritized in spawning periods, mechanisms for fishers to confidentially report bad actors should be developed, and communication campaigns to foster responsibility of the fisher community towards the FSA must be considered. Monitoring points of sale during spawning season is also effective.

Control night fishing – night fishing, particularly illegal night fishing by fishers from Honduras and Guatemala was regularly highlighted as a problem. Enforcement at night can be difficult and dangerous, particularly in areas with shallow reefs and little or no reference points to guide captains. Where possible, efforts must be made to reduce the impact of night fishing during spawning periods, considering the safety of all involved.

Involving the fishing community in research helps build support – researchers and managers in the MAR should involve fishing communities in research and management (beyond only using fishers as sources of data). Researchers and managers should accept that it is highly unlikely that

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[10] Dr. Eloy Sosa (ECOSUR), Dr. Alfonso Aguilar (UADY) and Alejandro Medina (ITCH)
[11] Stuart Fulton and Jacobo Caamal (COBI)
[12] Ian Drysdale (HRI), Marco Aronne (Fundación Cayos Cochinos)
[13] Researchers should try to conduct visual surveys during the days of highest fish abundance. Ideally, monitoring should continue until the abundance of fish on the site begins to decrease - this means the maximum abundance was seen.

"pristine" FSAs exist in the MAR that fishers do not know about. Most research conducted to date has drawn on the traditional ecological knowledge of fishers to locate FSAs. Even when researchers believe a site is "unknown", it often turns out that a high percentage of fishers already know about it (Pérez-Murcia 2020). Involving these fishers in encourages a shift to better practices, more respect for the rules and provides a cost-effective, scalable workforce (as a small group of researchers can only monitor one FSA at once, but teams of citizen scientists can work at more sites).

Design principles should guide marine reserve creation – in 2017, biophysical design principles for fish replenishment zones in the MAR were published through an international collaboration of researchers and managers (Green et al. 2017). Some individual countries then developed socioeconomic and governance design principles (COBI & TNC 2019, Bonilla 2019). These principles recommend protecting areas such as FSA as critical and unique habitats, as well as promoting good governance and social inclusive and just processes. The protection of new FSAs should follow these recommendations.

Climate change creates uncertainty – the effects of climate change are already being seen on many marine species (Morley et al. 2018), with one of the most visible changes being spatial shifts in populations due to changing water temperatures. Little is known about how climate change may effect FSAs, but with species using specific sites and geophysical features to spawn, possibly linked to oceanographic variables such as currents and temperature, it is likely that climate change will have a negative effect on FSAs. One estimate under a business as usual scenario, for Nassau grouper, estimates that by 2100 potential spawning habitat in the Caribbean would be reduced by 82% (Asch & Erisman 2018). Measures should be taken to allow adaptive management of FSA marine reserves in the face of climate change.

Conclusions

It is time for a paradigm shift in FSA conservation in the MAR. As we enter the fourth decade of widescale FSA conservation efforts in the region it is time to reflect on what has worked and what has not. The scientific literature is clear that protecting fish during spawning periods is critical to maintaining fish stocks. It also seems clear that despite significant efforts there is a still a lot of work to be done to recover fish stocks to levels seen even a few decades in the past. Coordinated regional efforts across the four MAR countries are needed. Adaptative management to respond the climate change must begin to be implemented, and improved science-based decision making should be commonplace. Managers should be aware of shifting baselines and the loss of institutional knowledge over time as this appears to contribute to the lack of clarity regarding whether FSA protection is effective or not.

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Annex 1 – MARFish workshop participants

Name	Organization	Country
Nicole Craig	Healthy Reefs Initiative	Belize
Ana Giró	Healthy Reefs Initiative	Guatemala
Melanie McField	Healthy Reefs Initiative	Belize
Eliceo Cobb	TASA	Belize
Tyrell Reyes	Belize Fisheries Department	Belize
Gisselle Brady	BICA Roatan	Honduras
Antonella Rivera	CORAL	Honduras
Patricia Kramer	AGRRA	USA
Myles Phillips	WCS Belize	Belize
Nicanor Requena	EDF	Belize
Alejandro Medina Quej	TNM / ITCH Chetumal	México
Guillermo Galvez	FUNDAECO	Guatemala
Alfonso Aguilar Perera	UADY	México
Claudio González	MAR Fund	México
Melina Soto	Healthy Reefs Initiative	México
Ana Silvia Martínez	MAR Fund	Guatemala
María José González	MAR Fund	Guatemala
Tanya Barona	Belize Audubon Society	Belize
Denise García	Southern Environmental Association	Belize
Alex Solis	Fundación Cayos Cochinos	Honduras
Marcio Aronne	Fundación Cayos Cochinos	Honduras
Magdiel Naal	Sociedad Cooperativa de Producción Pesquera Vigía Chico	México
Baltazar Hoil	Sociedad Cooperativa de Producción Pesquera José María Azcorra	México
Estefanía Medina	CONANP - RBCM	México
Stuart Fulton	COBI	México
Jacobo Caamal	COBI	México
José Estrada	COBI	México
Araceli Acevedo	COBI	México

Annex 2 – Google Forms interview format

1. Name
2. Country
3. Organisation
4. Sector
5. Name of spawning aggregation site
6. Species present at the aggregation *[Epinephelus striatus] [Epinephelus guttatus] [Epinephelus itajara] [Mycteroperca bonaci] [Mycteroperca venenosa] [Mycteroperca tigris] [Lutjanus jocu] [Lutjanus analis] [Lutjanus cyanopterus] [Lutjanus buccanella] [Lutjanus griseus] [Lutjanus synagris] [Ocyurus chrysurus]*
7. Current protection status
8. Protection type (name of legal tool used)
9. Institution or organisation responsible for managing the area (if any)
10. Institution or organisation responsible for enforcement (if any)
11. Institution or organisation responsible for biophysical monitoring (if any)
12. For the visually verified species, please report maximum abundances from the last monitoring period *[Epinephelus striatus] [Epinephelus guttatus] [Epinephelus itajara] [Mycteroperca bonaci] [Mycteroperca venenosa] [Mycteroperca tigris] [Lutjanus jocu] [Lutjanus analis] [Lutjanus cyanopterus] [Lutjanus buccanella] [Lutjanus griseus] [Lutjanus synagris] [Ocyurus chrysurus]*
13. Tendencies in abundance *[Epinephelus striatus] [Mycteroperca bonaci] [Mycteroperca venenosa] [Mycteroperca tigris] [Epinephelus guttatus] [Epinephelus itajara] [Lutjanus jocu] [Lutjanus analis] [Lutjanus cyanopterus] [Lutjanus buccanella] [Lutjanus griseus] [Lutjanus synagris] [Ocyurus chrysurus]*
14. Have you seen high abundances of other species at the site? Which species?
15. Physical site information *[The site is found between 20-35m depth?] [Is it a reef promontory?] [Is the site near deep water? (>500m)] [Are the converging currents?] [Is the site near a shallow lagoon?]*
16. Number of fishers that operate in and/or adjacent to the FSA (catchment area)
17. Fishing pressure on the FSA
18. Ease of enforcement
19. Describe the main threats to the FSA
20. What management recommendations would you make for the site?
21. Does another group, person or organisation have additional information about this site?
22. Please provide any additional information about the site that may be relevant to the MARFish project

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Annex 3 – Site status summary

Site name	Country	Visually verified	Protected	Protection Tool
Maya Ha	MEX	Yes	Yes	Subzone RBCM
Niche Habin (Punta Allen)	MEX	Yes	Yes	Fish refuge
El Faro (Punta Herrero)	MEX	Yes	Yes	Fish refuge
San Juan	MEX	Yes	Yes	Fish refuge
Xahuayxol	MEX	Yes	Yes	Core zone PNAX
Cayo Lobos	MEX	Yes	No	
Blanquizal	MEX	Yes	No	
Mahahual	MEX	Yes	No	
Dog Flea Caye	BZE	No	Yes	SI-162-2003
Rise and Fall Bank	BZE	No	Yes	SI-162-2003
Rocky Point	BZE	No	Yes	SI-162-2003
Seal Caye	BZE	No	Yes	SI-162-2003
Soldier Caye	BZE	No	Yes	Conservation zone
Northern Two Cayes	BZE	No	Yes	SI-49-2009
Caye Bokel	BZE	Yes	Yes	SI-162-2003
Emily (Caye Glory)	BZE	Yes	Yes	SI-162-2003
Gladden Spit	BZE	Yes	Yes	SI-162-2003
Halfmoon Caye	BZE	Yes	Yes	Natural Monument
Mauger Caye	BZE	Yes	Yes	SI-49-2009
Nicholas Caye	BZE	Yes	Yes	SI-162-2003
Northeast Point (Northern Glovers)	BZE	Yes	Yes	SI-162-2003
Sandbore	BZE	Yes	Yes	SI-162-2003
Southpoint	BZE	Yes	Yes	SI-162-2003
Tiger Point	BZE	Yes	Yes	Conservation zone
Cayman Crown	GUA	No	Yes	Spatial Closure
La Grupera	HON	No	Temporal	Spawning season closure
North East Nak (aka Barbareta)	HON	No	Temporal	Spawning season closure
Banco Capiro	HON	No	No	
Izopo	HON	No	No	
Punta Sal/Vietnam	HON	No	No	
Cordelia Banks	HON	Yes	Temporal	Spawning season closure
Mariposales	HON	Yes	Temporal	Spawning season closure
Punta Pelicanos	HON	Yes	Temporal	Spawning season closure
Roatan Bank	HON	Yes	Temporal	Spawning season closure
Power Point (Lawson Rock-Sandy Bay)	HON	Yes	Temporal	Spawning season closure
Western Bank (Texas – West End)	HON	Yes	Temporal	Spawning season closure