Policy recommendations: fish spawning aggregations

marfish

Photo: Cristina Limonta

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Executive summary

Fish Spawning Aggregations (FSAs) are a crucial ecological element of the Mesoamerican Reef System (MAR). These aggregations serve as biological indicators of ecosystem health and represent vital nodes in the reproductive cycles of many fish species. The most representative commercial fish that support important regional fisheries and form FSAs are groupers *(Epinephelidae)* and snappers *(Lutjanidae)*.

The importance of FSAs lies in their multifunctional role within ecosystems: they serve as centers of mass reproduction, support complex food chains, and concentrate biological diversity to a remarkable extent. In FSA sites, intricate interaction networks develop that encompass a wide variety of biological elements, from the congregated spawning fish to the predators that take advantage of high prey concentrations. Thus, FSAs create true critical areas of biological activity.

Grouper and snapper conservation faces notable challenges due to the migratory behavior of these fishes, which can include travelling more than 100 kilometers to reproduce. As a result, groupers and snappers face multiple threats, including illegal or off-season fishing, being caught during their reproductive migrations, and exploitation in spawning areas. In the MAR, the situation is highly worrying. Of the 24 MAR breeding sites only four show signs of recovery, while seven are in decline, three remain stable, and ten lack adequate monitoring.

To protect FSAs, we propose a comprehensive system starting with the establishment of areas that prohibit fishing, such as fish replenishment zones or marine reserves. This system must be complemented by coordinated actions, including improving surveillance, establishing uniform regulations that determine minimum catch sizes, and coordinating season closures that are backed by rigorous scientific research.

1 Introduction

Fish Spawning Aggregations are defined as concentrations of conspecific fish that predicably and repeatedly congregate to reproduce [1]. The individuals that participate in these large FSAs may travel vast distances to arrive and reproduce at specific times and locations [2]. Thus, FSA sites are crucial for ensuring the persistence of populations of diverse marine fish species [3]. Moreover, FSAs which can occur in tropical and temperate coastal waters, are important for maintaining ecological processes and ensuring food security [1, 3].

The predictability of FSAs in time and space and the large numbers of fish that comprise these aggregations, make FSA sites important for fishing. Indeed, fisheries can capitalize on the predictable nature of FSAs to harvest an abundance of fish with minimal effort [2, 4]. Unfortunately, these characteristics make FSAs vulnerable to overfishing, and many FSAs have either declined in abundance or collapsed as a result. At present, multiple fish species are at risk of extinction [2, 4]. Combined with increasing fishing pressure in FSAs, this has led to rapid population declines, localized extirpation, fishery collapses, ecosystem imbalances, and a loss of the structural and functional integrity of marine ecosystems [4, 5].

The protection of FSAs has become crucial to the sustainability of the MAR, given that it directly links the conservation of biodiversity with the well-being of coastal communities. The success of FSA protection requires a deep understanding of ecological dynamics and must be supported by solid legal frameworks and regional cooperation. The effective management of shared FSA resources requires transcending national borders via coordinated and scientifically backed policies. This document provides detailed information on FSAs in the MAR region and highlights the important legal and scientific justifications for their protection.

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2 Which species aggregate, and what are the characteristics of the FSA sites?

Fish spawning aggregations may be either comprised of transient migrants or local residents [1, 4]. Transient migrant fish may travel great distances (>100 km) to participate in FSAs, which may only last for a few days or weeks. The FSAs that are comprised of transient migrants tend to form at specific times, which often occur during lunar or tidal phases. The species that form transient migrant FSAs exhibit "slow" life history traits such as slow growth, large size, longevity, and late maturity. The Nassau grouper *(Epinephelus striatus)* is an excellent example of a transient migrant. Currently, the Nassau grouper is listed as Critically Endangered by the IUCN, primarily due to overfishing in its FSAs [6].

Resident spawners spawn frequently within their home ranges and travel short distances (meters to kilometers) to arrive at FSA sites. These FSAs are often synchronized and may even occur daily. The fish species that are commonly found in resident spawner FSAs often include small herbivores such as wrasses (Labridae), parrotfishes (Scaridae), surgeonfishes (Acanthuridae), and jacks and pompanos (Carangidae). One such example is the wrasse *Thalassoma bifasciatum*, which spawns daily each year at the same locations, with site fidelity lasting up to four generations [1].

Some FSA sites host multiple species, with different species spawning at the same time but at various times of the year. In addition, FSA sites can serve as productivity hotspots, attracting large numbers of spawning fish, apex predators that feed on the spawners, and plankton that consume the resulting protein-rich gamete packets [7]. Thus, beyond their reproductive potential, FSAs can support high biodiversity, productivity, and complex food webs [8].

In the wider Caribbean, the geomorphology of multi-species FSAs is strikingly similar [9]. According to the study conducted in Belize by Kobara and Heyman [10], all FSA sites are located along the edges of continental plates that exhibit convex reef structures that extend to steep drop-offs into deep water. Nonetheless, a better understanding of FSA geomorphology is needed to develop a fisheries-independent mechanism for identifying potential FSA sites [4]. By predicting these sites without relying on fisheries data, protection efforts can be prioritized, and Marine Protected Areas (MPAs) can be effectively designed for FSA management and conservation.

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3 What can be done to protect FSAs?

Historically, fishing had little impact on FSAs due to limited technical capabilities and the small size of the fishing sector. Today, FSAs are seen as fortuitous fishing opportunities during specific times of the year and may also coincide with special cultural events [3].

The most recent, comprehensive report on the global status of marine FSAs reported that 52% of documented FSAs have not been assessed, less than 35% of documented FSAs are protected by any form of management, and only 25% are being monitored in any way [4]. Among the FSAs that have been assessed, 53% are in decline, and 15% have disappeared entirely [4]. These results highlight the need for effective management interventions and initiatives to maintain the populations of large, ecologically important predatory fishes, such as groupers and snappers, as well as those of other important reef fish species [4]. To date, efforts to understand the recruitment of these species have mostly focused on their recovery and conservation following population collapse. Notably, the remaining large FSAs (e.g., Nassau grouper *[Epinephelus striatus])* appear to be self-sustaining, with the potential to export larvae to sites in the surrounding region where only remnant populations exist [36].

Looking to the future, FSAs should be protected from exploitation through carefully planned national and regional fisheries management and conservation. In addition, monitoring frameworks should be implemented to safeguard FSAs, and key biological, socioeconomic, fishery, and commercial information should be collected to inform management and conservation protocols. Importantly, community-based strategies must be developed and implemented to involve local fishing communities in management and science.

3.1 Available protective measures.

At present, management and conservation avenues for FSA sites vary from country to country due to differences in fisheries legislation and management options. Nonetheless, some of the most commonly used management tools include [4]:

- Species-specific protections, including those that impose restrictions on the sale, export, or possession of specific species; these may be either seasonal or year-round protections.
- Minimum catch sizes that safeguard fish growth, and maximum size limits that protect large, fertile females and large males.
- Temporal and spatial protection, including spawning reserves and closed fishing seasons.
- Restrictions on the carrying capacity of each fishery that establish limits on the number of licenses or permits issued to specific entities, catch quotas, fish sizes, and fishing gears.
- Complete species-specific fishing bans and protection for species threatened by overfishing.
- Community-managed fisheries, including locally managed marine areas (LMMAs).

The proper management of any FSA site or species must be undertaken on a case-by-case basis, as it depends on local socioeconomic factors, the reproductive behavior and biology of the target species, existing fishing pressure, and the conservation status of the target species.

In the MAR region, fish replenishment zones (e.g., no-take zones or marine reserves) and temporary fishery closures at FSA sites have been the preferred management tools, as they focus control on specific times and locations.

3.2 International legislation and recommendations to protect FSAs.

Recognizing the importance of FSAs, international agendas have emphasized the need to improve their management and conservation. For example, FSA sites are prime candidates for designation as ecologically and biologically significant areas (EBSAs) under the Convention on Biological Diversity (CBD). In addition, the Food and Agriculture Organization of the United Nations (FAO) clearly specifies in its Code of Conduct for Responsible Fisheries in Article 7.5.1 that *"The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures."* Similarly, Article 7.6.1 indicates that *"States should ensure that the level of fishing permitted is commensurate with the state of fisheries resources,"* given the best available information [11, pg. 19 and 20].

In 2004, during the World Conservation Congress organized by the International Union for Conservation of Nature (IUCN Rec 3.100, p. 115), the congress *"[urged] governments to establish sustainable management programmes for sustaining and protecting reef fish and their spawning aggregations (...)"*, and international and fisheries management organizations, including non-governmental organizations, were requested to *"take action to promote and facilitate the conservation and management of fish spawning aggregations (...)."* Other important conservation entities and working groups include the IUCN Grouper and Wrasse Specialist Group [13] and the Fish Spawning Aggregation CFMC/WECAFC/OSPESCA/CRFM working group [12], which developed the Regional Fish Spawning Aggregation Fishery Management Plan: Focus on Nassau Grouper and Mutton Snapper (FSAMP). This management plan represents a collaborative policy tool developed for the Caribbean between 2008 and 2019 to protect the Nassau grouper *(Epinephelus striatus)* and mutton snapper *(Lutjanus analis),* both endangered fish species, during spawning events [35]. Both management groups strongly recommend enhancing management actions to protect FSA sites and highlight the need for fisheries management plans that protect FSA species, in addition to standardizing existing FSA monitoring programs to improve local, national, and regional management efforts and inviting fishers and other stakeholders to collaborate in FSA research and management actions (see [14]).

In particular, FSAMP proposes 16 management measures that address the problems and lessons learned in countries of the greater Caribbean region. These measures are grouped into six objectives to improve the regional management of grouper and snapper aggregations [35]:

- Increase the amount of information and knowledge on the status of grouper and snapper populations to garner support for protecting FSAs.
- Determine the current status of FSAs, including the presence and abundance of fish, their locations, and their active periods, and identify FSAs in need of further protection.
- Develop regionally consistent and complementary monitoring frameworks and protocols to collect key biological, commercial, and socioeconomic data on groupers and snappers during FSAs, including those that occur at other times and locations.
- Establish coordinated and complementary mechanisms to effectively protect FSAs from extractive use in the Caribbean region.
- Notably increase the awareness and engagement of key stakeholders to build support for protecting FSAs, with particular attention to equitable benefits for local communities.
- Integrate the protection of FSAs into broader ecosystem-level planning and management initiatives.

The International Coral Reef Initiative (ICRI) released a statement on coral reef fish spawning aggregations in 2006. This statement calls for governments to establish sustainable management programs to maintain and protect reef fishes and their spawning aggregations, including a range of spatial and seasonal measures tailored to meet local needs.

The existing statements and recommendations have greatly influenced government and non-governmental organizations to advance conservation initiatives for MPAs, given that assessing FSAs has been recognized as essential for proper fisheries and MPA management [15, 16].

The biophysical principles guiding the effective design of fish replenishment zones in the MAR consider FSA sites as vital life-history areas for focal species [17]. These principles suggest that areas crucial to the life cycles of species, such as nursery or spawning grounds, should be protected, which will benefit future fisheries. Implementing effective national management strategies is as important as strengthening regional management. Management at both these scales requires comprehensive coordination encompassing the establishment of seasonal and spatial protections and statistical monitoring, which may or may not depend of fisheries, as well as effective law enforcement, outreach, and education. Moreover, given that many biological life-history processes transcend national boundaries, management and planning efforts must be coordinated among all involved countries [35].

4 Fish Spawning Aggregations in the Mesoamerican Reef System

In the Caribbean, 37 fish species from 10 families are known to form FSAs [9]. In a recent literature review, Kobara et. al [9] reported 29 FSA sites in the region; however, research in the four MAR countries, including contributions from leading experts, suggests that there are currently 24 active FSA sites [18]. Of these 24 FSA sites, non-governmental organizations, managers, and researchers have identified seven sites with declining fish populations, three sites with stable populations, four sites with increasing populations, and ten sites where the population trend is unknown due to a lack of consistent monitoring [19].

Defining the total number of FSA sites in the MAR region is difficult given the challenges of regularly monitoring each site and differing opinions on what constitutes an active FSA [20]. Groupers *(Epinephelidae)* and snappers (*Lutjanidae)* are commonly found in FSA sites [21], including the Nassau grouper *(Epinephelus striatus,* Critically Endangered), Black grouper *(Mycteroperca bonaci,* Near Threatened), Yellowfin grouper *(Mycteroperca venenosa,* Near Threatened), Mutton snapper *(Lutjanus analis,* Near Threatened), Dog snapper *(Lutjanus jocu,* Data Deficient), and Cubera snapper *(Lutjanus cyanopterus,* Vulnerable). Many of these species have suffered dramatic population declines throughout the Caribbean, with some being extirpated at some FSA sites [22]. *Acanthuridae* (surgeonfishes), *Siganidae* (rabbitfishes), *Scaridae* (parrotfishes), and *Labridae* (wrasses) also aggregate to spawn, although to a lesser extent [21].

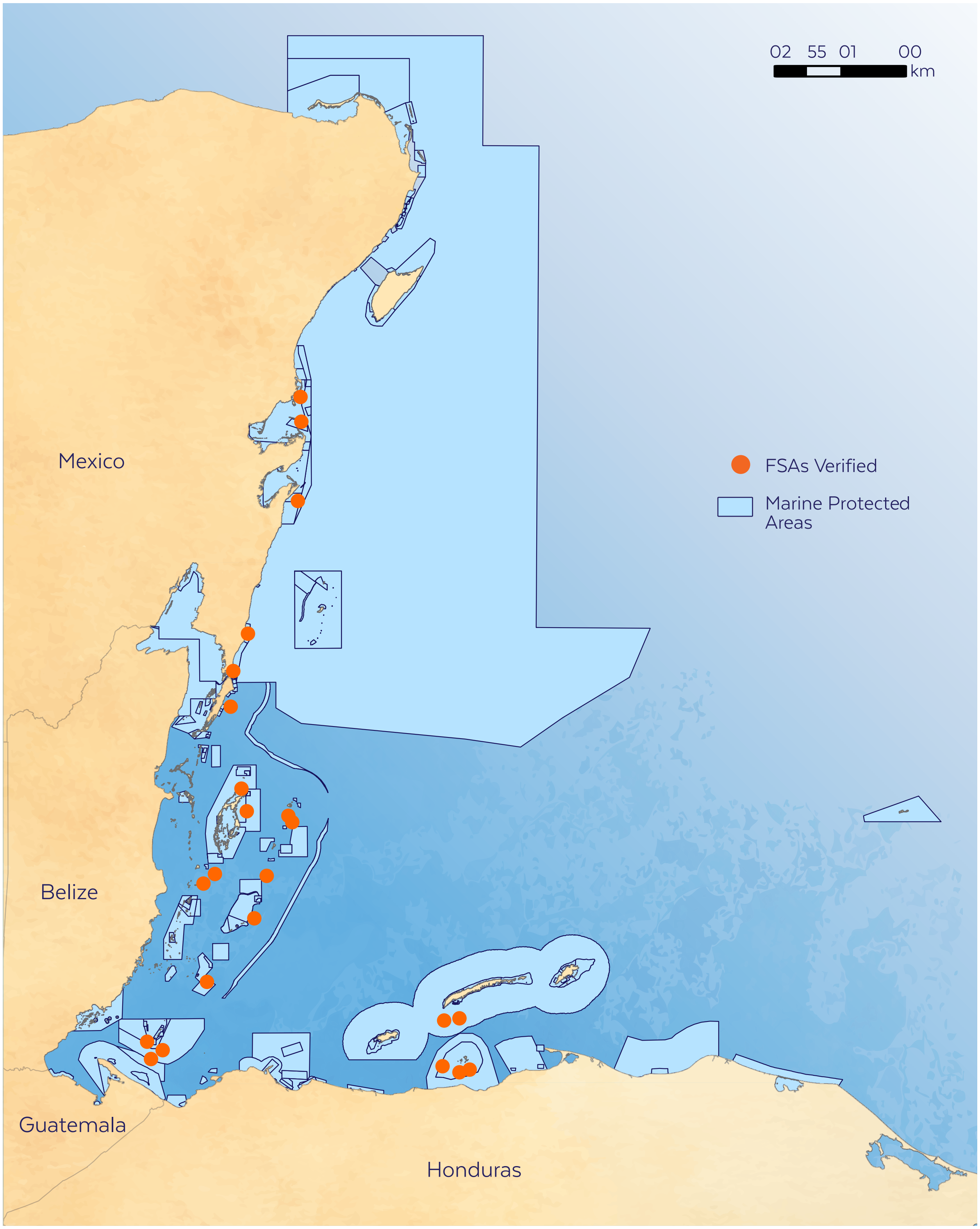

Figure 1. Approximate locations of the known and verified fish spawning aggregation (FSA) sites in the Mesoamerican Reef System (MAR).

M. McField, M. Soto, R. Martinez, A. Giró, C. Guerrero, M. Rueda, P. Kramer, L. Roth, I. Muñiz (2024). 2024 Mesoamerican Reef Report Card. Healthy Reefs for Healthy People. www.healthyreefs.org

4.1 Conservation measures for FSAs in the MAR region.

4.1.1 Mexico

Grouper management plans and fishing regulations have been established in the Gulf of Mexico and Mexican Caribbean; however, they are focused on the Red grouper *(Epinephelus morio)*, which is relatively unimportant in Caribbean fisheries.

- Fish replenishment zones (either fish refuges or sub-zones of protected areas) have been implemented specifically to protect FSAs (five of eight visually verified FSAs are currently protected).
- There are currently eight visually verified FSA sites in the Mexican Caribbean; four are stable, two are declining, one has disappeared, and the status of the last is unknown.
- The management plans of protected areas limit fishing grounds and the use of some gears.
- A Community Center for Underwater Research and Monitoring has been established in the Mexican Caribbean, consisting of 12 fishers from the Punta Allen community. This group focuses on annual monitoring of verified FSAs within the Sian Ka'an Biosphere Reserve.

4.1.2 Belize

In 2020, the Sapodilla Cayes Marine Reserve was expanded to cover the Belizean portion of the Cayman Crown marine area, a network protecting 13 known multi-species FSAs (7 are specific to the Nassau Grouper *[Epinephelus striatus])* was established in 2001.

- Most FSAs are located near, alongside, or within a marine reserve. However, marine reserve and FSA management are independent and have different regulations limiting the types of fishing and gears allowed.
- At the moment, there are no formal management plans for identified FSAs. Their development will be guided by the relatively new Fisheries Resources Law (signed on 20 February 2020).
- Eight of the 13 FSAs undergo some form of direct monitoring for Nassau grouper populations (over the past 15 years); the remaining 7 FSAs have also been monitored at different times [23].
- Currently, most FSAs are believed to be in decline, although their actual states remain mostly unknown.
- Further research is needed to recharacterize each FSA site.
- A multi-specific FSA is present in the Gladden Spit and Silk Cayes Marine Reserve. Traditional fishing for snapper is allowed on a seasonal basis.
- The different regulations for each marine reserve can be found at http://fisheries.gov.bz/.

In Belize, a 2023 objective the FSA working group was to evaluate the success of management measures to support grouper and snapper aggregations. The activities to complete the objective focused on four axes: monitoring, data collection and analysis, public awareness, and training (https://www.spagbelize.org/).

4.1.3 Guatemala

The Cayman Crown FSA site consists of a submerged coral bank located on the Caribbean coast of Guatemala near Belize and is a crucial spawning site for multiple fish species. The site was protected for ten years beginning in 2020 through a ministerial agreement (85-2020).

4.1.4 Honduras

The management plans of two protected areas, the Bay Islands National Marine Park and Cayos Cochinos Archipelago Natural Marine Monument, have established regulations for FSAs. Most management plans are updated every five years and include sections on the management of any existing FSAs.

- There are six validated FSAs in two protected areas:
    - Bay Islands: two FSAs are located within the Special Marine Protection Zone (a sub-zone within the national park) where fishing for grouper and snapper is not permitted.
    - Cayos Cochinos: fishing is not permitted within the national marine monument, where there are four FSAs, from December to March.
- Minimum landing size: there are no national regulations limiting landing size, although the Bay Islands National Marine Park has established a minimum landing size of 20 cm for all finfish.
- Permitted fishing gears are listed in management plans or protected area decrees.

Table 1. Grouper and snapper regulations in the MAR.

REGULATION	MEXICO	BELIZE	GUATEMALA	HONDURAS
Nassau Grouper *(Epinephelus striatus)* closed seasons	1 February to 31 March	1 December to 31 March	1 December to 31 March	1 December to 31 March
Closed seasons for other groupers	1 February to 31 March	No	No	No
Size limits for groupers	Only for *Epinephelus morio* (minimum total length of 36.3 cm)	Groupers *(Nassau grouper)* should measure 50–76 cm and should be landed whole.	No	No
Fishing ban for snappers	No	No	1 May - 15 June (under ministerial agreement 40-2020)	No
Protected FSA	5	10	1	0 (6 sites with special protection)

5 Shifting baselines: how things used to be and their role in supporting fisheries

Historical scientific evidence, combined with the traditional ecological knowledge of fishers, constitutes a powerful tool for understanding changes in the populations of key species. This powerful tool can also be used to understand changing perceptions of resources over time [25]. In 1971, an FSA of over 100,000 Nassau grouper was reported in the Bahamas [26]. By 2013, this site only contained five individuals [27]. Reports for the same period in the MAR are similar, with considerable fishing activity associated with FSA sites. For example, in the 1960s in Belize, 300 boats, each with three people on board, headed to Glory Caye (Emily) during the spawning season and caught ~100 tons of grouper. During that period, an experienced fishing crew could catch 1,200 to 1,800 fish during the season [28], despite fishing in the 1960s being much lower than in previous years.

Fishing at FSA sites is generally not economically advantageous. Given the large catch sizes in FSAs, the market receives an oversupply of specific species at given times, which drives down prices [29]. Nonetheless, fishing in FSAs has remained important for local economies, although the catch declines in recent decades have further reduced profitability. As the efficiency of fishing in FSAs increased, catches declined. Indeed, powerful vessels that are able to catch large quantities of fish that operate in rough waters now carry a fraction of the catch of previous years.

Our scientific understanding of FSAs has been generated over a short period of time. Before the advent of scuba diving in the 1940s, FSA sites could only be identified by the abundant catches of fishers at certain times of the year. Once scientists donned scuba gear, they began documenting incredible underwater spectacles. Today, FSAs with 1,000 fish are considered “large” or “extraordinary” by scientists and young fishers. However, what is considered a “normal” size for an FSA today likely reflects a population decline spanning 50 to 100 years. This “shifting baseline” has been reported for the same species in different regions [30, 31] and describes a situation in which it is difficult to recognize past abundances, as only current reference points are available for comparison.

6 The need for a regional vision

6.1 Shared resource management requires national and regional coordination

The importance of FSAs to MAR fisheries has been documented for over 80 years [37]. Importantly, groupers and snappers are transboundary resources in the MAR. In the Caribbean, Nassau grouper have been known to migrate over 300 km to FSA sites [32], which is roughly equivalent to a fish swimming from Guatemala to Mexico to spawn. Therefore, coordinated population recovery plans for flagship and commercially important species must consider their ranges. While groupers and snappers are present throughout the Caribbean, the MAR is likely an important self-recruitment area that maintains local populations, given that Nassau grouper in the MAR are genetically distinct from those found in the eastern Caribbean and Bahamas [34]. Thus, actions taken in the MAR directly impact the health of fish stocks.

Further research is needed to evaluate poorly understood population movements between spawning sites. Declining FSAs at specific sites could reflect the disappearance of geographically close and possibly connected FSAs. Additionally, when FSAs have been exploited consistently over long periods, as is the case at Mahahual in Mexico [34], the removal of older fish leaves few experienced individuals to guide new recruits to traditional spawning sites. This lack of guidance can make migrations to traditional sites inefficient, further reducing the spawning potential and reproductive capacity of the affected species [34].

The evolution of fisheries policies in the MAR region in recent years has been notable but uneven. For example, new regulations implemented in Belize have strengthened FSA protection by expanding no-take zones and establishing stricter closed periods. In Mexico, updated fisheries management plans now include specific criteria to protect FSAs, which have previously been ignored, including greater restrictions during spawning seasons. However, policy agreement among the four MAR countries remains challenging, particularly regarding the standardization of control and surveillance measures. Lastly, a lack of resources to effectively enforce regulations remains a continual problem throughout the region.

6.2 Despite legal protection, FSA sites face a worrying decline

To address the challenges posed by the increasing human population and its consequent demand for marine products, and the threat of illegal, unreported, and unregulated (IUU) fishing, while ensuring sustainable marine ecosystems and a legitimate fishing industry, scientifically based regulations are needed, and fishers must be empowered in management efforts [38]. To ensure healthy grouper and snapper populations, management must go beyond protecting FSA sites, especially in resource-limited countries with few existing regulations. Fish abundance at spawning sites will likely continue to decline due to considerable fishing pressure outside of the spawning season, during migrations to FSA sites, and illegal and legal fishing in FSA sites. In addition, most FSA sites were only recently protected, after their abundance had declined to a fraction of previous levels. Recovery will take time, given the great migration distances of spawning adults and the dispersion potential of larvae, which can travel across national boundaries. The only way to ensure healthy populations is for actions to be guided by a regional and multilateral vision. Individual actions by MAR countries are insufficient.

6.3 Actions to protect FSAs

The first step for effective conservation is to identify and characterize FSA sites, followed by the implementation of species-specific measures that take into consideration the characteristics and specific needs of each site and the regulations of each country. Once FSA sites are identified, they must be monitored effectively to evaluate changes in fish populations and the impacts of conservation actions. One way to ensure processes are effective is to use standardized protocols for site assessments and monitoring such as the 2020 MAR Fish monitoring protocol. In addition, the successful implementation of regionally complementary fisheries regulations requires active community participation, the development of financial support mechanisms, and economic alternatives for fishers, which together strengthen community resilience while conserving marine resources [38].

© Alexander Tewfik, Nassau grouper. Glover's Atoll, Belize.

6.3.1 Involving the stakeholders

While identifying new FSA sites is often the goal of researchers and conservationists, it is unlikely that many untouched FSA sites in the MAR and the wider Caribbean exist, given that most, if not all, FSA sites are already known to fishers. Likewise, conservation and sustainable fisheries measures cannot be effectively implemented without the support of local fishing communities, particularly in regions with limited resources to enforce regulations. To ensure long-term conservation benefits, build capacity, and share responsibilities, fishing communities must actively participate in exploring and monitoring FSA sites, ideally through citizen science [14].

6.3.2 The role of the MAR Fish project

The MAR Fish Project is a conservation initiative aimed at protecting marine biodiversity and fishery resources in the region, with its main objective to support the rebuilding of the Mesoamerican reef fish stock by strengthening the protection and monitoring of a network of fish spawning aggregations sites, as critical areas of the life cycle of these species. The MAR region, which includes the coastal areas of Mexico, Belize, Guatemala, and Honduras, is home to a great diversity of marine species. The FSAs are essential to maintaining healthy populations and ensuring the functional balance of marine ecosystems in the MAR region. However, overfishing and the degradation of key habitats have threatened the sustainability of MAR ecosystems. The MAR Fish project aims to address these threats through an integrated approach that combines scientific research, community engagement, and strategic management.

Key activities include:

- Scientific research: the identification, characterization, and monitoring of FSA sites using advanced observation and analytical techniques.
- Community participation: training and raising awareness in local communities, promoting sustainable fishing practices, and strengthening community governance.
- Creation of protected areas: implementing spatial conservation measures to minimize extraction during critical breeding periods.

In 2023, the MAR Fish regional partner workshop was held in Cancun, Mexico. The main objective of the workshop was to follow up on the efforts of the project partners since the last workshop in 2020, with participants presenting their achievements, sharing their challenges, and identifying future opportunities. A total of 19 people (ten women and nine men) from ten organizations in the MAR region participated, representing civil society, fishing communities, resource managers, and research organizations. During the workshop, a follow-up on the standardization of data collection was conducted, evaluating its advantages and disadvantages across various contexts. In addition, participants shared the results of new monitoring technologies, such as passive acoustic monitoring, tagging, fisheries monitoring, and environmental DNA (eDNA) analysis. A key point of the workshop was the description and analysis of results from the MAR sentinel sites, enabling a deeper evaluation of these strategic locations.

6.4 Recommendations by country

6.4.1 Mexico

- Officially recognize FSAs as critically important sites in fisheries legislation and strengthen the enforcement of regulations during spawning seasons.
- Separate the fishing ban for the Gulf of Mexico from that of the Caribbean region and its species; extend the ban from Cabo Catoche to the Belize border from two months to four months to align with the regulations established by Belize.
- Increase minimum landing sizes for grouper species to include size at maturity to ensure spawning potential.
- Assess the snapper fishery to create science-based recommendations and a regional management plan.
- Review and update the management plans of the MPAs, considering FSA information. The management plans of the MPAs should be reviewed every five years as part of an adaptive management regime; many of them have remained unchanged.

6.4.2 Belize

- Complete fishing bans in FSA sites.
- Integrate and align the FSA network into a multi-species finfish management plan for Belize.
- Increase strategic patrolling and surveillance at FSA sites inside and outside MPAs.
- Conduct a national assessment of the status of all grouper and snapper FSAs.
- Empower fishers and local fishing cooperatives to protect, monitor, and manage FSA sites in their fishing areas.
- Implement technologies to improve the monitoring of FSA sites.

Monitoring recommendations:

- Use of submersible drones to monitor FSAs.
- Use of acoustic monitoring devices to detect the movements and sounds of fish and vessels at FSA sites.

- Replace patrol equipment (e.g., motors, SMART equipment, and computers).
- Support research efforts.

6.4.3 Guatemala

- The fishing bans for all grouper and snapper species should be extended:
    - Grouper: December to March
    - Snapper: April to June

- Increase surveillance and the enforcement of regulations during spawning seasons.
- Update MPA management plans to include FSAs as a management tool for FSA sites.
- Characterize and monitor FSA sites and fish populations to gain insights that may be applied to adaptive fisheries management.

6.4.4 Honduras

- Create fish replenishment zones in FSA sites with adequate monitoring and the proper enforcement of regulations.
- Management measures should be established at different time scales, given the lack of validated FSA sites:
    - Short term: general product control measures, such as bans on specific species, seasonal sales restrictions, and minimum fishing sizes.
    - Mid-term: once the locations of the FSAs, species, and seasons have been determined, input control measures, such as fishing gear restrictions, temporary closures, and fish replenishment zones, can be implemented.
    - Long term: after generating information on exploited fish stocks, species-specific fishing limits should be established.

- Include local fishers in actions to protect, monitor, and manage FSAs in their fishing areas to build capacity and empower local communities in long-term management.

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7 The future scenario without FSAs

The recovery of fish populations in the region likely depends on the fate of the eggs and larvae produced and dispersed from the few remaining FSAs, especially considering that fisheries targeting these aggregations are particularly vulnerable to overfishing, threatening many species, particularly in the tropics [36]. A future without FSAs is one without a healthy MAR. Fish spawning at FSA sites are important to the food webs of coral reefs, support fisheries and sustain livelihoods, and draw tourism to the sites.

Climate change directly affects FSAs in multiple ways. Rising sea temperatures have begun to alter the traditional reproductive cycles of various species, with changes in the traditional timing of FSAs. Studies in the Caribbean have shown that the increased frequency and intensity of extreme weather events has affected the stability of FSA sites, particularly in shallow areas. In addition, ocean acidification has impacted coral reefs that serve as reference points for species during their reproductive migrations, which could affect the reproductive success of FSAs.

Despite the actions that the MAR countries have taken to date, our efforts have been insufficient. It is time to concentrate our efforts to protect and conserve these vital resources through concrete, aligned multilateral efforts from the four MAR countries.

7.1 Actions required to sustain FSA sites in the MAR

Over the past few years, FSA monitoring and protection in the MAR region has notably improved, although challenges remain. The implementation of new monitoring technologies, such as underwater drones and advanced acoustic systems, has produced a better understanding of FSAs and the movement patterns of key species. Citizen science programs and community engagement have also strengthened, especially in Belize and Mexico, where local fishing communities now play active roles in protecting and monitoring FSAs. However, the effects of climate change, such as changes in temperature patterns and marine currents, have begun to impact the reproductive cycles of various species, adding a new layer of complexity to conservation efforts. Although regional coordination has improved, greater collaboration and agreement on protection policies and measures among the four MAR countries is still needed.

Specific recommendations:

- Further develop a shared vision for the regional management and conservation planning of FSA sites.
- Create fish replenishment zones in FSA sites that are currently not protected, considering the biophysical, socioeconomic, and governance principles established for the MAR.
- Prioritize and align surveillance and enforcement efforts with the timing of spawning seasons.

- Standardize size limit regulations and closed seasons for key species, especially for groupers and snappers.
- Validate, characterize, and periodically monitor all FSA sites to generate scientific data to guide adaptive management efforts. Implement standardized monitoring frameworks to generate essential biological, socioeconomic, and governance information using standardized protocols.
- Develop a regional database and data sharing protocols to ensure continuity, effective data management, and institutional knowledge of FSAs over time.
- Promote the conservation and restoration of key habitats for FSAs such as mangroves and reefs.
- Promote community-based strategies for monitoring, data collection, and management to foster shared responsibility, project acceptance, and sustainability.
- Ensure the effective enforcement of regulations at all FSA sites and during closed seasons.
- Evaluate the impacts of climate change on FSAs.
- Raise awareness through communication campaigns targeting key stakeholders and the general public about the importance of FSA sites in maintaining food security and conserving biodiversity.

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