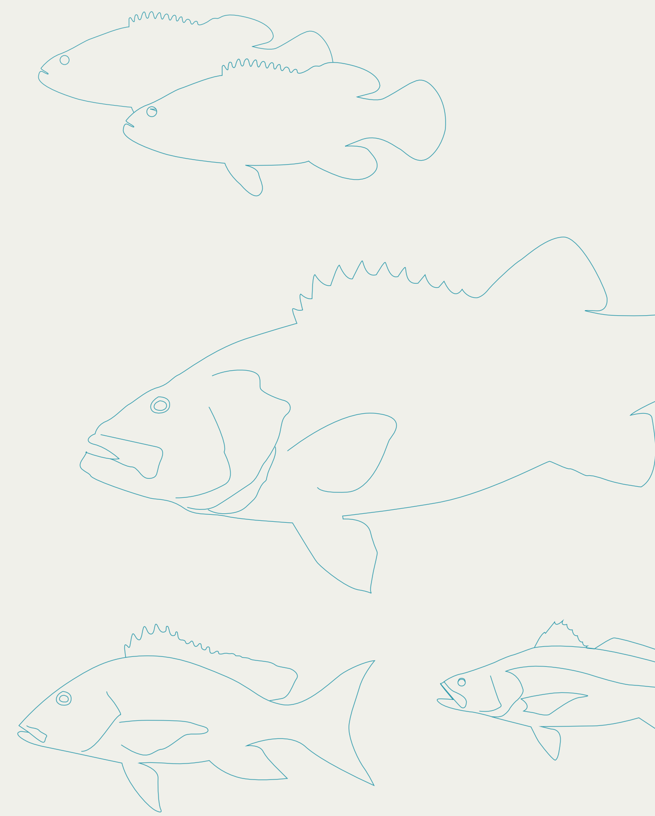
Fish Spawning Aggregations

a focal point of fisheries management and marine conservation in Mexico

Photo: Octavio Aburto



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GC MARINE PROGRAM

COBI Comunidad y Biodiversidad

LGL

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Introduction

Fish spawning aggregations (FSAs) are massive gatherings of fishes that form for breeding and are critically important to the survival of the species that form them. The predictability of FSAs in time and space and the large numbers of fish they include make them important sites for fisheries and large sources of income for local communities. Unfortunately, these same characteristics often make them sensitive to fishing pressure; large numbers of fishes can be harvested in short time periods, and global declines in FSAs are associated with widespread overfishing.

The strong, direct interaction between fisheries and reproduction and the importance of aggregations to ecosystems necessitates that FSAs be a focal point for fisheries management and marine conservation on a global scale. The good news is that there is a growing body of evidence that small, well-planned investments in the management of FSAs can provide disproportionately large benefits to both fisheries and biodiversity conservation.

Recognizing the importance of FSAs to national fisheries and conservation efforts and the need for broader education and outreach, researchers from the Coastal Fisheries Research Program (CFRP) at The University of Texas at Austin Marine Science Institute, the Gulf of California Marine Program (GCMP), COBI, and LGL have been studying aspects of the ecology and fisheries of FSAs in Mexico for decades. Our mission is to work in partnership with fishers, scientists, conservation groups, and government agencies to engage in research, monitoring, and assessments for FSAs that inform management and support healthy ecosystems and livelihoods of coastal communities.

This document provides a brief summary of the ecology and management of FSAs based on the collective experiences of research conducted in the Gulf of California, the Mexican Caribbean, and other areas around the world.

Photos: Richard Barnden (above), Douglas David Seifert (top right), Walt Stearns (middle right), Octavio Aburto (bottom right)

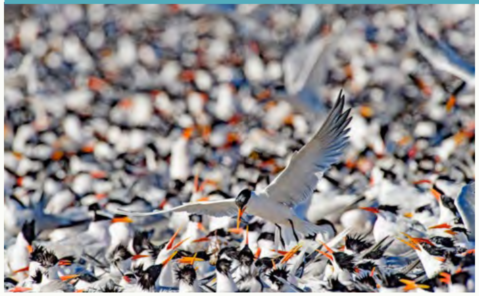
What are fish spawning aggregations (FSAs)?

Photo: Richard Barnden

Fish spawning aggregations (FSAs) are temporary gatherings of large numbers of conspecific fish that form for the sole purpose of reproduction.

FSAs are critical life-cycle events to those species that engage in such behavior, often representing the only opportunities when fish reproduce and thus comprising the major source of reproductive output for an entire population. FSAs are comparable in importance to breeding aggregations of seabirds, sea turtles, whales and other animals. FSAs are predictable in time and space with locations and cycles dictated by the adaptation of species to interactions between habitat features and ocean dynamics that generate linkages through ocean food webs and attract top predators and mega-planktivores. Numerous are multi-species aggregations, where many species gather to breed simultaneously or at different times of the year according to specific seasonal, lunar, tidal and diel cycles.

Other aggregations: *Birds, turtles, invertebrates and mammals also form massive breeding migrations or aggregations*



Photos (L to R): Octavio Aburto, Octavio Aburto, Octavio Aburto, Madeline Wukusick

What kinds of fishes form FSAs?

The most commonly known representatives include members from several families such as groupers (Epinephelidae), seabasses (Serranidae), snappers (Lutjanidae), croakers and drums (Sciaenidae), wrasses and parrotfishes (Labridae), surgeonfishes (Acanthuridae), and jacks (Carangidae).

While less commonly known, fishes from many other families also breed in aggregations including triggerfishes (Balistidae), porcupinefishes (Diodontidae), mackerels and tunas (Scombridae), flatfishes (Pleuronectidae), and Grunts (Haemulidae). Even some deep sea fishes such as orange roughy (*Hoplostethus atlanticus*) spawn in aggregations. Some rays form massive aggregations in Mexican waters such as Munk's devil ray, *Mobula munkiana*, which is known for its spectacular aerial acrobatics.

Photos: Octavio Aburto

FSAs have been documented in 300 species of fishes from 44 families

Twin Spot Red Snapper

Photo: Richard Barnden

Nassau Grouper

Photo: Cristina Limonta

Moorish Idols

Photo: Richard Barnden

Are there different types of FSAs?

Transient spawning aggregations

Many large-bodied species form **transient spawning aggregations** in which fish travel long distances to spawn in aggregations that persist for only a few days to weeks. They tend to be brief and form at specific times of the year, often during specific lunar or tidal phases. Many are commercially important, large-bodied apex predators (e.g. groupers and snappers).

Examples include Nassau Grouper and Cubera Snapper from the Mexican Caribbean; Gulf Corvina and Totoaba from the Gulf of California

Photo: Douglas David Seifert

Resident spawning aggregations

Resident spawning aggregations consist of fish that travel short distances (meters to a few kms) and persist for months or even year-round. Small bodied herbivores and grazers (e.g. wrasses and surgeonfishes) tend to form frequent resident spawning aggregations within their home ranges. These are often synchronized for specific times and can occur daily.

Examples include Hogfish and Blue Tang from the Mexican Caribbean and Convict Tangs and Longspine Porcupinefish from the Gulf of California

Photo: Octavio Aburto

Partial migrations

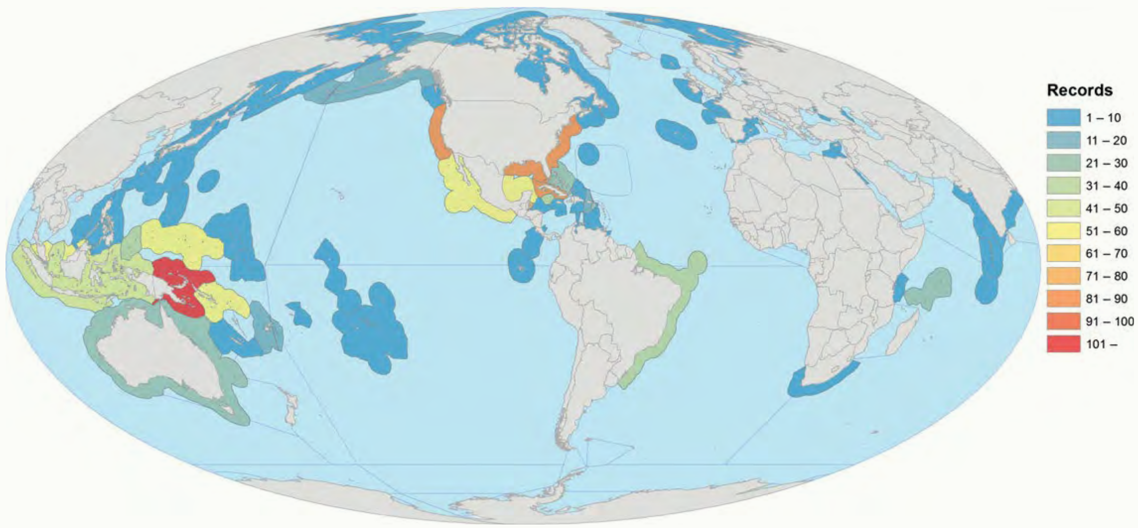
Partial migrations are spawning aggregations that consist of a mixture of residents and transients. Species may also adopt a diversity of behaviors that range between the extremes of resident and transient aggregation, and multiple patterns of aggregation behavior may exist within a species or population.

Example include Leopard Grouper and Yellow Snapper at Los Islotes vs. El Bajo seamount in the Gulf of California

Photo: Octavio Aburto

Where do FSAs occur?

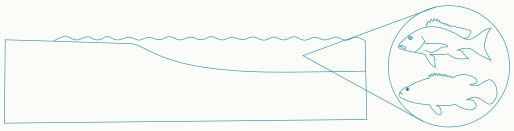
FSAs are most studied on coral reefs, but they have been identified within nearly every marine eco-region and habitat type, ranging from shallow tropical coral reefs, subtropical estuaries, coastal bays and lagoons, and temperate offshore banks to seamounts in the deep ocean. FSAs have been documented across all 5 oceans, and in 53 countries, but many FSAs throughout the world remain undocumented.



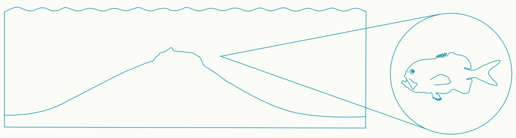
Global map showing areas of documented FSAs organized by region or country. Data (n = 906 verified records). Figure from Erisman et al. 2015.

Species and habitats:

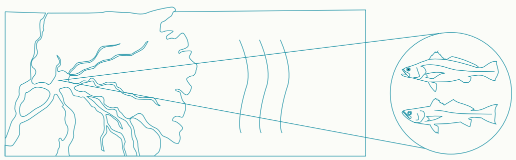
Groupers and Snappers off shelf-edges



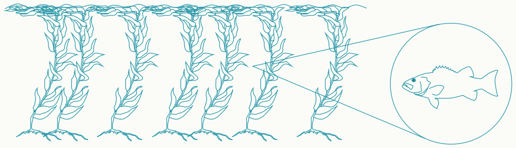
Orange Roughy on deep seamounts



Gulf Corvina and Totoaba in river deltas



Giant Sea Bass in kelp forests



How are FSAs important for ecosystem health?

Productivity hotspots:

The large concentrations of fishes create temporary productivity hotspots that cascade into diverse coastal and pelagic food webs. The massive clouds of eggs released by aggregating fish represent a rich source of nutrients that benefits organisms throughout the food chain from massive whale sharks to tiny microorganisms too small to see. The nutritious eggs represent a major trophic pathway that creates linkages and feedbacks between organisms and environments across all trophic levels and among the few pathways that recycle essential nutrients from apex predators to the lower trophic levels. These events are comparable to the synchronized mass spawning of corals that create pulses of nutrients that are rapidly assimilated into local food webs.

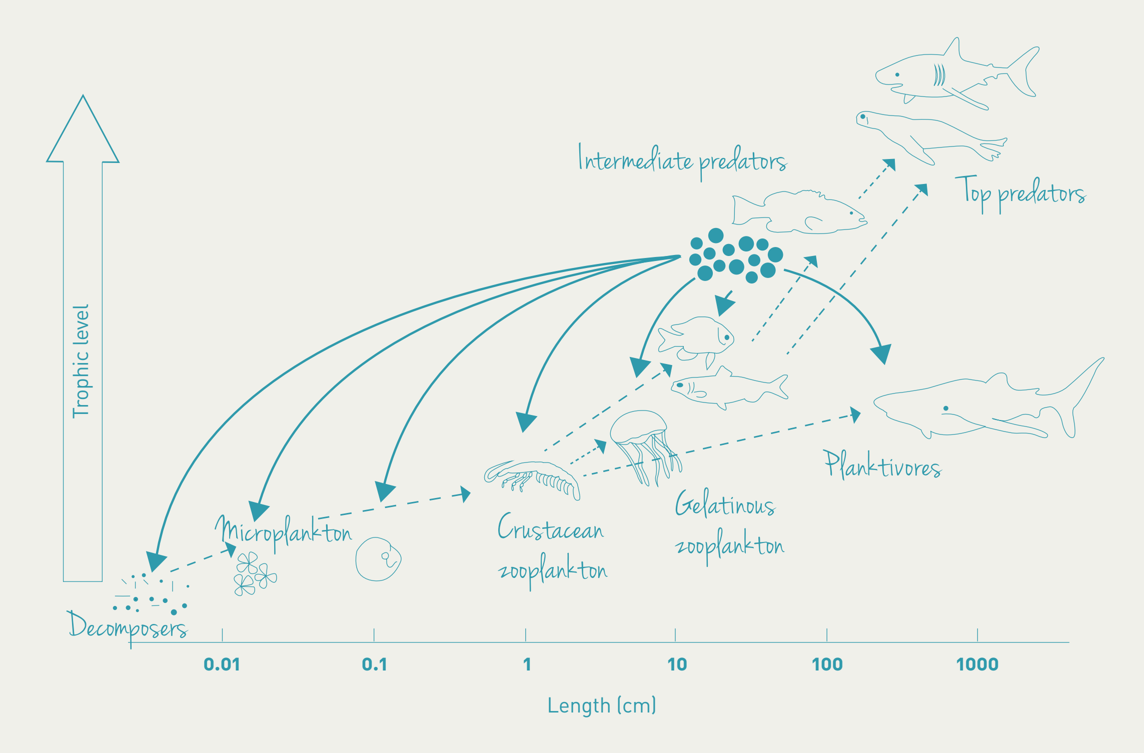


Figure redrawn from Fuiman et al. 2015

Megafauna magnets:

The ephemeral concentrations of food resources at FSA sites are also associated with timed migrations by a wide diversity of large, migratory predators (e.g. sharks, billfishes, dolphins, and tunas) that feed on aggregating fishes.

Mega-planktivores (e.g. whale sharks and manta rays) also aggregate to feed on the spawned eggs.

Photos: Richard Barnden (top), Douglas David Seifert (above)

How are FSAs important for ecosystem health?

Apex predators:

Many fishes that form FSAs (e.g. groupers and snappers) occupy the highest trophic levels on tropical and temperate reefs. The presence of these species is therefore important to shaping the stability, structure, function, and health of reef ecosystems. Overfishing of spawning aggregations of predatory fishes can alter community structure in complex and indirect ways, including inducing changes in benthic dynamics and coral health, fish diversity, condition and population demographics of lower trophic groups, and resilience to climate change.

Photo: Octavio Aburto

Umbrella effects:

Photos: Octavio Aburto

Many sites are multi-species FSAs where numerous species spawn at different times of the year, each attracting many other species that visit the site to feed on spawning fish or their eggs. Thus, protection of a single site can contribute to the protection of many other species (incl. apex predators and iconic megafauna) and the maintenance of entire ecosystems.

How are FSAs important for fisheries and livelihoods?

Photos: Octavio Aburto

FSAs support some of the most important and productive commercial, recreational, and subsistence fisheries across the globe, and multi-species FSAs sites often represent the most important regional fishing grounds.

Notable examples from commercial fisheries include Atlantic Cod, groupers and snappers from the Live Reef Fish Food Trade in Southeast Asia, Orange Roughy fisheries at seamounts off New Zealand and Namibia, and salmon fisheries in the U.S. Pacific Northwest that represent multi-billion dollar fisheries. Other commercially important species that migrate and aggregate to spawn include the Alaska Pollock and the Atlantic Herring that both contribute several million tons and tens of billions of dollars annually to global fisheries production.

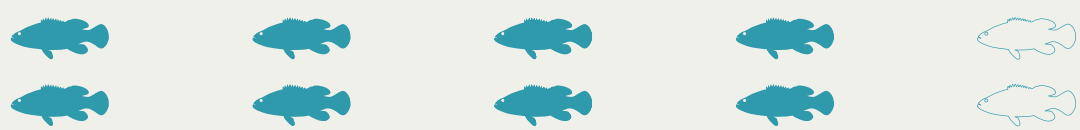
FSAs are also crucial to the livelihoods and food security of small-scale and subsistence fishers around the world, particularly in developing nations in the subtropics and tropical regions.

The high abundance of fish present at FSAs during predictable periods and at known locations, which can range from tens to even millions of individuals confined to small areas, generates the ideal scenario for fishers; large catches and sizeable earnings with minimal effort.

Photo: Octavio Aburto

In Mexico...

Spawning aggregations support 8 of the top 10 most important reef fish fisheries in the Southern Gulf of California, and 21 of 29 species of reef fishes reported in the commercial fisheries landings of the region form FSAs. Likewise, the most valuable reef fisheries in the Mexican Caribbean target FSAs of groupers and snappers.



How can overfishing FSAs impact species and ecosystems?

General effects:

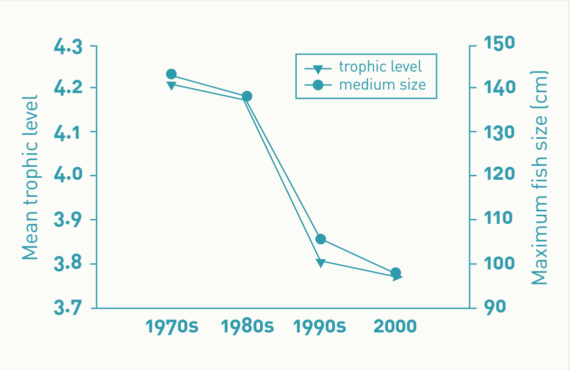
As FSAs may attract the majority of breeding fish from a radius of 10-100s of kilometers, the extirpation of fish from the spawning site effectively removes the species from a much larger surrounding area. Since FSAs are often the only time and place fish reproduce, harvesting from these sites can rapidly and dramatically reduce the reproductive capacity of the stock by removing future egg production. In turn, this can reduce stock resilience – i.e. their ability to maintain themselves in the face of fishing pressure and climate change.

Specific effects:

(Direct and indirect effects):

Exploitation of aggregated fish may compromise reproductive function, reproductive output, and fertilization rates by interfering with the mating process. This occurs via disruptions of complex courtship rituals and mate encounters, impairment of visual or auditory communication, alterations of sex ratios and social structure during mating, damage to spawning habitat by destructive gear, and stress-caused changes in hormone levels, fecundity, egg development and survival.

Given the importance of aggregations on ecosystem-scales, it makes sense that overfishing of FSAs is associated with rapid declines in fish stocks, fishery collapses, ecosystem imbalances, and the loss of structural and functional integrity of marine ecosystems.



Temporal changes in mean trophic level and maximum fish size of coastal fisheries landings in the southern Gulf of California. The decline is associated with extirpation of FSAs of large-bodied groupers (e.g. Goliath Grouper and Gulf Grouper). Sala et al. (2004)

What is the status of FSAs around the world?

The most recent and comprehensive report on the global status of marine FSAs revealed that 52% of the documented aggregations have not been assessed, less than 35% of known FSAs are protected by any form of management, and only about 25% have some form of monitoring in place. Among those FSAs that have been evaluated, 53% are in decline and 15% have disappeared altogether. Approximately 10% of aggregations have shown evidence of recovery, and the remaining 27% are stable or have not shown evidence of noticeable change.

FSAs...

Status of documented spawning aggregations...

52% unknown

26% are decreasing

4% are gone

Of those sites that are studied...

<35% are protected

53% are decreasing

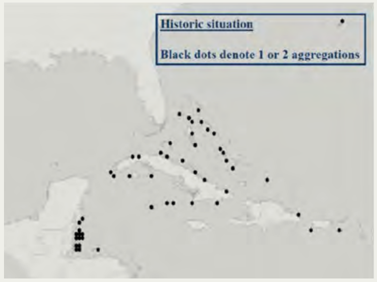
15% of reef FSAs have disappeared

The most pervasive and serious declines have been documented for large-bodied, high value species in the tropics such as groupers and snappers. For example, twenty of 163 species (12%) of groupers risk extinction if current fishing trends continue, and a comparative analysis among grouper species of known reproductive strategy demonstrated that FSA formation is associated with higher extinction risk.

Example: Nassau Grouper

Once the most important finfish fishery in the wider Caribbean, the majority of the known Nassau Grouper FSAs throughout its range have been extirpated or reduced to negligible numbers. Fisheries for Nassau have collapsed in most areas, and the species is classified as critically endangered by the IUCN.

Historic Situation



Current Situation

Sadovy, et. al (2012)

Is monitoring of FSAs practical?

The tendency of FSAs to form at spatially discrete locations at predictable times means that monitoring, enforcement and research can all be scaled down and streamlined accordingly.

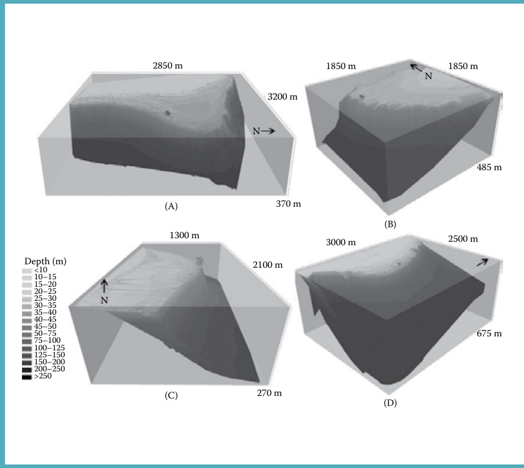
Since aggregations include all or nearly all the breeding adults from the surrounding area, FSAs offer the unique opportunity to rapidly and efficiently access and evaluate entire fish stocks that would otherwise be dispersed over a much larger geographic area.

The small area of spawning grounds compared to the area over which fish migrate and establish home ranges creates the most "bang for the buck", in that successful protection of spawning can scale up to the level of the entire population. Therefore, the management of small FSAs can help replenish fish populations at much larger scales that benefit stakeholders and are congruent with successful conservation practice.

Similarities in geomorphology among spawning sites for suites of species allow researchers and resource managers to predict timing and locations of previously unknown, multi-species sites that can greatly aid in marine spatial planning such as the design of marine reserves. The high degree of geomorphological similarity among FSAs within regions facilitates the designation of locations for seasonal or permanent marine reserves that have the potential to support a high diversity and biomass of fishes.

Photos: Richard Barnden (above left), Octavio Aburto (above right)

Geomorphology:



Kobara et. al (2013)

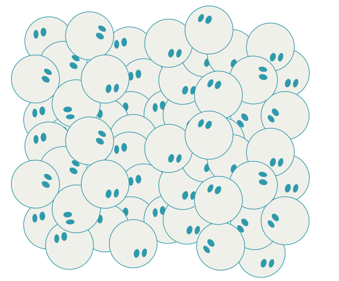
Geomorphology of multi-species FSA sites throughout the wider Caribbean are all strikingly similar. This allows managers to predict where aggregations should occur (independent of whether they are there presently or have declined), and thus which areas are likely to recover and be productive if protected. It's a very powerful tool that is being used in Mexico, the U.S. South Atlantic, and other areas.

Does protection work and does it benefit fisheries?

Proper management of FSAs benefit fisheries through enhanced production and survivorship of larvae, the dispersal of nutritious eggs, and the potential spillover of these rich sources of productivity into fished areas.

FSAs can help replenish fish populations at much larger scales that benefit stakeholders through the buildup of fish biomass at the protected site and measurable spillover of adults and juveniles into adjacent fished sites.

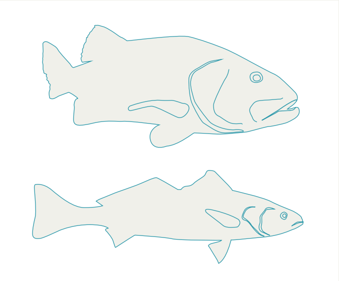
Spawning Aggregation Reserves



Dispersal and connectivity are an example of how the inclusion of important spawning aggregation sites can become a source of larvae to surrounding areas that are important fishing grounds (Munguia et al. 2015).

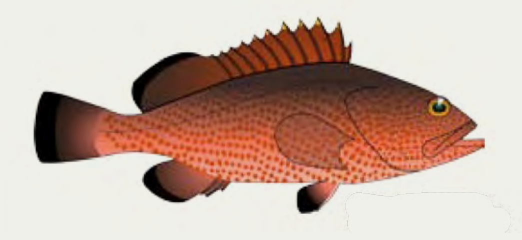
There is a growing list of examples of protected FSAs that had been extirpated or heavily depleted returning and forming aggregations once again.

Protection Leads to Recovery



For example, the banning of gill nets in the kelp forests of California, where Giant Sea Bass and White Seabass form FSAs, led to dramatic population and fisheries increases in the years following (Russell et al 2014).

Protection of FSAs results in direct benefits to fisheries through increases in catch rates and the average size of fish caught outside the spawning season and at fished sites.



Red Hind Illustration: Larry Allen

Take, for instance, the work on Red Hind (Nemeth 2005) in the US Virgin Islands. A large, permanent marine protected area (no-take) was created at a FSA site in the US Virgin Islands, which was seasonally closed for 9 years. This resulted in a dramatic increase in Red Hind (E. guttatus), with the estimated spawning population increasing 3-fold (26,200 to 84,000) in 3 years.

Do fishers support protection of FSAs?

Photo: Octavio Aburto

Fishers have known for centuries where and when aggregations form. FSAs are critical sources of food security for subsistence cultures and are strongly linked to economic livelihoods for small-scale fishing communities.

For that reason, fishers are often willing to protect FSAs in order to sustain their fisheries and livelihoods, and FSAs represent rare and important opportunities for consensus-based, co-management approaches that align fisheries and conservation sectors through merged agendas and mutual benefits.

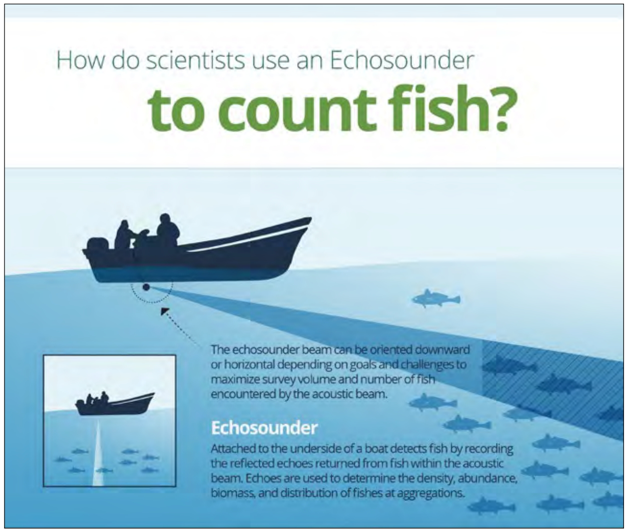
Collaboration

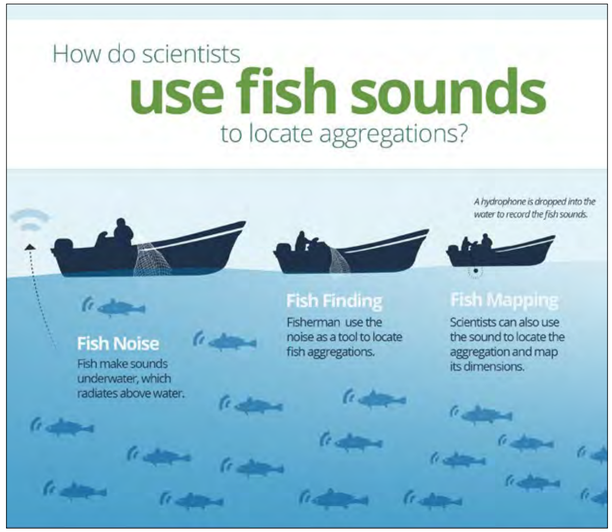
The GCMP and CFRP have been working with fishermen from Punta Abreojos on the Pacific Coast of Baja California to understand interactions between spawning aggregations of Barred Sand Bass (*Paralabrax nebulifer*) and the commercial trap fishery and to use this information to design management strategies that protect spawning while also allowing fishers to access the resource.


Photo: Octavio Aburto

Since 2012 in the Mexican Caribbean, COBI has worked with fishers who have petitioned the government to create four marine protected areas for the protection of grouper spawning aggregations. These areas are monitored and managed cooperatively between fishers, NGOs, scientists, and government.

How do we effectively monitor FSAs and their fisheries?





Fisher interviews are critical for identifying the location and timing of undocumented aggregations and for establishing partnerships on the monitoring and management of FSAs.

Catch and effort data can provide detailed information on the importance of FSAs to fisheries as well as the potential impacts of fishing on spawning. Understanding how fishing activities interact with spawning in time and space is essential for determining how best to manage or protect the aggregation to maintain a sustainable fishery.

Dockside and biological sampling of fish captured at FSAs are useful for gathering detailed information on the exact timing of spawning (e.g. time of day, season, how often spawning occurs) and the size or age structure of fish at FSAs sites.

Bathymetric mapping using single-beam or multi-beam sonar surveys provides valuable information on the geomorphology and habitat type of FSAs sites in relation to the depth, location, and distribution of spawning fish.

In locations with suitable conditions, **underwater visual or video surveys** are essential to verify the existence of FSAs, quantify the number and size composition of fishes in spawning aggregations, document courtship and spawning behaviors, and to monitor changes in these dynamics over time.

In locations with poor visibility or challenging conditions, **echosounder (sonar) surveys** conducted from boats can produce robust estimates on the density, distribution, and abundance of fish at FSAs. Similarly, **passive acoustics (hydrophones)** can be used to monitor the presence and spawning activity of fishes that produce sound in relation to reproduction. The use of **acoustic telemetry (electronic tags on fish)** allows for estimates of residency time, site fidelity, and movement patterns of fish in relation to FSAs sites.

Illustrations: Madeline Wukusick

Cooperative Monitoring

COBI has trained fishers to characterize and monitor FSAs in the Mexican Caribbean. Interviews with fishers led to the discovery of new sites, and trained fishers helped scientists to map and characterize sites using single beam sonar. Fishers now work with scientists to conduct regular visual censuses of FSAs with SCUBA. Four sites in the Mexican Caribbean have now been closed to fishing at the request of the fishers themselves.


Photo: Octavio Aburto

GCMP scientists collaborate with fishers and reserve managers to monitor the Gulf Corvina population and its fishery through field surveys of its massive FSA at the mouth of the Colorado River Delta each spring. Due to the turbid water conditions, the team conducts echosounder surveys to estimate the abundance of fish at the aggregation, hydrophone and egg collection surveys to determine the exact timing and location of spawning, and they place GPS trackers on fishing boats to understand spatio-temporal interactions between fishing and spawning activities.

Illustration: Larry Allen

#1 Nassau Grouper (*Epinephelus striatus*)

The Nassau Grouper is a large-bodied grouper (grows to > 1m and 25 kg) associated with coral reefs in the western Atlantic from Florida and Bermuda south to Guyana, including the eastern Gulf of Mexico and throughout the Caribbean. It is a common predator on reefs and an iconic reef fish in the Caribbean Sea. While solitary for much of the year, adults migrate up to several hundreds of kilometers to form large, transient FSAs of hundreds to tens of thousands of fish at specific locations during the winter months. In the Mexican Caribbean, these aggregations form on reef promontories along the shelf edge reef promontories over a 7 to 10 day period in relation to the full moons of December through March, with peak spawning activity taking place approximately six days after the full moon.

Commercial and recreational fishing activities for Nassau Grouper have long focused primarily on the FSAs, and this interaction is the principal driver of the decline and collapse of aggregation sites, fisheries, and populations of the species in Mexico and elsewhere throughout its range. The species is listed as critically endangered on the IUCN Redlist due to widespread declines and the disappearance of most aggregations due to overfishing. At least one spawning site in Mexico has been fished to extinction in the past decade, and several other sites have undergone severe declines or are thought to have disappeared.

While the species is heavily managed or fully protected in other countries, Nassau Grouper are not protected or managed in Mexico. In the Mexican Caribbean, the season is closed from the 1st February until 31st March in 2017. However this closed season was primarily established for the Red Grouper (Epinephelus morio), which is fished in the Gulf of Mexico, and does not adequately protect the Nassau Grouper during its peak spawning period in the Caribbean.

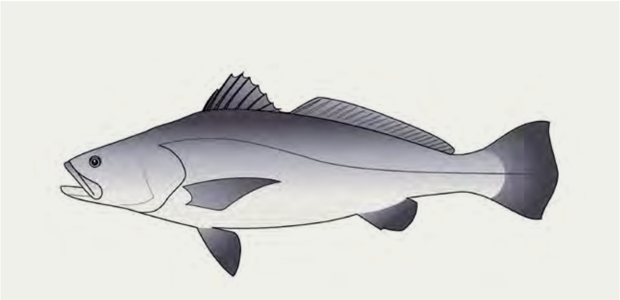


Illustration: Larry Allen

#2 Totoaba (*Totoaba macdonaldi*)

The Totoaba is the world's largest sciaenid fish, with a maximum reported weight of over 100 kg and a length of more than 2 m. This massive coastal predatory species is endemic to the Gulf of California, and adults undertake seasonal migrations to different regions of the Gulf to feed and to reproduce. Each winter, the entire adult population begins to migrate from their home territories spread throughout the Gulf and into the Upper Gulf of California in preparation for spawning. Spawning occurs in aggregations of thousands of fish that form around the estuaries and coastlines of the Colorado River Delta region from February through May, with peak spawning in March and April.

Important to the subsistence fisheries of indigenous cultures throughout the Gulf of California for more than a century, the Totoaba fishery became the first commercial finfish fishery in the region in the early 1900s. The fishery developed in response to an international demand for the gas bladder, (known as "buche"), which was exported to China and Chinese communities in California. A market for the whole fish developed later in the 1920s and peaked in 1942, but it was never as important as the international market for the swimbladder. Persistent overfishing of FSAs of Totoaba for several decades was a principal driver of a collapse of the fishery by the 1950s. Bycatch of juvenile Totoaba in the shrimp trawl fishery and reduced nursery habitat resulting from declining flow from the Colorado River also contributed to fishery and population declines.

Attempting to protect Totoaba during their spawning season, Mexico instituted a closed season beginning in 1940 on the Totoaba fishery between March 20 and May 1. A complete closure of the fishery was implemented in 1975 along with designation of a reserve zone at the mouth of the Colorado River. Due to continued, widespread poaching and incidental take of Totoaba, the Mexican government expanded the reserve zone in 1993. The Totoaba was was listed in 1976 on Appendix I of the International Convention on Trade in

Endangered Species of Fauna and Flora (CITES), which prohibited importation of the species into the United States, except for the purpose of scientific research. In 1986, it was listed as endangered in the IUCN Red List.

After 40 years of protection, some evidence of recovery is emerging. However, the illegal international market for Totoaba swimbladders skyrocketed after 2010, such that individual swimbladders from large fish can sell for up to U.S. $50,000 at Markets in Hong Kong. Widespread poaching of adult Totoaba from their FSAs now supports an illegal international market that is speculated to exceed the value of illegal drugs such that it is now referred to as "aquatic cocaine". Government and non-government agencies in Mexico, the United States, and Asia have increased efforts to reduce the poaching and trade of swimbladders.

#3 Goliath Grouper (*Epinephelus itajara*)

The Goliath Grouper is one of the largest groupers in the world, reaching 400 kg and 2.5 m in length. Adults are found on natural and artificial reefs, wrecks and other structural habitats in the tropical Atlantic, from the west coast of Africa to the east coast of Central America (including the Caribbean and Gulf of Mexico), and from Florida to Brazil. Adults spawn within aggregations of tens to several hundred adults that form during specific lunar phases from July to September in the Yucatan peninsula and along the eastern Gulf of Mexico.

Of historical importance to commercial fisheries throughout its range, the Goliath Grouper has also long been prized by recreational and sport fishers using spear guns or hook and line gear. Persistent and widespread overfishing of FSAs has resulted in the extirpation of the species in many areas, and

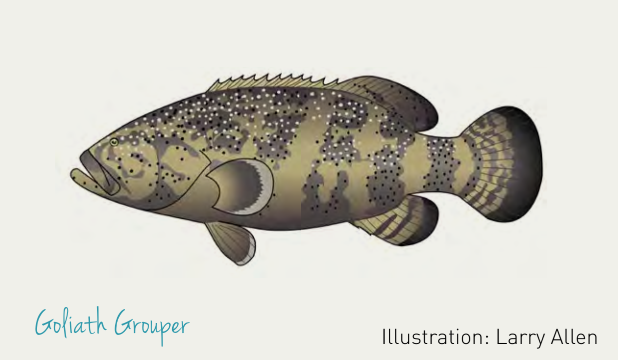


Illustration: Larry Allen

the species is listed as critically endangered by the IUCN. Destruction of mangroves, the principal habitat for juveniles during the first 5 years of life, has also contributed to the decline and slow recovery of the species following protection. Interviews of fishers from the Yucatan region in Mexico indicate the Goliath Grouper fishery has declined severely since it began in the early 1970s, and the species currently represents only incidental catch and is no longer targeted.

Goliath Grouper have been protected from fishing in the U.S. since 1990, which has led to significant increases in populations in recent years. Similarly, the species has been protected in the Caribbean since 1993. However, as goliath grouper are very slow growing and require several years to reach sexual maturity, recovery for this species is expected to be slow. Very little information is known about the biology or spawning patterns of Goliath Grouper in Mexican waters, as most populations were extirpated several decades ago. Likewise, fisheries information necessary to determine the status of its populations is scarce. Although protected from fishing in many countries, the species is not managed in Mexico.

The Pacific Goliath Grouper (*Epinephelus quinquefasciatus*) has recently been identified as a separate species that ranges from Peru to Baja California, Mexico, including the Gulf of California. While information on its biology and fisheries throughout its range is very limited, it is suspected to have undergone severe population declines in most areas. In the Gulf of California, intense fishing pressure on FSAs of the species from the 1960s to the 1980s resulted in the complete collapse of the fishery by the 1990s. Nowadays, sightings of this species in the Gulf of California are incredibly rare, but small populations remain along the Pacific coast of Baja California. The species is not managed or protected in Mexico.

#4 Gulf Grouper (*Mycteroperca jordani*)

The Gulf Grouper is the second largest grouper in the eastern Pacific (grows to 2 m and over 90 kg) that grows slowly and can live for more than 48 years. It is a top predator that ranges from from southern La Jolla, California, USA, to Mazatlán, Mexico. It is found on rocky reefs and seamounts in the Gulf of California and on kelp beds along the southern Pacific coast of the Baja California peninsula, but it is naturally rare north of Bahía Magdalena along the Pacific coast of Baja California, Mexico. Adults form FSAs of 40 or more individuals from April to June on or near rocky reefs, with spawning activity believed to be influenced by the lunar cycle.

In the 1960s, Gulf Grouper were among the most important reef fishes in the small-scale fishery in the Gulf of California, representing 45% of the catch of the artisanal fleet in the southern Gulf. Fish were harvested by spearfishing, longlines, and handlines. Due to their large size and high market value, *Mycteroperca jordani* were also a primary target

Illustration: Larry Allen

of recreational spearfishermen and hook and line fishermen dating back earlier than the 1950s. While targeted by commercial and recreational fishermen throughout the year, effort and landings peak during the spawning season, and the persistent targeting of their FSAs is known to be a principal cause of fishery and population declines. Gulf Grouper were widely abundant in the Gulf of California just 30 years ago, but populations are now dwindling due to widespread overfishing, and fishing stocks in most areas collapsed by the 1980s. Landings of Gulf Grouper in the Gulf of California are estimated to have declined by more than 95%, with current landings supported primarily by the capture of juveniles, and populations are estimated to have declined by 99%.

The Gulf Grouper is listed as endangered on the IUCN Redlist due to the overfishing of its spawning aggregations. Similarly, the species was recently listed as endangered with a high risk of extinction by the National Marine Fisheries Service in the U.S. However, no fishing regulations or harvest restrictions exist in Mexico to protect the species or stimulate recovery of its fishery or populations. Moreover, basic information that is essential for restoring and managing Gulf Grouper (e.g. life history, habitat use, movement and spawning patterns) remains largely unknown.

#5 Gulf Corvina (*Cynoscion othonopterus*)

The Gulf Corvina is a large, fast growing marine fish that can reach 1 m in length, 12 kg in weight, and 10 years in age. The species is endemic to the northern Gulf of California in Mexico, and the entire adult population migrates from their home ranges and towards the Colorado River Delta in the Upper Gulf during the early spring months. Corvina aggregate to spawn in the shallow estuaries and channels of the Delta from late February to May, with spawning occurring with the outgoing tide over a 3-4 day period leading up to the new and full moons. The aggregations may hold up to 2 million individuals that are continuous and densely packed along more than 10 km of the river channels.

FSAs of Corvina are heavily targeted by the commercial fishery, which uses small boats (pangas) with gill nets to harvest large volumes of fish as they move into the river to reproduce. Individual pangas are capable of harvesting more than 2 tons of fish in a single trip, and the commercial fleet is capable of landing up to 5,900 tons of Corvina in less than 30 days of fishing each year. Spawning and fishing are synchronized on a semi-lunar cycle, with peaks in both occurring 5 to 2 days before the new and full moon, and fishing intensity and catch are highest at the spawning grounds within a no-take reserve. On average, more than 98% of the annual catch of Corvina comes from the spawning season, and 90% of fish are harvested during the days in which spawning occurs. The Corvina fishery is almost entirely domestic, with fish sold in markets throughout Mexico as a major source of seafood during Lent. However, international demand and

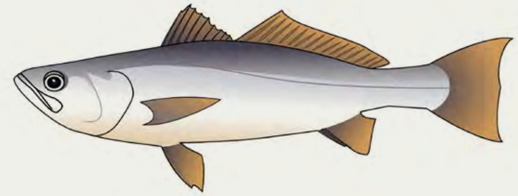


Illustration: Larry Allen

markets for the export of Corvina swimbladders to Asia has greatly increased in recent years. Notably, the predictable migration of Corvina has also served as a critical source of food for indigenous communities along the Colorado River for centuries.

A no-take zone within the Upper Gulf of California and Colorado River Delta Biosphere Reserve is meant to protect the spawning and nursery habitat of Corvina, which is also managed under a suite of regulations that include gear, effort, and catch limits, a seasonal closure, and an annual harvest quota. However, the intense fishing effort and large catch volumes that target the entire breeding population at its only known spawning grounds within the no-take zone is a major cause for concern for the sustainability of the population and its fishery. Sufficient protection of Gulf Corvina FSAs is critical given their extreme vulnerability to overfishing during spawning, evidence of a prior fishery collapse due to fishing of its aggregations, and the well-known collapse of the Totoaba and its fishery in the same region due to overfishing of its FSAs.

What types of management options are available for FSAs?


Photo: Octavio Aburto

The most appropriate management for any particular FSA or species is best made on a case by case basis and depends on local social and economic factors and the spawning behavior, biology, prevailing pressure, and conservation status of the target species.

For many species, multiple management approaches may be needed to minimize the risks of overfishing in all areas where the species is vulnerable to fishing. Multiple management measures should be complimentary and may be needed if enforcement is a problem. Ideally, More emphasis needs to be placed on coupling management measures directed at protecting FSAs with measures also directed at the non-aggregation component, i.e. the wider fishery.

When fishing pressure is focused primarily at FSA sites or at least during the peak spawning, **spawning reserves** may offer meaningful protection that helps to protect stocks or rebuild declining stocks through increased reproductive output and subsequent enhancement in recruitment, and which offsets any increased mortality outside marine reserves due to displaced fishing effort.

Species that migrate long distances to form only a few, large, FSAs for very brief periods (transient) are likely to benefit **from area closures at important spawning sites** and fishing bans or other controls during spawning periods, whereas those that move only short distances to form large numbers of small aggregations over several months (resident) may be sufficiently managed by **daily catch limits, annual or seasonal quotas, gear restrictions or other traditional measures**. Much depends on the available information regarding the timing and location of spawning, the number of aggregations, spawning behavior and local enforcement capacity.

Permanent area closures (no-take reserves) can provide significant protection if FSA sites are known and the closed area encompasses staging areas, migration routes, and spawning sites for multiple species.

When the seasonal timing and location of spawning is known and consistent each year, **seasonal area closures** of FSA sites can provide measurable benefits by allowing fish to spawn undisturbed. Since many areas offer spawning opportunity for multiple species all year around, permanent closures may offer more ecosystem benefits.

If only the season or timing of spawning is known, **simple temporal closures of fishing or the sale or possession of fish during peak spawning** periods


Photo: Octavio Aburto

or the spawning season can be cost-effective and an easy to enforce strategy if many FSAs are heavily targeted and vulnerable to fishing pressure.

Fishing gear restrictions such as limiting or prohibiting the use of SCUBA and hookah, traps, nets, spears, night fishing and explosives can reduce overfishing of FSAs. Likewise, restricting the use of gill nets or channel nets can protect spawning migrations to and from FSA sites.

Minimum size limits help ensure that fish grow large enough to reproduce before recruiting to a fishery, irrespective of where and when the species is fished, whereas **maximum size limits** help protect large, highly fecund females and large males (protogynous species) crucial for maintaining sufficient productivity for the population over many years. **"Window" or "slot" limits** provide both minimum and maximum harvest sizes for a species.

Complete protection of a species from fishing may be required to rebuild FSAs and stocks that have been decimated by persistent overfishing of FSAs that have resulted in fishery and population collapses.

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