

CONSULTANCY FINAL REPORT

**Fish Spawning Aggregation Sites in the MBRS Region:
Recommendations for monitoring and management**



**Prepared for: Mesoamerican Barrier Reef System Project
(MBRS)**

**Research Planning, Inc. (RPI)
1121 Park Street; Columbia, SC 29201
Tel: 803-256-7322; Fax: 803-254-6445
E-mail: jdahlin@researchplanning.com**

September 19, 2003

LIST OF ACRONYMS AND ABBREVIATIONS USED

ASK	Amigos de Sian Ka'an
BAS	Belize Audubon Society
BICA	Bay Islands Conservation Association
BCMR	Bacalar Chico Marine Reserve
ECOSUR	El Colégio de la Frontera Sur
FoN	Friends of Nature
Green Reef	Green Reef Environmental Institute
GRMR	Glover's Reef Marine Reserve
MAR	Meso-American Reef
PROLANSATE	Fundación para la Protección de Lancetilla, Punta Sal, y Texiguat
RBBC	Reserva Biósfera de Banco Chinchorro
RPI	Research Planning, Inc.
SCMR	Sapodilla Cayes Marine Reserve
SWCMR	South Water Caye Marine Reserve
TIDE	Toledo Institute for Development and Environment
TNC	The Nature Conservancy
UB	University of Belize
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund for Nature

Acknowledgements: This report could not have been prepared without the close working relationship with the Belize National Spawning Aggregation Working Committee, its members, and some of its data. Members include: Belize Fisheries Department, Green Reef Environmental Institute, Toledo Institute for Development and Environment, Friends of Nature, Belize Audubon Society, World Wildlife Fund for Nature, Wildlife Conservation Society, and The Nature Conservancy. We also recognize that this information has been compiled with the assistance of myriad local fishers from around the region, to whom we are deeply indebted and hope that this document and the processes that follow it, adequately repay the fishers by helping to conserve spawning aggregations and reef fisheries throughout the MBRS region for years to come.

Executive Summary:

This document serves as the Final Report for the MBRS Project on the monitoring and management of spawning aggregations within the MBRS region. It is accompanied by three national reports – for Mexico, Belize, Honduras, as well as database materials, GIS maps, and a spawning aggregation monitoring protocol. Since the accompanying documents serve as backup to this document, we have intentionally kept this document short and synthesized to facilitate its utility and the implementation of the recommendations, herein.

Spawning aggregations for reef fish species occur at discreet times and places (Domeier and Colin, 1997). These are critical life phases in the lives of reef fishes and generally represent all of the annual reproductive output from these species (Shapiro et al., 1993). Significant evidence exists from within Belize and other areas of the Caribbean that these sites are highly vulnerable to overfishing and aggregations of Nassau grouper, *Epinephelus striatus*, the best-studied species, have been extirpated in many areas (Sadovy, 1994; Sadovy and Eklund, 1999). Spawning aggregation sites for reef fishes, throughout the MBRS region are in need of immediate management and monitoring (Coleman et al., 1999).

Belize has made great progress in recent years on the monitoring and management of spawning aggregations. Monitoring of these sites in Belize has been relatively comprehensive, with coordinated national assessments in January 2001, 2002, and 2003 and May 2003, plus comprehensive monitoring at Northern Glover's Reef and at Gladden Spit. Assessments have also been completed at varying times of year at several other places. The spawning aggregations of Belize are probably the best studied in the world, and these studies can serve as guide to other monitoring efforts. Recent findings suggest that many of the spawning areas are utilized by many species for spawning, at varying times of year. Therefore, the Government of Belize has enacted legislation that places 11 of these multi-species spawning aggregation sites into marine reserves that restrict all fishing. Further legislation protects the endangered Nassau grouper completely between December and March every year. Monitoring in Belize requires further investigation of the multi-species aspects of the aggregations via monitoring many sites at varying times of year.

Mexico has known of several spawning aggregation sites, and in some cases enacted monitoring and protection of them. This study, however, has expanded the known number of sites from 10 to 39, based on interviews with fishermen. Very few of these sites have been assessed and, to date, none are fully protected. Mexico appears to have infrastructure in place for comprehensive monitoring and management of spawning aggregations, particularly in Sian Ka'an, Banco Chinchorro, Xcalak, and Mahajual. In each of these locations, comprehensive assessments during January and April/May, should reveal the pattern of utilization by various species at these sites.

For Honduras, the present study increases the number of suspected spawning aggregations via interviews with fishermen, though field verification is needed to corroborate information. The most important information that has been gleaned concerns a mutton snapper, *Lutjanus analis*, migration that takes place along the north costs from west to east in the months of October and November.

Comprehensive data from Belize collected over the last 4 years and synthesized by The Nature Conservancy suggest that spawning aggregation sites, particularly those at reef promontories that jut windward into deep waters, support multi-species spawning aggregation sites that are utilized through much of the year (Heyman and Boucher *unpublished manuscript*). This report details how these sites can be successfully predicted using analysis of Landsat TM imagery. This report further details recommendation for the evaluation and monitoring of these sites, based on data gathered in Belize. Finally, the report offers suggestion for management of spawning aggregations.

Recommendations are included within the report for the management of spawning aggregation sites and the regional harmonization of policies to protect them. We recommend that if data are available that confirm the presence of a multi-species spawning aggregation; the site should be closed to fishing year-round. We also recommend closed seasons be enacted for particularly endangered or threatened species such as Nassau grouper, *Epinephelus striatus*: either a closed season from December to March as enacted for Belize or a complete ban on the species as has been enacted in the state of Florida. Should total closures be politically impossible, we suggest that only handline fishing be allowed on aggregations and migration routes (no spears, traps, nets, diving, etc.). Finally, we recommend the development of economic alternatives for displaced fishers such as involvement in monitoring, management and research, ecotourism, etc. Carefully monitored ecotourism at these sites, particularly involving displaced fishers, should be explored on an experimental basis and should be carefully managed to avoid impacts to the aggregations.

Via a priority setting exercise, also described herein, we have suggested an initial series of priority sites for monitoring throughout the region, based on the ecological importance, the vulnerability, and the capacity for monitoring and management at the sites. Through this exercise we have selected 1 – 4 high priority sites in each country that should undergo intensive monitoring, 2 – 10 sites per country that should undergo semi-intensive monitoring, and a remainder of sites (including new sites predicted from satellite imagery) that should undergo exploratory monitoring. These priorities might change as new data becomes available.

To accomplish all of these recommendations will require close coordination between many groups, including the MBRS project, The Nature Conservancy, World Wildlife Fund for Nature, Wildlife Conservation Society, and myriad local non-government organizations, funding agencies, tour operators, fishers, and national governments in each of four MBRS countries. This coordination will include data sharing and standardization, and sharing of the burden of funding support in coordinated ways to enhance rather than duplicate existing efforts.

Introduction and Background:

Recognizing the significance of the Mesoamerican Barrier Reef System (MBRS), the presidents of Honduras, Guatemala, Mexico, and the Prime Minister of Belize signed the Tulum Declaration in June 1997. This signing led the Central American Commission for Environment and Development (CCAD), the World Bank, and the four nations to develop the MBRS project, which had its official launch on June 20, 2001.

The Mesoamerican Barrier Reef System (MBRS) includes the second longest barrier reef in the world, and contains a unique assemblage of reef types (including patch, barrier reefs, and atolls), and a salinity driven habitat gradient ranging from tropical mangrove estuaries, coastal wetlands and sea grass beds, and fully oceanic waters of the Cayman Trench. The MBRS project was designed in order to promote the conservation and sustainable use of this system, using scientific and technical information, anecdotal information and the political support from the government leaders of the four countries that make up the MBRS coupled with a broad stakeholder consultation and participation process.

One component of the project endeavors to promote sustainable use of the MBRS system – specifically by promoting sustainable fisheries management. This consultancy report partially fulfills one component of the sustainable fisheries component of the MBRS project. There are several groups now focused on the sustainable management of the MBRS, including World Wildlife Fund for Nature, Wildlife Conservation Society, and The Nature Conservancy (TNC). In fact, TNC has recently launched a Mesoamerican Reef Project called simply the MAR project, which endeavors to collaborate with other existing projects, to promote a regional network of marine reserves that promote the resiliency of the entire system.

Most commercially important reef fish species within the MBRS region have complex life cycles utilizing multiple habitats throughout their ontogenetic development (Eggelston 1995; Grover 1993; Sadovy and Eklund 1999). These fish often have seasonal migrations for feeding and breeding (e.g. Luckhurst 1998), and produce pelagic larvae that float on ocean currents for weeks, before settling into suitable juvenile habitat (Leis 1987; Boehlert 1996). Therefore, in order to promote the sustainable use of these species, it is important to understand the dynamic life history patterns, and the most vulnerable phases, places, and times, that form bottlenecks in their reproduction (Coleman et al. 2000; Warner et al. 2000).

As many of these species are known to form spawning aggregations at specific times and places, and these areas are particularly vulnerable to overfishing, MBRS has focused this consultancy on the identification of spawning aggregation sites throughout the region, and seeks information on their status, timing, as well as pointing out gaps in the existing information, and proposed monitoring and management systems. TNC has been working on this subject intensively since 1998, along with The University of South Carolina, investigating the regional oceanography and the biology of spawning aggregations in Belize. To implement this project, Research Planning, Inc. teamed with TNC, and four local experts who served as national consultants (selected and

contracted by MBRS). These are Mito Paz for Belize, Eloy Sosa-Cordero for Mexico, Jose Antonio Fuentes for Honduras, and Hernan King and Hugo Hidalgo for Guatemala.

Terms of Reference for the Consultancy

The broad terms of reference for this consultancy were to collate and synthesize existing information on the status of spawning aggregations within the MBRS region, and make recommendations for the monitoring and management. Specifically RPI endeavored to synthesize the locations and times for the spawning of five primary species – *Epinephelus striatus*, Nassau Grouper; *Lutjanus analis*, Mutton Snapper; *Lachnolimus maximus*, Hogfish; *Centropomus undecimalis*, common snook; and *Anchoa lyolepis*, Dusky anchovy or Manjua,

RPI has taken a lead role in designing and organizing all aspects of the project, including the development of guidelines and supporting materials to assist the national consultants (base maps, data collection forms, questionnaires, metadata and source documentation materials, etc.). A kickoff meeting in Belize at the onset of the project was planned to discuss the project plan, methods, goals, expectations, schedule and deliverables with the MBRS PCU and the four national consultants. Particular emphasis was to be placed on identifying information gaps, and suggesting ways to fill these gaps. Detailed recommendations for the future monitoring and management of spawning aggregations in the MBRS region will be a key focal point.

Deliverables include a database, GIS map of sites, four national reports, copies of compiled literature, and a synthesis report, with recommendations for monitoring and management.

Execution of Project

The coordination meeting was held in Belize City on 3 September 2002 and was attended by Oscar Lara (MBRS), Eloy Sosa (Ecosur, Mexico), Mito Paz (Green Reef, Belize), José Antonio Fuentes (Prolansate, Honduras), Herman King (Guatemala) (arrived at the very end of the of meeting), Jeffrey Dahlin (RPI), Nicanor Requena and Will Heyman (TNC), Mariana Panuncio (Summit Foundation). RPI provided the national consultants with digital and hard copy data sheets for database development, base maps, and a clear description of desired products. Dates and times for execution were agreed upon and work commenced. Scientific and anecdotal information on spawning aggregations and their locations was collected from the literature, available reports, expert scientists, local and regional resource managers, local fishermen, and other local groups. Literature searches were conducted at libraries and institutions in the four project countries, at the University of South Carolina, and via the Internet. Copies of existing literature form part of the submission for this consultancy.

National Consultants from Mexico, Honduras, and Belize provided their completed reports to RPI on or before the November 15, 2002. The Guatemalan report was submitted by Hugo Hidalgo on 7, April, 2003 and as such forms part of this final report. Guatemalan waters are more estuarine, and contain almost no reef-dominated habitat. These waters are the main areas

within the MBRS for manjua and snook (Heyman and Graham, eds., 2000 a,b,c). The Guatemala report provides an overview of the importance of the Snook and Anchovy fishery, however there is limited information related to the location and timing of spawning aggregations for these species.

To add to the utility of the report, we have submitted a comprehensive reef fish spawning aggregation monitoring protocol, which is being considered by the Gulf and Caribbean Fisheries Institute as the regional standard manual for monitoring spawning aggregations. The manual contains the practical recommendations for monitoring as outlined in the terms of reference for this report.

Brief Highlights from National Reports on Reef Fish Spawning Aggregations:

Belize: Report by Mito Paz

The report provides a comprehensive review of literature and a species-specific account of known information for Belize. The study has expanded the number of known (reported/suspected) sites in Belize, and supported the idea that groupers and snappers often spawn at the same sites, but at varying times of year. The study therefore recommends sampling at both January and April/May moon times. This report concurs with the recommendation, and has included this as part of Category 2 monitoring (see below). The report is highly detailed and contains much valuable and previously unreported information. Belize is well on its way to comprehensive monitoring and management of spawning aggregations via years of detailed study collaboration, and the passing of recent legislation. Belize serves as a leader in the MBRS (and Caribbean Region) on the monitoring and management of spawning aggregations.

Guatemala: Report by Hugo Hidalgo

The report provides a general overview of the Snook and *Anchoa Lyolepis* of the Amatique Bay, El Golfete and Rio area. There is clearly little scientific information about spawning aggregation for any of the commercial fish species in the area. Most of what is known is anecdotal information from fishermen in the local communities. The *Anchoa Lyolepis* fishery has historically been a very important fishery in the area that has drastically decline over the years, yet limited information exists for this species. Anecdotal information from fishermen in Guatemala suggests that there is a snook aggregation in an area known as Laguna Grande in the Sarstún River. Local fishermen have observed schools of fish numbering up to about 300. When these fish are speared they are observed with mature gonads. There is very little information on snook *Centropomus undecimalis* for this area. The report indicates general areas where Snook and *Anchoa Lyolepis* are observed but have not been field verified to be spawning aggregation sites. It also indicates the need for more data collection.

Honduras: Report coordinated by José Antonio Fuentes Morales

The report is focused primarily on the areas around Tela and provides some new information about possible spawning aggregation sites there. There is little information on spawning areas provided for the Bay Islands, or Cayos Cochinos. This area should be considered a data gap, and will require exploratory monitoring, further ground based information collection, and field work in order to direct future monitoring and management efforts. The report does describe a predictable migration of mutton snapper, *Lutjanus analis*, along the north coast of Honduras, which requires further investigation. It is recommended, herein, that satellite-based predictions for the Bay Islands and Cayos Cochinos be expanded and field verified. Of the three countries that have submitted reports, data is most limited for Honduras.

Mexico: Report coordinated by Eloy Sosa-Cordero

The report dramatically expands the known (reported/suspected) number of spawning aggregation sites in Mexico, particularly focusing on the areas in central and southern Yucatán Peninsula. It is likely that other aggregations have occurred further north, but may have been exploited in the past years and are no-longer relevant to present fishers. It is suggested herein, however, that some sites that can be predicted by satellite analysis be field evaluated. For southern and central Yucatán Peninsula, there are clear priorities for monitoring and management and there is institutional infrastructure in place to commence monitoring immediately. Priorities for monitoring and management were not laid out in the report from Mexico, but have been submitted herein. There is a great deal of new information described for various sites within the report and it serves to expand the existing knowledge of spawning aggregations in the region. Several (more than half) of the sites are noted as multi-species spawning aggregation sites, and many of these appear to be located at reef promontories. Cayo Lobos, for example, on the southern tip of Banco Chinchoro, has seven reported species aggregated for spawning, and at the date of Sosa's report, no underwater observations had occurred there. Verification of spawning aggregations for these species at Cayo Lobos would provide further support to the hypothesis that many reef promontory spawning aggregation sites serve as multi-species spawning aggregation sites (see below).

Summary Information on Snook, Manjua, and Hogfish

Snook: As indicated above in the summaries of national reports, there is very limited information on the timing and location of spawning aggregations for snook *Centropomus undecimalis*. This species is known to spend major portions of its life cycle in estuarine habitats where there is a seasonal freshwater discharge into the sea. There are no known and confirmed spawning aggregation sites in Belize. Local fishermen in Honduras report increased captures during the months of May to September and suggest spawning takes during the months of July to September in coastal lagoons and river mouths (Fuentes and Paz, 2002). In northern Belize fishermen report December to February as the time of the year when snook aggregate to spawn (Paz, 2002). There is wide variation with regards to the time when fishermen capture most snook in Belize and Honduras.

Snook have been observed lying in shallow waters off sandy beaches in the mouths of various saline open water passes of Southern Florida's Gulf coast during the months June and July. Gonad observations suggest that spawning probably begins in May and continue until mid-November. By assuming that the collection sites of gravid snook were spawning locations, it was proposed that snook congregate for spawning around the mouths of rivers, canals and passes along the shoreline (Seaman and Collins, 1983).

Due to lack of scientific information and limited anecdotal information about the reproductive life cycle of this species in this region, we recommend that a more comprehensive study be conducted to evaluate the status of snook in the MBRS areas of priority with the objective of identifying aggregation sites and migration routes, and verifying the timing of these events. Gonosomatic index and tagging studies will be important to help reveal these patterns.

Manjua: Similarly there is limited data on *Anchoa Lyolepis*, this species being most common in Guatemala where it forms a major fishery (the largest in northern Guatemala as measured in pounds landed) during the months of January to April (Heyman and Graham, eds., 2001c). In Belize, Honduras, and Mexico it is reported as not being of commercial importance as it is only used as baitfish. This species, however, forms a major part of the food supply for carnivorous fish species such as mackerels and jacks. Very little is known about the reproductive life cycle of *Anchoa Lyolepis* in this area. Most of what is known about the location and timing of spawning aggregation is anecdotal.

Hogfish: Information from the national reports was also rather limited for spawning times and location for hogfish, *Lachnolimus maximus*. A spawning aggregation monitoring team led by TNC observed a hogfish spawning aggregations on the fore reef at Gladden Spit and Southern Lighthouse, near the shelf edge, in 25 m water depth (Heyman and Boucher *unpublished manuscript*). These aggregations are clearly visible when males guard territories that are parallel to the reef dropoff, ~2 m wide and 5 – 10 m long, with a harem of smaller 2 - 10 females. These aggregations form around the same time and location as cubera snapper spawning aggregation at Gladden Spit – in April and May, 2 days before – 8 days after full moon. There are very few other observations of this species in other locations that have been monitored in the region.

Synthesis on Snappers, Groupers and other Reef Fish Spawning Aggregations in MBRS

In Belize, the National Spawning Aggregations Working committee includes the collaboration government agencies, international and local organizations, and has compiled four years of data that, when synthesized, suggest that reef promontory sites serve as multi-species spawning aggregation sites for a variety of reef fish species- including a number of Serranidae, groupers; Lutjanidae, snappers, Carangidae, jacks; and may include over 20 different species as has been demonstrated at Gladden Spit, Halfmoon Caye, and South Point Lighthouse (El Nic) in Belize (Heyman and Requena 2002; Heyman et al. *unpublished manuscript*). Further documenting the phenomenon, Table 1 (below) using data from the working committee, indicates confirmed spawning aggregations for a variety of species at 14 reef promontory sites in Belize.

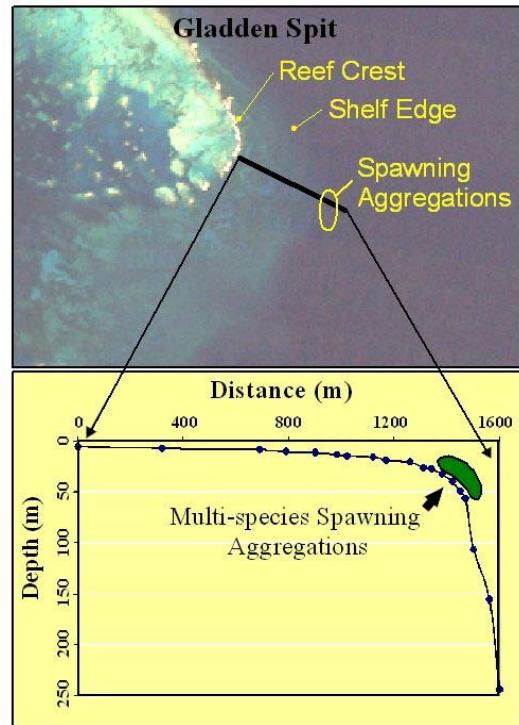
Table 1: Confirmed spawning aggregations at 14 reef promontories in Belize (Heyman and Boucher, *unpublished manuscript*)

	Common Name	Mutton snapper	Cubera snapper	Dog snapper	Yellowtail snapper	Nassau grouper	Rd hind	Black grouper	Yellowfin grouper	Tiger Grouper	Amber jack	Bar jack	Blue runner	Yellow jack	Jack crevalle	Horse-eye jack	White margate	Hogfish	Ocean triggerfish	Jolthead pogy	Permit	Smooth trunkfish
	Species	<i>Lutjanus analis</i>	<i>Lutjanus cyanopterus</i>	<i>Lutjanus jocu</i>	<i>Ocyurus chrysurus</i>	<i>Epinephelus striatus</i>	<i>Epinephelus guttatus</i>	<i>Mycteroperca bonaci</i>	<i>Mycteroperca venenosa</i>	<i>Mycteroperca tigris</i>	<i>Seriola dumerili</i>	<i>Caranx ruber</i>	<i>Caranx crysos</i>	<i>Caranx bartholomaei</i>	<i>Caranx hippos</i>	<i>Caranx latus</i>	<i>Haemulon album</i>	<i>Lachnolaimus maximus</i>	<i>Canthidermis sufflamen</i>	<i>Calamus bajonado</i>	<i>Trachionatus fulcatus</i>	<i>Lactophrys triqueter</i>
	SITES																					
1	Rocky Point	■		■												■	■					
2	Soldier Caye							■														■
3	Calabash Caye				■																■	
4	Caye Bokel	■	■	■		■		■		■											■	
5	Emily, Caye Glory			■		■		■		■											■	
6	Sandbore				■					■				■							■	■
7	Halfmoon Caye		■	■									■				■				■	■
8	“El Nic” South Point	■		■								■									■	■
9	Northern Glover’s Reef	■				■		■		■												
10	Middle Caye Glover’s																					■
11	Gladden Spit	■	■	■		■		■		■											■	■
13	Rise and Fall Bank			■		■										■						
14	Nicholas Caye							■														

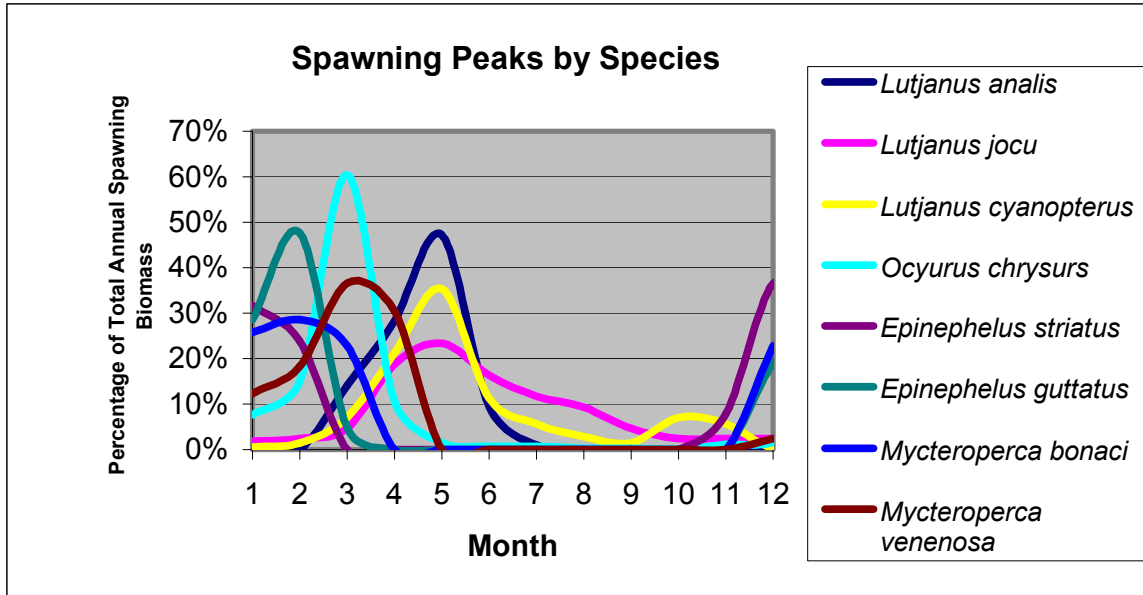
■ = Confirmed spawning aggregation for this species at this site.

Each of the aggregation sites indicated above in Table 1, share similar geomorphological characteristics. Specifically, they are all found at reef promontories such that the multi-species spawning aggregation cloaks the apex of the three dimensional reef promontories. The figure to the right (from Heyman and Boucher, in prep.) shows the spawning aggregation site at Gladden Spit, and indicates the location of the aggregation with respect to the shelf edge and the nearly right-angle bend in the reef. Other aggregation sites listed in Table 1 above are similar- cloaking the windward edge of reef promontories that drop into deep waters.

Heyman and Boucher (*unpublished manuscript*) document that spawning aggregation sites are predictable in space and time and their locations can be determined using spatial analysis of satellite imagery. Specifically, 13 sites have been predicted and verified using Landsat TM imagery. We suggest that this technique be applied and further utilized in the monitoring and identification of spawning aggregation sites in the Mesoamerican Reef. In order to begin this process, we have made a few predictions about sites in Mexico and Honduras, and provide the UTM coordinates in sections below. In order to standardize data collection and data sharing of geographic coordinates, we suggest that geographic data be standardized and shared as UTM coordinates with datum, WGS 84.



It is likely that the patterns observed in Belize will be similar throughout the MBRS (and the Caribbean at large). Data presented within the three national consultancy reports provide additional support to the hypothesis that multi-species spawning aggregations form at reef promontories. The MBRS project, in partnership with national governments, local and international organizations, and via regional coordination, will allow a comprehensive test of this hypothesis, via simultaneous monitoring of spawning aggregations, using identical protocols. This phenomenon has been described (Heyman, 2001; Heyman and Requena, 2002; Heyman and Boucher, *unpublished manuscript*) though most scientific researchers have studied only one or two species at a given site, and then generally only at one time of year. The generalized pattern that we have observed indicates that grouper species tend to spawn during the months of December – March, snappers in March – June, hogfish and jacks in April-May. Other species spawn at these same times, and the promontories appear to be utilized by some species throughout the year. The timing in reproduction for the major grouper and snapper species in Belize are illustrated below for Gladden Spit (from Heyman and Boucher, *unpublished manuscript*). It is likely that the same seasonal pattern exists throughout the MBRS region.



The monitoring protocol presented herein, for the Meso-American Reef assumes that reef promontories serve as multi-species spawning aggregation sites, utilized throughout the year, as illustrated for 14 sites in Belize. (Though this is still only a hypothesis, further monitoring will either dispel or support it and in any case it will serve as a “straw man” to define a monitoring program.) We recommend that some sites be monitored exhaustively, to serve as a baseline for other sites in the region, while some sites are monitored during the peak snapper and grouper times, and finally some sites, where little or no information exists, should be spot-checked via exploratory monitoring, during supposed peak times for important species. If, through field verification at more sites, a general pattern of multi-species spawning aggregations at reef promontories exists, a simplified management of these sites throughout the region – specifically, that they should be closed to fishing year-round. This was the solution that Belize has adopted for clear reasons of efficiency and precautionary management of the important breeding sites for the majority of commercially important reef fish species.

Recommendations for Monitoring

A comprehensive monitoring protocol has been developed by collaboration of the Belize National Spawning Aggregations Working Committee and is appended to this report. The protocol details methodologies for fisheries dependent and fisheries independent monitoring of spawning aggregations. The report also details how to locate these aggregations in the field, how to do tagging studies, evaluations of local oceanography, and tissue collection procedures for sex, age, and growth studies. Selected individuals throughout the MBRS region have been trained in the use of the methodology in March, 2002, August 2002, November 2002, and February 2003. The methodology has been developed and utilized by at least 8 organizations in Belize for the last two years and is being used in the Cayman Islands and the Bahamas and is

being considered for a Caribbean Regional standard at the Gulf and Caribbean Fisheries Institute. We suggest the monitoring methodology be adopted for the MBRS region.

To determine where and when monitoring should take place, we have done a draft priority setting exercise based on an analysis of the known management and monitoring capacities of local organizations, ecological importance, vulnerability (fishing pressure), and the feasibility of management. This exercise can be and should be repeated with a larger group of stakeholders, and when more information becomes available, but should serve as a guide for similar and adaptive priority setting exercises.

Given the information presented from the three national reports, in addition to what Belize the work of government agencies, local and international organizations has determined in 5 years of aggregation research, we propose that a stratified monitoring protocol be adapted for the MBRS region. More specifically, we recommend three levels of monitoring effort for sites, that can be applied to each site as needed. The categories include #1) the most intensive but least common; #2 semi-intensive (or standard) and most common, and #3, the least intensive – exploration. More specifically they are described as:

General Categories for Monitoring Intensity and Effort

1. Intensive monitoring throughout the year (2 - 3 per country/ >300 days/year)
2. Standard monitoring during January, and April or May (8-15 per country/ ~20 days/year)
3. Exploratory monitoring of various sites and times of year (remaining sites/ 2-10 times/year)

Category 1 sites will be monitored intensively, and provide a baseline for the evaluation of other sites that might be similar. Category 3 monitoring will be used for initial evaluations for sites that have been described anecdotally, but require field validation before any more intensive monitoring takes place. Category 2 should be considered as standard monitoring for spawning aggregation sites throughout the region. By monitoring a site for 10 days in January and 10 days in April or May will allow an indication of the health of the most important snapper and grouper species, which are likely to be the most vulnerable to fishing effort.

Using the intensity categories described above, and knowing the status of some of the aggregations in the MBRS region, some possible Category 1 and Category 2 sites for monitoring are suggested in Table 2, below. Organizations mentioned have some institutional presence and capacity in the area but may or may not be the correct institution. In fact all recommendations, including the list of sites and organizations must be discussed, vetted and decided on with national decision makers. Ideas for exploratory monitoring are presented subsequently.

Table 2: Proposed Category 1 (intensive) and 2 (standard) monitoring sites and priorities and monitoring organizations. This table should be considered as provisional, and can be updated as more and better information becomes available.

Site No.	Site Name	Vulnerability (1)	Ecological Importance (2)	Management capacity (3)	Overall Priority Ranking	Most suited Organization to Monitor and Protect the site	Monitoring Category (4)
B016	Gladden Spit	3	3	3	9	Friends of Nature	1
B027	Halfmoon Caye	1	3	3	7	BAS/TNC	1
B029	Northern Glover's	3	3	3	9	GRMR/WCS	1
B031	Middle Caye	1	3	3	7	GRMR/WCS	1
B001	Rocky Point	1	2	3	6	BCMR	2
B015	Emily, Caye Glory	3	3	1	7	SWCMR	2
B017	Nicholas Caye	2	3	3	8	TIDE/ SCMR	2
B018	Rise and Fall Bank	3	1	2	6	TIDE/ SCMR	2
B019	Seal Caye	2	2	3	7	TIDE/ SCMR	2
B022	Dog Flea Caye	1	3	1	5	Green Reef/U.B.	2
B023	Soldier Caye	1	?	3	4	Green Reef/U.B.	2
B024	Calabash Caye	1	?	3	4	Green Reef/U.B.	2
B025	Mauger Caye	3	3	1	7	Green Reef/U.B.	2
B026	Sandbore	2	3	2	7	BAS/TNC	2
B027	Caye Bokel	2	3	?	5	Green Reef/U.B.	2
B028	"El Nic"	2	3	3	8	BAS/TNC	2
M38	Cayo Lobos	3	3	3	9	RBBC	1
M23-25	Mahajual	3	3	3	9	Ecosur	1
M9/10	Quebrada de Chal	?	3	3	6	ASK	2
M11/12	Punta Herrero	?	3	3	6	ASK	2
M16/M17	Posas Gorilas	?	3	2	5	ASK	2
M35	Cayo Norte	3	3	2	8	RBBC	2
M36	Glenview	3	3	2	8	RBBC	2
M37	Herradura-Cassel	3	3	2	8	RBBC	2
H1	Caldera del Diablo	3	3	1	7	BICA?	1
H2	Banco Vietnam	3	3	2	8	Prolansate	2
H3	Banco Capiro	3	3	2	8	Prolansate	2

(1) Vulnerability: (Existing and future fishing pressure)

1. Low vulnerability
2. Medium vulnerability
3. High vulnerability

(2) Ecological Importance: (based on the number of species and individuals spawning at the site)

1. Low importance
2. Medium importance
3. High importance

(3) Management and Monitoring Capacity (Institutional presence, infrastructure, equipment, personnel)

1. Low capacity
2. Medium capacity
3. High capacity

(4) Monitoring Category

- 1: Intensive, year-round monitoring – as many dives as possible, hopefully > 300/year
- 2: Intensive monitoring in January and April – 10 days consecutive, 2 days before - 10 days after full moon
- 3: Exploratory monitoring – as many dives as possible during any months of the year but most importantly during January – May and from 2 days to 8 days after full moon.

Recommendations for Exploratory Monitoring

For several sites, there is not sufficient information to warrant the resources for standard monitoring, but indications are that these sites do warrant some exploration. There exists a migration of Mutton snapper, *Lutjanus analis*, which occurs on the north coast of Honduras during October and November each year (Fuentes and Paz, 2001). The fish that are migrating do not appear to have mature gonads, and were not found to be linked to any specific spawning aggregation site within the study area. This species is heavily exploited during the migration and should be investigated as part of Category 3 monitoring.

Several sites for Nassau grouper have been heavily fished in Honduras and these sites are showing signs of drastic decline according to local fishers. These sites include Banco Vietnam and Banco de Capiro (north of Punta Sal), Lanteros Bank (near Punta Izopo), Nueva Escocia and Boot Bank (near Turtle Harbor, Utila). These should be examined on an exploratory basis during the months of January and April/May, between 2 days and 8 days after full moon. Should fish be observed, they can be moved to Category 2 for semi-intensive monitoring.

Many other sites indicated with the reports for Belize and Mexico and further sites as predicted from satellite imagery analysis should also be included in Category 3, exploratory monitoring. These include three sites as predicted using Landsat TM imagery, using coordinates in UTM and Datum WGS 84 as follows:

Country	Location (zone 16)	Eastings	Northings
Honduras	Cayos Cochinos	547938	1760117
Honduras	Southwest Roatan	542352	1798085
Honduras	Northwest Utila	506825	1782615

There are probably several other sites worthy of exploratory monitoring throughout the region.

Summary of Recommendations for Regional Coordination and Exchanges

After several years of intensive monitoring, Belize has several experienced monitoring teams and a wealth of data. Belize also contains a larger reef area than the other countries and may actually contain more aggregation sites. The extensive experience in Belize can be used by the other countries to rapidly expand their knowledge. The data in Belize can serve as a baseline for monitoring programs elsewhere. Further, and most importantly, Belizean organizations and individuals can help to train others throughout the region, via exchange programs and in-the-field trainings.

Recommendations for Regional Policy Harmonization

The MBRS region is linked by ocean currents and many of the commercially important reef fish species are shared between adjacent countries. It is recommended that scientific data collection and monitoring be harmonized throughout the MBRS region, followed by the harmonization of policy and legislation.

Belize has acted judiciously by recently enacting comprehensive legislation to conserve spawning aggregations. One new law protects the endangered Nassau grouper (no possession) from December 1 – March 31, every year – the time when the fish is known to breed. During the development of this legislation, some scientists believed that additional legislation is needed to protect dwindling stocks of these species.

Recognizing that many species aggregate at the same reef promontories, and that enforcement is more efficient and simpler in full year closures, Belize recently enacted a new law that protects 11 multi-species spawning aggregations, year round. Some provisions are made for special permits for traditional harvest of Nassau grouper and other species at some of these sites. In total however, this legislation is unprecedented through the region, and serves as a regional example of proactive and precautionary management of reef fish spawning aggregations – an important step towards sustainable fisheries management within the MBRS.

It is recommended here that Honduras, Guatemala, and Mexico adopt identical legislation; if and when the data are available that verify the presence of multi-species spawning aggregations that are active throughout the year. It is further recommended that all countries consider a seasonal (December – March, inclusive) and/or total ban on the harvest of the endangered Nassau grouper, to ensure that this apex predator and symbolic fish, remains extant in the MBRS region. Finally, if migration routes, such as that identified for mutton snapper on the north coast of Honduras are recognized and documented, a system will need to be enacted to ensure that these pathways are conserved.

If full protection for the aggregation sites is not politically feasible, it is recommended that gear restrictions be enacted to include the banning of industrial fishing fleets and the use of spearfishing, traps, nets, dynamite, and/or any gear other than handline fishing. It is further suggested that economic alternatives be developed for displaced fishers, whose livelihood is linked to spawning aggregation. Each country within the MBRS region is different in culture and socio-economics. It is herein recommended that an analysis of the socio-economic conditions throughout the region be conducted, particularly with reference to the exploitation of spawning aggregations. With the study as a base, further recommendations can be made for alternative livelihoods of the locals that are consistent with the long term management of spawning aggregations for each particular site.

Economic Alternative Livelihood Programs

In order to manage spawning aggregations will require a reduction in fishing effort at the sites. This will displace existing fishers from their livelihood. Belize has been successful in offering training in alternative livelihoods for SPAG (and other) fishers, which has helped garner fisher support for management. To provide economic alternatives to the exploitative use of aggregation sites, ecotourism, particularly carefully monitored SCUBA expeditions, should be considered. The site at Gladden Spit has received some dive tourism and there is potential. It will be critical that any tourism development be carefully monitored with strict carrying capacities, to ensure that no ill effects are brought on the aggregations. Some species are far less impacted by divers than others (e.g. snappers are less disturbed than groupers) and most species are less disturbed during the day, than during the evening, spawning time. In other spawning aggregation areas, other alternative livelihood programs may be more appropriate. For example, investments in value-added fisheries, fly fishing, small scale aquaculture or other economic alternatives may prove more effective and consistent with the local socio-economic conditions. If additional markets for other species or value added products can be developed (such as pelagic fishes, smoked fish, etc.) then these should be developed to ease pressure on reef fisheries. Further, it is recommended that fishers be involved in exchanges throughout the region to promote shared understanding and support for management measures. By involving fishers at every stage of research, monitoring, policy development and management, they will become active supporters of conservation programs that may appear to displace them.

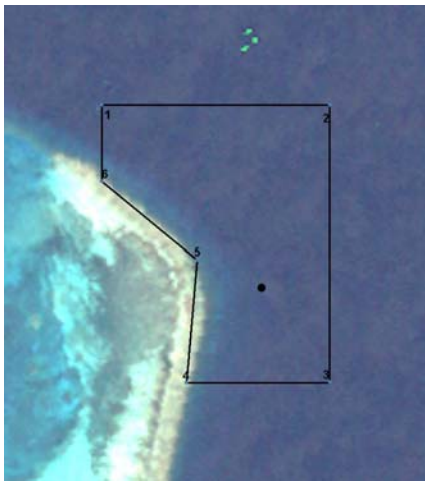
Recommendations for Management

Protection of spawning aggregations can be considered similar to the protection of savings in a bank. If possible, we should harvest the interest, not the principal from the savings. In other words, if spawning aggregation sites, migration routes, and important nursery habitat are protected, the number and size of these fish should increase, leading to the sustainable harvest of these species throughout the region. There is increasing evidence that reserves can contribute to fisheries outside of their boundaries (Roberts et al. 2002; Gell and Roberts, 2003). This analogy is particularly true when considering the management of spawning aggregations – source sites for reproduction for most of the commercially important reef fish in the MBRS region.

Management of spawning aggregation sites cannot fall to one single organization or individual, given their large geographic spread. Because the sites are small in space, and often time specific, the management and control of these sites can be easier and more efficient than the management of larger areas. This is particularly true if traditional fishers are given a chance to participate in the management and monitoring (and even tourism) that might eventually take place at these sites. For several areas in Belize, Mexico, and Honduras, spawning aggregation sites fall within existing marine reserves (eg. Glover's Reef, Banco Chinchorro, and Cayos Cochinos). When this occurs, increased protection for the spawning areas can be accomplished relatively easily. For spawning sites that are distant, and outside of existing protected areas, management and

enforcement is more expensive and complex, requiring new legislation and high costs for enforcement.

In Belize, many government and non-government organizations are participating in the management and monitoring of spawning aggregation sites within marine reserves through co-management agreements between the Government of Belize and non-government organizations. Similarly, fishers have been brought on board as part of the monitoring teams and in some cases, hired as park rangers, to provide direct economic alternatives for displaced fishers at these sites. It is here recommended that similar strategies be adopted throughout the Mesoamerican Reef.



The size of spawning aggregation protection zones varies from place to place but in many cases, the aggregation areas are very small, < 400m x 100m and found at reef promontories. These sites can be comfortably protected therefore, in areas of only 2 – 6 square miles, as has been found in Belize. The site at Caye Glory, for example, shown to the left in a Landsat TM image, contains the aggregation site, shown as a dot at the reef promontory, and the entire closed area is only 2.1 square miles. It is recommended here that spawning aggregations should be incorporated into larger marine reserves, whenever possible, but should provide at least one mile of buffer for the site within a closed area – a figure arrived at empirically by negotiation with fishers and protected areas planners in Belize. Riley’s Hump, within the Dry Tortugas in Florida, serves as a multi-species spawning aggregation and was closed completely to fishing based on pressure from local fishers. The Tortugas South Reserve includes the spawning aggregation within a 61 square mile area to protect the aggregation site, in its natural ecological context, and providing sufficient food fish for the transient spawning species that will need to feed around the time and location of spawning (P. Gladding, pers. comm.).

Connectivity

Though very few studies address the regional oceanography and larval transport within the MBRS region, it is clear that spawning aggregations produce pelagic larvae that are transported by ocean currents. General circulation within the MBRS region is driven by meso-scale eddies (Heyman and Kjerfve, 2000), that could entrain eggs and larvae. There is a great deal of stochasticity in the arrival of the eddies though generally, the MBRS region is dominated by cyclonic eddies in the Gulf of Honduras, and anti-cyclonic eddies in the north of Belize and Mexico, which can transport eggs and larvae to the areas of juvenile recruitment. The average pelagic larval duration for snappers is approximately 32 days (Lindeman et al., 2001) and probably representative of other reef fish species. Depending on how larvae are entrained in ocean currents, transport can be very localized (retention) or involve long-range larval transport (Warner et al., 2000; Lindeman et al., 2001).

Initial studies by The Nature Conservancy at Gladden Spit indicate that wind-driven surface currents (as opposed to the deeper eddies) transport recently-spawned eggs through the channel, inside of the reef for hatching. During times of little or no wind the eggs are likely transported by deeper, oceanic currents (Heyman et al., *unpublished manuscript*). There is a great need for further studies of the regional oceanography and the effects on larval transport. These are being addressed via the MBRS project and the University of South Carolina, via the development of a regional circulation model. Early outputs from the model indicate that the currents on the barrier reef are governed by the arrival and departure of meso-scale eddies that interact with the reef system.

Recommendations for Funding the Program

Given the great number of sites that require monitoring and management throughout the region, and the expense of both the monitoring and management, it is suggested that the MBRS project work in close partnership with other funding agencies, such as the Oak and Summit Foundation, and other multi-national projects, and conservation organizations, such as PROARCA/Costas, The Nature Conservancy, World Wildlife Fund for Nature, Wildlife Conservation Society, and others to coordinate activities for the support of local national organizations, and national governments to conduct monitoring and management activities at these and other sites. It is highly recommended that a donor coordination meeting take place in order to discuss priorities and a joint strategy that evades duplication of effort, and maximizes the efficient use of resources. It is further recommended that additional resources be sought.

Anexes: Maps, Database, Monitoring protocol, National Reports from Belize, Honduras, Guatemala, and Mexico, Literature.

Literature Cited

- Boehlert, G.W. 1996. Larval dispersal and survival in tropical reef fishes. pp. 61-84 In *Reef Fisheries*, edited by Polunin, N.V.C. and Roberts C.M., Chapman and Hall, London, 477 p.
- Coleman, F.C., Koenig, C.C., Eklund, A.M. and Grimes, C. 1999. Management and conservation of temperate reef fishes in the snapper-grouper complex of the southeastern United States. pp. 233-242 In *Life in the Slow Lane: Ecology and Conservation of Long-lived Marine Animals*, edited by Musick, J.A., American Fisheries Society Symposium 23.
- Coleman, F.C., Koenig, C.C., Huntsman, G.R., Musick, J.A., Eklund, A.M., McGovern, J.C., Chapman, R.W., Sedberry G.R., and Grimes, C.B. 2000. Long-lived reef fishes: the grouper-snapper complex. *Fisheries* 25 (3): 14-21.
- Domeier, M.L. and Colin, P.L. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science* 60: 698-726.
- Eggelston, D.B. 1995. Recruitment of Nassau grouper, *Epinephelus striatus*: post-settlement abundance, microhabitat features, and ontogenetic diet shifts. *Marine Ecology Progress Series* 124: 9-22.
- Fuentes-Morales, J.A.M. and C.R. Paz-Morales. 2002. Informe Final: Proyecto para Conservacion y uso Sostenible del Sistema Arrecifal Mesoamericano. Prolansate.
- Gell, F.R. and C.M. Roberts. 2003. Benefits beyond boundaries: the fishery effects of marine reserves. *Trends in Ecology and Evolution*, in press.
- Grover, J.J. 1993. Trophic ecology of pelagic early juvenile-juvenile Nassau grouper, *Epinephelus striatus*, during an early phase of recruitment into demersal habitats. *Bulletin of Marine Science* 53: 1117-1125.
- Heyman, W., B. Kjerfve, R. Graham, E. Cuevas, K. Rhodes. (In review) Characterizing spawning aggregations of cubera snappers, *Lutjanus cyanopterus* (Pisces: Lutjanidae) on the Belize Barrier Reef. (*Environmental Biology of Fishes*)
- Heyman, W. 2001. Spawning aggregations in Belize. Workshop report, presented in "Towards the sustainable management of Nassau groupers in Belize", Belize City, 30 July, 2001, The Nature Conservancy, Belize
- Heyman, W. and T. Boucher (In review). Siting marine protected areas at multi-species spawning aggregations. (*Marine Biology*).

- Heyman and Requena, 2002. Status of multi-species reef fish spawning aggregations in Belize. The Nature Conservancy, Belize.
- Heyman, W.D. and B. Kjerfve. 2000. The Gulf of Honduras. pp.17-32, *In*: U. Seeliger and B. Kjerfve (eds.) *Coastal Marine Ecosystems of Latin America*. Ecological Studies Vol. 144. Springer-Verlag, Berlin.
- Heyman and Graham, (editors). 2000a. Voice of the Fishermen from Southern Belize. TIDE and TRIGOH. 44pp.
- Heyman, W. and R. Graham (eds.). 2000b. Voz de los Pescadores de la Costa Atlantica de Honduras. Prolansate, TIDE, y TRIGOH. 44pp.
- Heyman, W. and R. Graham (eds.). 2000c. Voz de los Pescadores de Guatemala, FUNDAECO, TIDE, y TRIGOH. 44pp.
- Hidalgo, H.C. 2003. Consultaria sobre sitios de agregaciones de Peces en Guatemala. Róbalo (*Centropomus undecimalis* y *C. robalito*) y Manjua (*Anchoa lyolepis* y otras *Anchoas* spp.) en el Mar Caribe. Realizada para el Sistema Arrecifal Mesoamericana – SAM.
- Leis, J.M. 1987. Review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae). pp. 189-238 *In Tropical Groupers and Snappers: Biology and Fisheries Management*, edited by Polovina, J.J. and Ralston, S., Westview Press, Boulder, Colorado, 658 p.
- Lindeman, K.C., T.N. Lee, W.D. Wilson, R. Claro & J.S. Ault. 2001. Transport of larvae originating in southwest Cuba and the Dry Tortugas: Evidence for partial retention in grunts and snappers. *Proceedings of the Gulf and Caribbean Fisheries Institute* 52: 732-747.
- Luckhurst, B.E. 1998. Site fidelity and return migration of tagged red hind (*Epinephelus guttatus*) to a spawning aggregation site in Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50:750-763.
- Paz, M. 2002. Critical analysis of information on spawning aggregation sites in MBRS project countries and recommendations for their monitoring and management.
- Roberts, C.M., J.A. Bohnsack, F. Gell, J.P. Hawkins, R. Goodridge. 2001. The effects of marine reserves on adjacent fisheries. *Science*. 294: 1920-1923.
- Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute* 43: 43-65.

- Sadovy, Y. and Eklund, A.M. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Technical Report NMFS 146. 65 pp.
- Seaman, W., Jr and M. Collins 1983. Species Profile: Life history and environment requirements of coast fishes and invertebrates (South Florida)—snook. U.S. Fish Wildlife Service.
- Shapiro, D.Y., Sadovy, Y. and McGhee, M.A. 1993. Periodicity of sex change and reproduction in the red hind, *Epinephelus guttatus*, a protogynous grouper. *Bulletin of Marine Science* 53: 1151-1162.
- Sosa-Cordero, E., A. Medina-Quej, R. Herrera, W. Aguilar-Dávila. 2002. Agregaciones reproductivas de peces en el Sistema Arrecifal Mesoamericano: Consultoría Nacional – Mexico. Informe preparado para el consultor internacional, Research Planning Inc., y Proyecto SAM-Banco Mundial-Belice.
- Warner, R.R., Swearer, S.E. and Caselle, J.E. 2000. Larval accumulation and retention: implications for the design of marine reserves and essential fish habitat. *Bulletin of Marine Science* 66 (3): 821-830.