USAID REGIONAL PROGRAM FOR THE MANAGEMENT OF AQUATIC RESOURCES AND ECONOMIC ALTERNATIVES

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ASSESSMENT OF THE CURRENT STATUS OF NASSAU GROUPER (*Epinephelus striatus*), MANAGEMENT AND CONSERVATION IN THE GULF OF HONDURAS

USAID REGIONAL PROGRAM FOR THE MANAGEMENT OF AQUATIC RESOURCES AND ECONOMIC ALTERNATIVES

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LIST OF ACRONYMS

BICA	Bay Islands Conservation Association (Utila, Honduras)
CSO	Central Statistic Office (Belize)
DIGEPESCA	General Directorate of Fisheries and Aquaculture / Dirección General de Pesca y Acuicultura (Honduras)
FUNDAECO	Fundación para el Desarrollo y la Conservación (Guatemala)
FUNDARY	Fundación Mario Dary (Guatemala)
GPD	Gross Domestic Product
GSSCMR	Gladen Spit and Silk Cayes Marine Reserve

INE	Instituto Nacional de Estadística (Guatemala)
IUCN	International Union for Conservation of Nature
Lps	Lempiras (national currency, Honduras)
MPA	Marine Protected Areas
NGO	Non-Government Organization
PMAIB	Bay Islands Environmental Management Program / Programa de Manejo Ambiental Islas de la Bahía (Honduras)
SEA	Southern Environmental Alliance (Belize)
SI	Statutory Instruments (Belize)
SPAGs	Spawning Aggregations
TIDE	Toledo Institute for Development and Environment (Belize)
TRIGoH	Tri-National Gulf of Honduras Alliance
UCME	Utila Center for Marine Ecology (Honduras)
WCS	Wildlife Conservation Society
WTTC	World Travel and Tourism Council

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INTRODUCTION

The Nassau Grouper, *Epinephelus striatus*, is a commercially important species in coral reefs in the Western Atlantic and Caribbean Sea (Sadovy and Eklund 1999) where it has been fished by local communities for many years. Normally inhabiting relatively shallow reefs this species can be found at depths up to 300 m during reproductive migrations (Starr *et al*. 2007). It is a predator that can exceed 80 cm in length and reaches a minimum size at sexual maturity of 40 cm (or 4 years old) (Sadovy and Eklund 1999). Unlike the majority of members of the Serranidae family that are protogynous hermaphrodites (change female to male), Nassau Grouper's sexual development pattern, is predominantly gonochoristic (separate sexes) (Sadovy and Colin 1995).

The reproductive strategy of Nassau Grouper involves the formation of spawning aggregations in certain reef sites during specific times of the year, around winter's full moon. In the Gulf of Honduras this strategy is known to local fishermen who have exploited this species without regulation for over 80 years (Sadovy and Eklund 1999). Unregulated fishing of this species has caused several aggregations to show a progressive disappearance, as seen in Puerto Rico, Cuba and the Virgin Islands. Nevertheless, there are still areas where aggregations show evidence of substantial permanence (Cayman Islands, Belize and Mexico).

Current fishing regulations for Nassau Grouper vary from no-take marine reserves in Belize to a permanent fishing ban in Florida, Puerto Rico, and Virgin Islands. Initiatives have been raised about their situation in the West Atlantic and Caribbean to determine the aspects of management and conservation at the regional level.

The ongoing exploitation of Nassau Grouper, combined with elements of its life history, such as the formation of spawning aggregations, their longevity, late sexual maturity and high site fidelity (Sadovy and Eklund 1999) have resulted in gradual disappearance of traditional sites leading to the complete disappearance of this species. Such is the case of Glory Cay, Belize, where in the 1960s Nassau Grouper had been known to aggregate and spawn in thousands, but by the 1990s had only formed groups of less than 100 fish (Carter *et al*. 1994, Sala *et al.* 2001). Similar trends have been reported in Jamaica, Puerto Rico and Cuba (Sadovy and Eklund 1999).

However, there are some areas where spawning aggregations are relatively consistent; such is the case of the Cayman Islands (Whayleen *et al*. 2004) where there has been a group composed of about 5.000 groupers. The Nassau Grouper is one of twenty groupers considered by IUCN as endangered in the Western Atlantic, where open access and unregulated fishing, mainly centered in spawning areas, has brought this species to near collapse.

The Nassau Grouper in the Gulf of Honduras

Currently, the Nassau Grouper fishery in the Gulf of Honduras has a relatively low economic importance. Nevertheless, until recently, the species was considered important in Belize and Honduras, the latter exporting to the U.S.A. until to 2008. Nassau Grouper

fishing in the Mesoamerican Reef is commonly conducted with hook and line, but spears and nets are also used. Species specific fishery statistics are only collected in Belize, while in Honduras only private companies' export records are available and the information in Guatemala is nonexistent.

With regard to fisheries management, Belize has made significant progress to moderate their fishing and establish no-take marine reserves, a process that has been supported by the involvement of NGOs and scientists. Recently there has been a closed fishing season established in Honduras from December 1st to March 30th at the Caldera del Diablo site.

In terms of management and conservation, Nassau Grouper fishing has been conducted in several sites in the Gulf of Honduras and some spawning aggregations in Belize and Honduras have disappeared. It is advisable to establish more stringent regulations as to avoid fishing during spawning aggregations. It is also necessary to consider the creation of an international coalition of fishermen, managers, conservationist and scientists from Belize, Guatemala and Honduras, perhaps trough the Tri-National Gulf of Honduras Alliance (TRIGoH). This would help address core aspects of fisheries, conservation and research of Nassau Grouper. To achieve a regional initiative it is important to consider a common fisheries management and conservation plan, along with scientific research support.

Objective

The objective of the current report is to establish the current condition of Nassau Grouper fishing and conservation in the Gulf of Honduras, and to assess the socioeconomic importance of this species fishery to local communities. Additionally, it is important to monitor the progress of conservation efforts regarding this species in Belize, Guatemala and Honduras.

Methods

The geographic scope of this report is the Gulf of Honduras, including the coast of Belize to Glover's Reef, the Caribbean coast of Guatemala and the Atlantic coast of Honduras, including the Bay Islands and Cayos Cochinos.

Field visits to areas in the three Gulf of Honduras countries were conducted to collect available information. Interviews with fishermen, NGOs, and government officials were conducted. A literature search of available information on the species and the geographic area was conducted. Main threats to the species sustainability were analyzed and successful management practices and lessons learned were described.

The government agencies responsible for fisheries administration and conservation organizations in each country were contacted. Finally, interviews with fishermen provided first hand information on the stakeholders' point of view in relation to the species level of exploitation and conservation.

RESULTS AND DISCUSION

Nassau Grouper population status

The information available on Nassau Grouper in the Gulf of Honduras varies from one country to another. Among them, Belize has the most information and research conducted to date, while little information is available in Honduras, and no records exist for Guatemala.

Nassau Grouper population status in Belize

Beginning with early studies conducted by Jacque Carter in the 1990s, important attention was drawn to the conservation status of this species. Carter and Marrow (1991) were first to identify that Nassau Grouper adult population structure was being affected at particular localities. Sex ratios have become female biased and length frequencies are significantly reduced for adult Nassau Grouper from historically heavily fished areas such as Caye Glory.

Catches of Nassau Grouper in Belize were as high as 100,000 pounds annually in the 1950's, but dropped to less than 30,000 pounds in 1986 (Carter and Marrow 1991). During the 1960's, Nassau Groupers were fished a rate of about 2 tons per day from a single aggregation site at Caye Glory (Craig 1969). As late as 1994, groupers comprised more than 30% (38,383 pounds) of the total finfish exported from Belize, of which, 64% (24,764 pounds) consisted of Nassau Grouper (Green Reef Environmental Institute 2001).

Belize fish export data demonstrated a steady decline from 1975 to 2005. The majority of finfish export from Belize consists of grouper and snapper (Figure 1). Highest export values approached 1,000,000 million pounds in 1983 and decreased to less than 50,000 pounds by 2004 (Heyman and Wade 2007).

The majority of the catch in the early fishery years was taken at spawning aggregations. Traditional spawning areas identified in 1991 included Caye Glory, Northern Two Cayes at Lighthouse Reef, Glover's Reef Atoll, Mauger Caye at Turneffe Islands Atoll, Gladden's Spit, and Rocky Point at Ambergris Caye.

Carter and Marrow (1991) identified that the future of the Nassau Grouper populations in Belize depended on several factors including, recruitment of larvae, and location of source population (where the recruits are coming from), adequate coral reef habitat, and the increase in fishing effort due to human population increase.

Nassau Groupers are considered to have been fished to extinction from 6 of their 10 historically-recognized spawning sites in Belize, and appear to have been extirpated from the site at Dog Flea Cay. Sites regarded as being intact are Northern Two Caye, Lighthouse Reef, and Northern Glovers Reef. Gladden Spit also shows Nassau Grouper spawning (Green Reef Environmental Institute 2002).

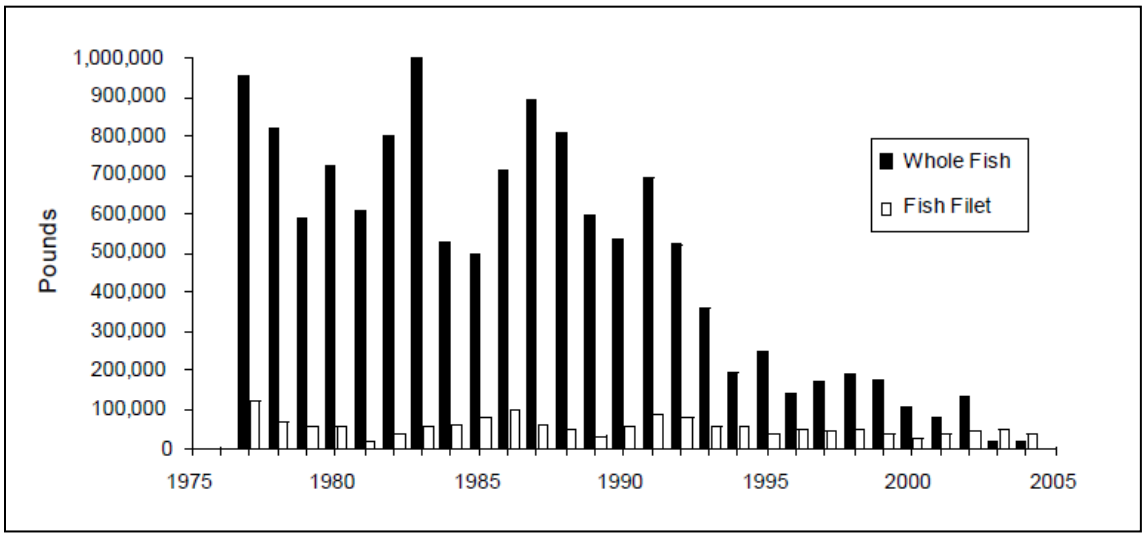


Figure 1. Belize's National and Northern Cooperatives fin fish export from 1975 to 2005. Data summarized by the Belize Fisheries Department (Heyman and Wade 2007).

Analyses of Nassau Grouper spawning aggregation data conducted in 2007 in Belize indicate populations are exceedingly low, but that protection efforts in some areas may be helping. Scientific evidence also shows that there are natural intra-annual and inter-annual variations in abundance (Heyman and Wade 2007).

Nassau Grouper population status in Honduras

Up to 2005, Honduras exported Nassau Grouper to the United States. Records from the export company show a steady decline from 1995 to 2007 (Figure 2). Also of importance is that the export peaks correspond to the reproductive season for this species, implying that most of the fish were being caught at spawning aggregations.

The known grouper fishing sites in Utila, Honduras, are all in deep water, between 30 m and 45 m. It is estimated that there are between 150 and 200 individual traps deployed by local fishermen during the months of December to March. The total landing for Nassau Grouper in the 2010 to 2011 season was 2,100 pounds. Daily landing records between August 2010 and March 2011 indicate that 87% of the landed catch of Nassau was between February 17th and February 27th, 2011. Nassau Grouper made up 25% of the total grouper catch over the period, but with much higher peaks than the other grouper species which are spread out over the same period. Nassau Grouper has a lower dockside price than other groupers at 17 Lps per pound, compared to 23 Lps for Yellowfin (*Myceroperca venenosa*) and Black Grouper (*Mycteroperca bonaci*). This price difference is most likely due to the ban on Nassau Grouper import in the United States supplying cheaper national markets. Nassau Grouper dockside price is now the same as Mutton Snapper (*Lutjanus analis*) and as a consequence it is often combined with this snapper during weighing and in subsequent fisheries records.

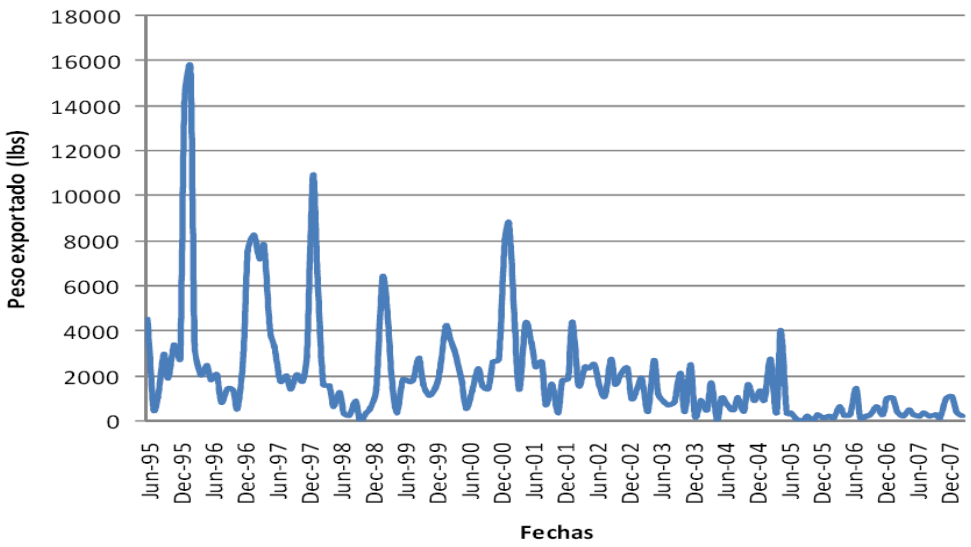


Figure 2. Export of Nassau Grouper (*Epinephelus striatus*) by Flying Fish Company (Honduras) from 1995 to 2007 (Box y Bonilla-Mejia 2008).

In past decades Nassau Grouper was of economic importance in Roatán, Honduras, but is now just an incidental catch. Landing records from the main fish purchaser between 2009 and 2011 indicate 26 commercial operators landed Nassau Grouper. The landing weight of this species represents 8% of the total grouper landings of a representative sample of commercial boats. The main grouper species now being landed are deep water grouper species, which is caught incidentally by the deep water boats. Moreover, most of this catch is coming from the banks on eastern Honduras and not from the Gulf of Honduras. Overall, groupers currently represent 5.4% of the total landings of the commercial fishery, with Nassau Grouper represents just 0.4% of the total fishery landings by weight. The peak landings for Nassau Grouper are in March, with 49% of landings between February and April. Data analysis showed spikes in landings are not are not date specific, suggesting they are the result of migrating grouper catches rather than specific targeting of aggregation sites. It is possible that the fish are migrating to the banks in the east following their spawning migration run.

Current fishing practices

Groupers are caught in Belize mostly by the use of spear, with hook and line being the second most common fishing gear (Star *et al.* 2007). Nevertheless, fishing for Nassau Grouper in Belize has declined due to reduced abundance and the legislation that prohibits fishing at spawning aggregations. The decline in Nassau Grouper exports also coincided with an increase in lobster and conch exports. In 2000, the Cooperatives in Belize stopped buying grouper due to a drop in the price.

The coastal communities in Belize that catch Nassau Grouper in the Gulf of Honduras include Punta Negra, Monkey River, Placencia, and Hopkins. Fishermen from the northern communities of Sarteneja, Chunox, and Cooper Bank fish for Nassau Grouper at Glovers Reef. Catch of Nassau Grouper is very occasional; the main targets being lobster and conch.

The coastal area in Guatemala has almost no reef habitat, as it is characterized by sand and silt soft bottoms, which is not suitable for Nassau Grouper habitat. The question as to whether mangroves and seagrasses in Amatique Bay could be nursery areas for Nassau Grouper has not been addressed. There is a potential to look into this possibility by examining manjua (*Anchoa* sp.) fishery by-catch data. The main fisheries in Guatemala are Snook, shrimp and snapper. According to fishermen from the Guatemalan community of Quetzalito, on the eastern shore of Punta de Manabique, catch of Nassau Grouper is extremely rare. Occasionally, this fish is caught with gill nets set to catch lobster or in long lines set to catch sharks.

In Honduras, the western fishing communities include the two main towns of Omoa and Puerto Cortes. Fishermen in Omoa traditionally fished the small reef patches adjacent to the town and the reefs around Punta Sal and into Tela Bay to the east. These reef areas are believed to have been heavily overfished, mainly for grouper and snapper species. The fishermen use a range of different fishing techniques depending on the time of year and the specific fishing association. Gears include traps that are too small to enable larger grouper or snapper to enter, suggesting that these fishermen do not target these fish, including Nassau Grouper. Even though there are no catch statistics, the fishermen say they predominantly catch small snappers such as Lane Snapper (*Lutjanus synagris*) which has market value of 25 Lps per pound. Additional fishing gear includes standard hook and line to catch jacks, marlin and mackerels, and 2 inch gill nets used for other pelagic species. Some fishermen use spear guns while diving for lobsters and conch. It is unlikely that currently there is any significant population of large groupers or snappers within the local fishing waters of Omoa and Puerto Cortes.

Despite the belief that populations of large groupers and snappers around Omoa and Puerto Cortes have been overfished, large groupers, including Yellowfin and Nassau Grouper, can be found in Puerto Cortes fish markets, especially around February. It is possible that these fish are being caught during night hours in Belizean waters, using hook and line, and then brought to the markets early in the morning, suggesting that Honduran fishermen are targeting spawning aggregations in southern Belize as the large fish are seen in the markets around February. To date there has been no attempt by management authorities to collect data on these fisheries and so there are no reliable records. The closest governmental office for DIGEPESCA is in San Pedro and they have no regular presence in the zone.

In Honduras, the Nassau Grouper fishery occurs mainly in the Bay Island of Utila. Local fishermen are one of the most active small scale fisheries on the north shore. Groupers including Nassau Grouper are specifically targeted by these fishermen between December and March using metal mesh traps with large straight entrance funnels, made of galvanized heavy duty steel square 1 ½ “ mesh. Most fishermen have about 4 to 6 traps set at known spawning sites for 3 to 4 days on either side of new and full moons. The

island of Roatán had an important Nassau Grouper market; however, this fish was being caught mostly outside the Gulf of Honduras, specifically on the Misquito Coast.

Interestingly, the price of Nassau Grouper in Honduras has not changed in at least 10 years, while the costs of fishing and of living have increased substantially during the same period. Local fishermen in the Bay Islands have little ability to set the price of their landed catch, thus they continually seek to increase catch volume to compensate their income in order to keep pace with inflation. As fuel costs continue to rise rapidly, it is likely to push fishermen to further exploit their resources (Box and Canty 2010). UCME has been working with local fishermen to find alternatives such as increasing the value of their catch. Post capture handling of local tunas, so that they can maintain the quality and become a premium “sushi grade” product suitable for high end markets is one of such options. The aim is to provide a viable economic alternative to the fishermen, should the grouper fisheries become closed.

Nassau Grouper life cycle

Nassau Grouper eggs are clear and buoyant. After they are fertilized, winds and tides carry the eggs away from the reef, and within 24 hours the larvae hatch. The larvae have transparent eyes, no fins and a large yolk sac which is their food source for the next five days. After hatching, the larvae spend about 25 to 45 days as plankton, feeding on other zooplankton (mostly tiny crustaceans, shrimp and other fish larvae). Once they reach about 20 millimeters in size they settle out on the bottom and take up residence on the reef. There is some evidence that larvae could recruit to the same area where the adults are spawning. After the juvenile fish have settled on the reef, they take up a cryptic life. There is some evidence that, as they grow larger, they move from the shallow grass beds into the sandy areas with small clumps of coral, then into the patches, and then into the deeper waters. The juveniles seem to feed predominantly on crustaceans.

Adult groupers are often found in deeper water in the spurs and groves and the deep fore-reef area. The larger fishes, as they descend towards deeper water, begin to feed predominantly on fish. Adult groupers are generalized opportunistic feeders; as ambushers, they stay close to the bottom and launch out, expanding their mouth like a vacuum sucking in their prey. They tend to feed mostly at dawn and at dusk. It is generally known that groups shift their diet as they grow older and they feed more on fishes than on crustaceans (Green Reef Environmental Institute and the Belize Fisheries Department 2001). The predominant diet of Nassau Groupers in Belize is fish (58%), benthic crustaceans (16%), and nektonic mollusks and cephalopods (6%) (Carter *et al.* 1994). Most of the species in Nassau Grouper diet occur in shallower water depths (Star *et al.* 2007).

Scientific information, research and monitoring efforts

As early as 1991 the information needed to develop a stock assessment was identified. This included long-term fishery statistics with fishing effort in terms of number of

fishermen, time expended fishing, catch statistics with size, weight, and sex ratios, and landings reports from registered fishermen (Carter and Marrow 1991). More recently, it has been acknowledge that the lack of comprehensive information on Nassau Grouper stock status requires a precautionary approach to management (Die and Carcamo 2008). The complexity of gathering scientific information on Nassau Grouper is related to its life cycle (Green Reef Environmental Institute and the Belize Fisheries Department 2001).

Nassau Grouper Spawning Aggregation Sites in Belize

Nassau Grouper research and monitoring has been conducted in Belize since 1998, when a total of 12 spawning aggregation sites were evaluated. In 2002 the maximum number recorded of Nassau Groupers at Glover's Reef was 4600 (Heyman and Requena 2002). The results from yearly monitoring efforts on spawning aggregation sites have provided information on spawning time, location and abundance. Table 1 summarizes data registered at selected sites in the Gulf of Honduras, while Figures 3 and 4 identify the period from January to March of each year as the reproductive season for Nassau Grouper.

Table 1. Summary of Nassau Grouper abundance at spawning aggregation sites from 1998 to 2006 (Rhodes 2006).

Site	1998	1999	2000	2001	2002	2003	2004	2005	2006
NE Glover's Reef						3		2,200	
Middle Caye, Glove's Reef					25			1	
Gladden Spit	2	90	50	100	400	496	846	797	1,030
Nicholas Caye, Sapodilla Cayes					70	3	204		
Rugged Caye				2	1				
Rise and Fall Banks, Sapodilla Cayes				10	1				

Evidence has shown that monitoring efforts should be long-term to conclusively evaluate trends. Results from Gladden Spit Nassau Grouper counts between 1998 and 2006 indicate a steady increase in abundance, going from almost no groupers in 1998 to almost 800 fish in 2006 (Figure 5, Heyman and Wade 2007).

Trends indicate increases in Nassau Grouper counts at some spawning sites that were closed to fishing, and in locations where the Fisheries Department and partners provide continuous surveillance and enforcement. Nevertheless, increases in abundance at the Sandbore and Caye Glory sites are considered insufficient to ensure full recovery of the endangered species (Figure 6).

Using acoustic telemetry, Star *et al*. (2007) showed that Nassau Grouper exhibit synchronous migration to spawning sites, despite their otherwise solitary habits. Reproductive adults leave their individual territories in shallow waters near the winter full moons, and migrate to the same spawning site up to four times per year. At the spawning

site, a population-wide depth change occurs within an hour as individuals dive to a maximum depth of 255 m (Star *et al.* 2007).

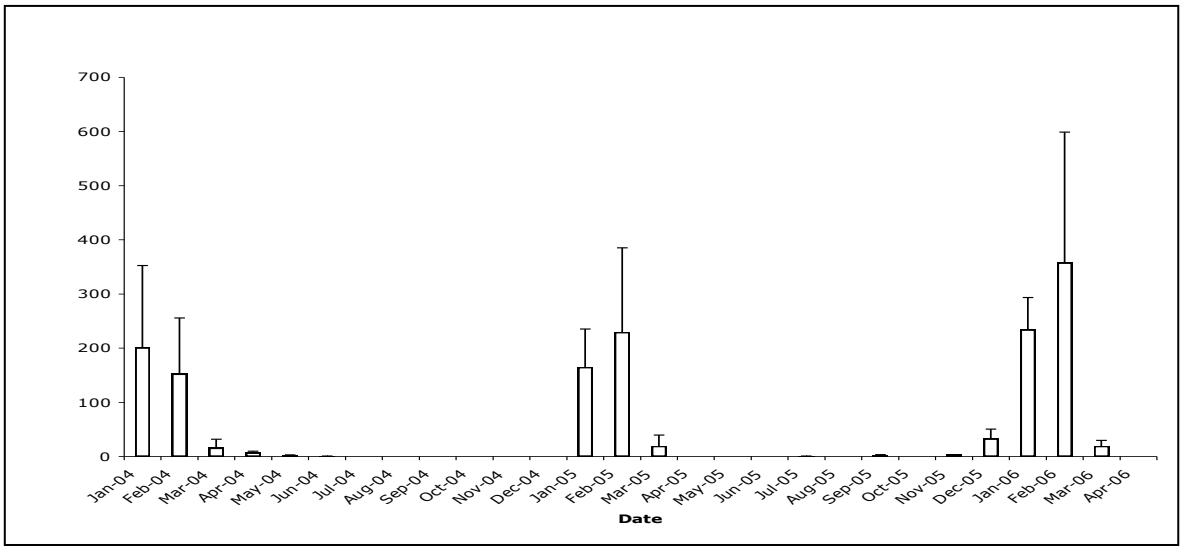


Figure 3. Abundance of Nassau Grouper at Gladden Spit between January 2004 and April 2006. Peak spawning months are clearly indicated by peaks in abundance (Rhodes 2006). Abundance expressed in number of individuals.

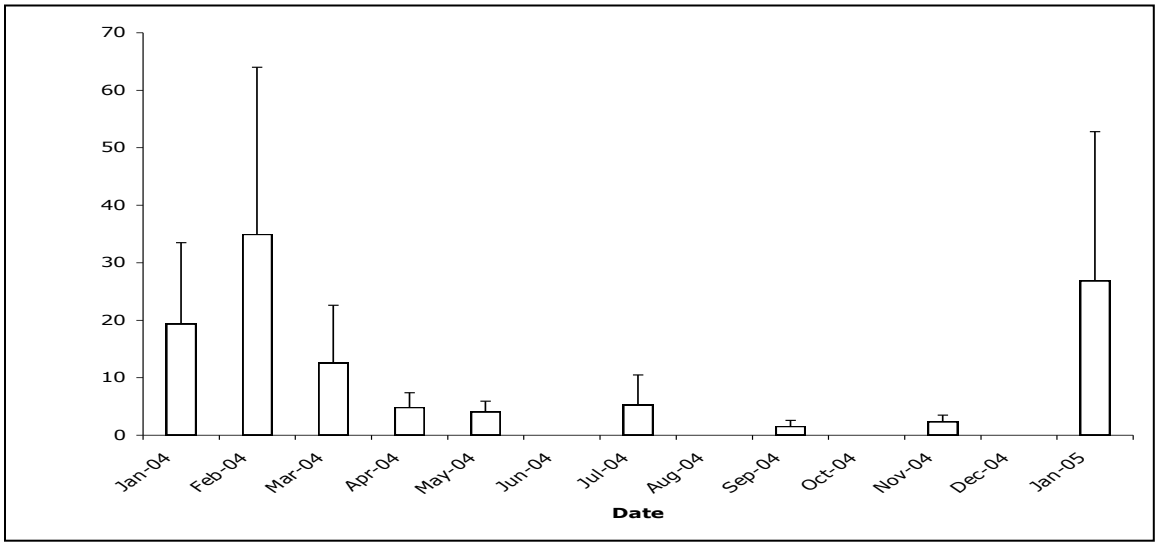


Figure 4. Abundance of Nassau Grouper at Nicholas Caye between January 2004 and 2005. Peak abundance is shown in February 2004, with a reproductive season indicated from January to March (Rhodes 2006). Abundance expressed in number of individuals.

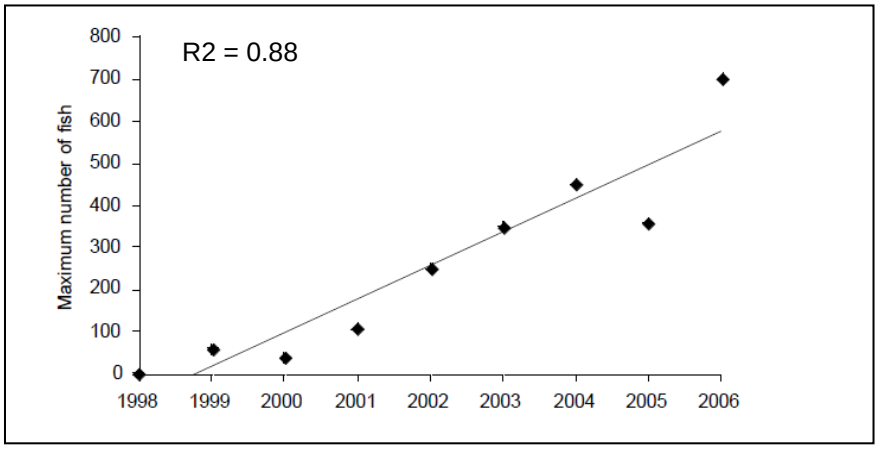


Figure 5. Nassau Grouper abundance at Gladden Spit 1998 to 2006; data provided by Friends of Nature (Heyman and Wade 2007).

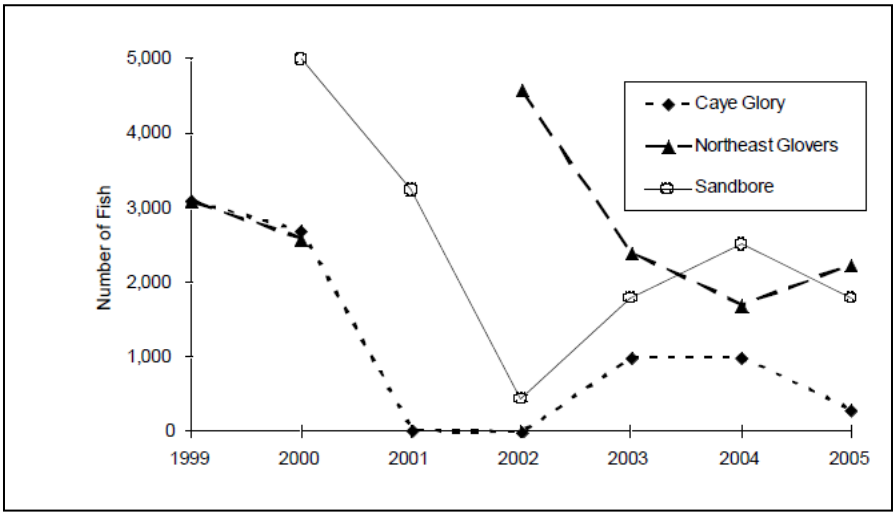


Figure 6. Underwater visual surveys of Nassau Grouper abundance from 1999 to 2005 at three healthy spawning aggregation sites in Belize. Data provided by the National Spawning Aggregations Working Committee (Heyman and Wade, 2007).

Initial estimated values of fishing mortality from the first year of acoustic tagging (F = 0.37) showed no decline in the mortality rates (F = 0.40) after the spawning site was protected by the Belize Department of Fisheries (2001). Nevertheless, estimates from the second year indicated a significant decline to half of the mortality rates (F = 0.22).

Nassau Grouper inhabiting Glover's Reef do not leave the atoll, suggesting that they are unlikely to swim long distances over deep water and require contiguous reef tracts to migrate. Their movement patterns at Glover's Reef indicates solitarily behavior in small

home ranges, except during winter full moons when they carry out population wide synchronous migrations to their spawning site (Star *et al*. 2007). Results indicate that replenishment of depleted populations may not occur via adult migration between isolated atolls, but would be entirely dependent upon larval recruitment. Due to the existence of reef fish larval dispersal barriers it is expected that some Nassau Grouper populations isolated by deep water that do not contain any spawning aggregations are doomed to extinction, or at least will be depleted for a very long time (Star *et al.* 2007).

The data used in a 2007 national Nassau Grouper analysis shows efforts in standardizing the methods of counting and measuring fish aggregating to spawn. Nevertheless, it also shows that the number of samples obtained in certain sites is inadequate for evaluating the effects of management on such sites (Die and Carcamo 2008).

Monitoring of Nassau Grouper numbers at spawning aggregation sites is coordinated by the Belize Spawning Aggregation Working Group. A summary of the monitoring results is presented in Table 2. and Figures 7.1 to 7.4.; only NE Point at Glover's Reef, Gladden Spit and Nicholas Caye are part of the Gulf of Honduras area.

Table 2. Summary of Nassau Grouper abundance at spawning aggregation sites monitored by the Belize SPAGs Working Group; numbers are peak counts. Data from NE Point, Glover's Reef provided by WCS, and data from Gladden Spit and Nicholas Caye was provided by SEA.

Site	2003	2004	2005	2006	2007	2008	2009	2010
NE Point, Glover's Reef	2,400	1,700	2,240	3,000	800	1190	1,100	3,328
Gladden Spit	250	450	360	239	255	350	260	238
Nicholas Caye	52	50	80	48	80	100	25	30
Dog Flea Caye, Turneffe	1,500	100	-	2	N/A	N/A	N/A	N/A
Caye Glory	1,000	1,000	350	7	69	405	3,000	N/A
Sandbore, Lighthouse	1,800	2,500	1,800	1,205	1,495	1,250	2,050	N/A
Rocky Point	0	200	200	0	N/A	0	N/A	N/A

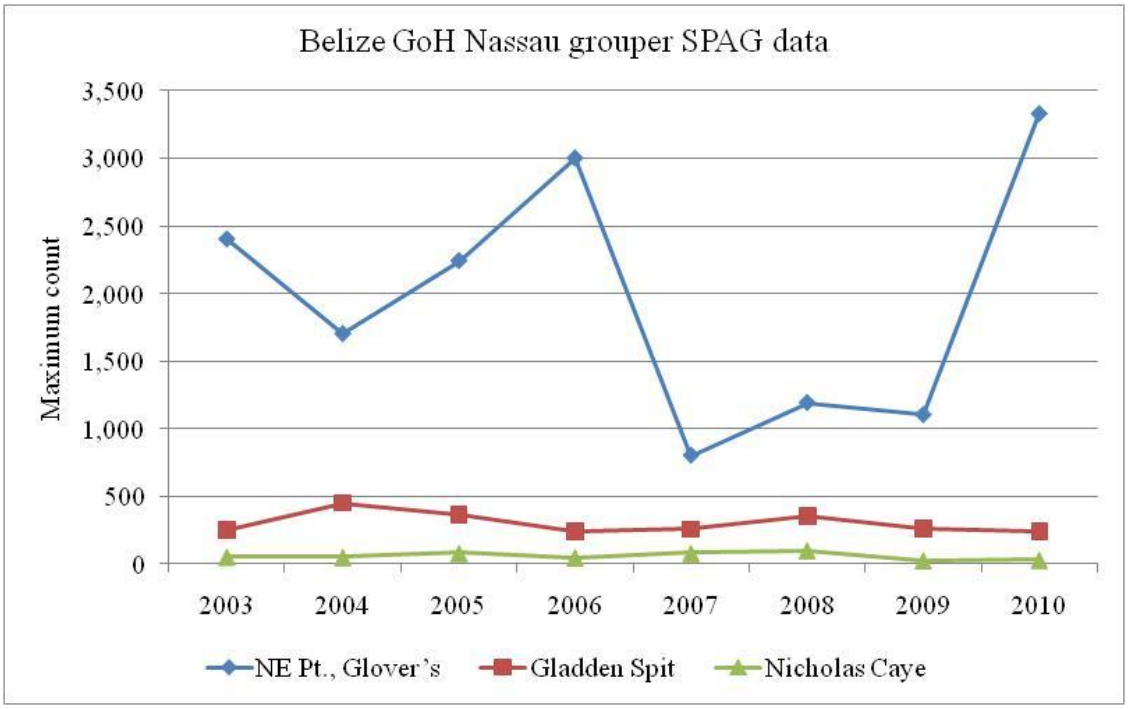
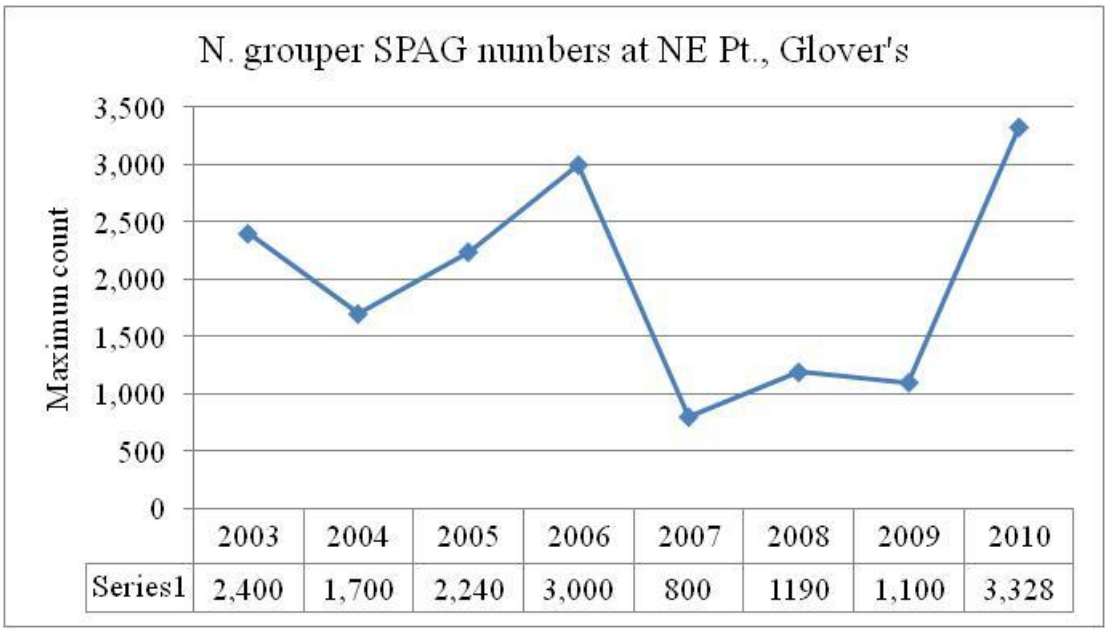


Figure 7.1. Nassau Grouper abundance at Gulf of Honduras spawning aggregation sites (Data from NE Point, Glover's Reef provided by WCS, data from Gladden Spit and Nicholas Caye was provided by SEA).



	2003	2004	2005	2006	2007	2008	2009	2010
Series1	2,400	1,700	2,240	3,000	800	1190	1,100	3,328

Figure 7.2. Nassau Grouper abundance from 2003 to 2010 at NE Point at Glover's Reef, Belize (Data provided by WCS).

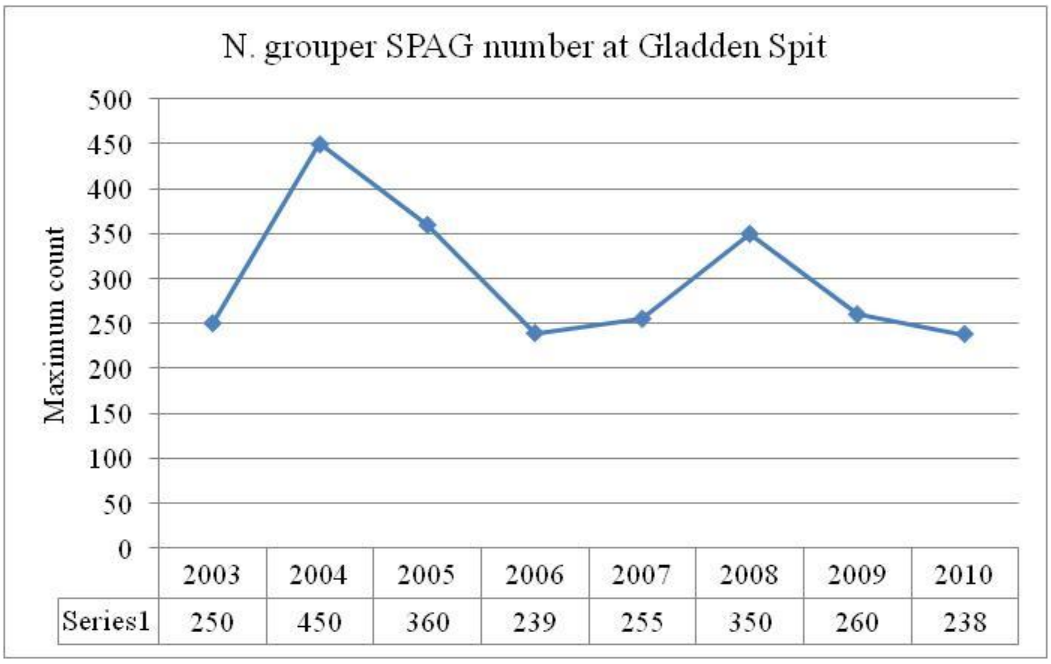


Figure 7.3. Nassau Grouper abundance from 2003 to 2010 at Gladden Spit, Belize (data provided by SEA).

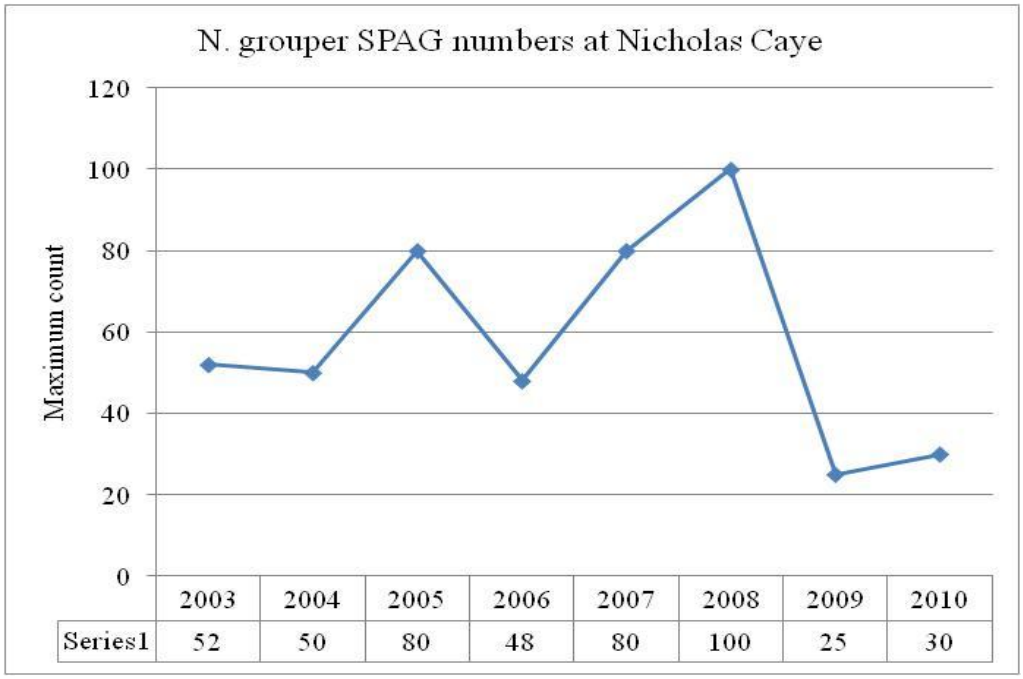


Figure 7.4. Nassau Grouper abundance from 2003 to 2010 at Nicholas Caye, Belize (data provided by SEA).

Nassau Grouper Spawning Aggregation Sites in Honduras

Research on Nassau Grouper in Honduras begun with diving assessments conducted by UCME from 2009 to 2010 at three of the known spawning aggregation sites. Dives at the sites around the full and new moon every month found very few groupers at any of the locations. These sites included two locations inside the boundaries of the protected areas, Joshua's Swash in Turtle Harbor, and the Elbow near Raggedy Cay. The third site was a traditional fishing site called Southeast Bank. Only 6 Black Groupers were seen and no Nassau groupers were seen. This was supported by the landing records as no Nassau Groupers were caught from these sites. Interestingly however, in 2010 – 2011, fishermen reported catching Nassau Grouper again at these sites, suggesting that there may be cyclical use of these locations that span years. It is possible that the spawning sites found around Utila are linked to others found across the Bay Islands, with the fish following a bathymetric contour of the continental shelf. Genetic analysis of groupers landed from each of the sites would help elucidate the connectivity between these sites.

There is at least one spawning aggregation near Roatán, which was initially identified and defined in 2009. The site has not been officially validated as the survey team did not have the opportunity to dive the site consecutively for 12 months, as recommended by the SPAGS monitoring manual for the Mesoamerican Reef (TNC). Their estimates of the number of aggregating fish were around 1,000 Nassau Groupers with color changing behavior and some courtship displays seen. The site is in deep water around 40 m making it difficult to monitor. It is not known if the site is fished. An evaluation conducted in Roatán in 2009 confirmed, through visual census, the existence of an active grouper species spawning aggregation in Banco Cordelia. This aggregation was verified and documented by indirect evidence. Species-specific spawning behaviors were identified for Black Grouper (*Mycteroperca bonaci*), Black Grouper (*Mycteroperca venenosa*), Tiger grouper (*Mycteroperca tigris*), and Nassau Grouper (*Epinephelus striatus*). Even though no direct evidence of spawning was obtained, discoloration, swollen abdomens, and increases in population density were observed.

The first documented Nassau Grouper spawning aggregation of Honduras was off the northeast coast of Guanaja, at a site called Caldera de Diablo. It is also the first documented decline of an aggregation by Fine (1990; 1992) where an estimated 10,000 individual fish declined to 500 over the course of 2 years. In the report by Fine (1990 and 1992) he called for immediate protection of the site.

In 2011 the fisheries resolution by DIGEPESCA for that year included a moratorium on fishing in a site called Caldera de Diablo. Unfortunately, in the published law Caldera de Diablo was placed off the island of Utila, 175 km away from the actual location of the aggregation near the Island of Guanaja. The law to date has provided no tangible protection for Nassau Groupers in Honduras.

Other spawning aggregation sites in Honduras have been verified to be used by other species but not Nassau Groupers. Visual censuses have confirmed the existence of four active fish spawning aggregation sites within the Cayos Cochinos Archipelago marine natural monument. These sites are known by the names of Punta Pelicano, La Grupera, Roatán Banks and Mariposales. The validation was performed by indirect evidence.

Spawning behaviors were identified and population density increases observed for *Carax Ruber, Lutjanus apodus, Cephalopholis fulva, Mycteroperca venenosa and Mycteroperca tigris*. Color changes and swollen abdomens were observed in some of these species.

Critical habitat condition and threats

The life cycle of Nassau Grouper involves at least four different habitat types (Green Reef Environmental Institute 2001). Nassau Grouper eggs and larvae are found in the open ocean, floating in the plankton in surface waters. Juveniles normally occupy mangrove areas and coral rubble, where they feed on small crustaceans and fishes. Sub adults and adults live in reef crevices and abyssal depths, feeding on large crustaceans and fishes. Finally, during the reproductive season, spawning adults move to spur and groove reef habitat, particularly the areas near reef promontories where they take advantage of the currents to help them spread their eggs.

Spawning Aggregation sites

Among Nassau Grouper critical habitat types, spawning aggregation sites have received the most attention. As early as 2001, information available indicated that just 2 of the 6 aggregation sites in Belize use by Nassau Grouper were intact, Sandbore Caye and Glovers Reef, with 4,000 - 6,000, and 2,700 adults still returning to spawn, respectively (Green Reef Environmental Institute 2001). Peaks abundance of Nassau Grouper at spawning sites usually occurs three to seven days after the full moon.

A study conducted at Glover's Reef, a single aggregation site surveyed by the WCS was found to be comprised of just 3,100 adults, from which fishermen had removed 219 individuals during the same season (Sala & Ballesteros 1999). In 2001 one of the last spawning aggregations still viable in Belize was still open. The aggregation had a fishing quota of 900 groupers, which represents about 30% of the aggregation. Fisheries models predicted that, if fishing continues, the spawning aggregation will disappear by 2013 and the fishery will be abandoned by 2009, at the latest (Sala *et al*. 2001).

Unsustainable fishing could eliminate spawning aggregations with subsequent negative effects on the grouper populations in the region. Sala *et al*. (2001) recommended that since most of the spawning aggregations in Belize have been fished out, it was necessary to protect the remaining spawning aggregations by closing these sites to fishing. A fishery closure would reduce income to some fishermen, but a simple economic analysis of the fishery, and an ecotourism alternative, shows that groupers are worth approximately 20 times more alive than when fished.

Green Reef Environmental Institute acknowledged in 2002 a total of 10 historical Nassau Grouper SPAGs sites: Rocky Point, Cay Caulker, St. George's Cay, Goff's Cay, Cay Glory, Gladden Spit, Sapodilla Cays, Mauger Cay, Turneffe Reef, Northern Two Cay (Lighthouse Reef), and North-Glovers Reef. With the exemption of Gladden Spit, Northern Two Caye and North-Glovers Reef, all others were extirpated by 2002.

Other sites reported as Nassau Grouper SPAGs are Dog Flea Caye, and Caye Bokel, Turneffe Reef (Paz and Grimshaw 2001), and Nicholas Caye on Belize's southern Barrier

Reef (Heyman and Requena 2002). An interesting finding derived from scientific research in Belize is that all of the spawning aggregation sites were identified as multispecies spawning sites (Heyman and Requena 2002). Nassau Grouper spawning sites are also shared by transient spawning aggregations of other species, during December–February when Nassau Grouper typically spawn (Heyman and Kjerfve 2008).

Although current management protects part of the spawning stock, there were still some spawning sites that continued to be open to fishing in 2008 (Die and Carcamo 2008); moreover, the need to consider other life history stages than spawning was identified by Gibson (2007). Most of the Nassau Grouper catch in Honduras' Bay Islands occurs from December to February, indicating that spawning aggregations are being fished.

Nassau Grouper nursery habitat main threats and climate change effects

Most fish species inhabit different habitat types during their life cycle and the Nassau Grouper is not the exception. The pelagic eggs and larvae stages duration of Nassau Grouper varies from 25 to 45 days, and takes place in the open ocean. After that period the benthic stages follow, beginning with the early juveniles settling to mangroves and coarse rubble bottoms, which are the preferred nursery habitat types. As the juveniles grow they move to reef crevices and upon reaching the adult stage they migrate to abyssal depths. Finally, when sexual maturity is reached, individuals visit spur and groove reef areas during spawning aggregation events. These coastal and marine habitats are crucial for the survival and posterior reproduction of the species, therefore, their protection, conservation and monitoring efforts should be considered a component of Nassau Grouper management strategies.

Main threats to Nassau Grouper nursery habitats throughout the Gulf of Honduras include ecosystems' degradation, fragmentation and destruction. Other threats include decline in the water quality, especially close to shore, and the introduction of invasive species as the lion fish. Natural phenomena like hurricane and storms and anthropogenic originated activities like climate change have been pointed out as a main threat to most ecosystems.

Climate change effects on terrestrial and marine organisms include shifts in species bio-geographic ranges, population dynamics changes, adjustments in the timing of seasonal activities (e.g., spawning events) and even the spread and establishment of invasive species, among other effects (Munday *et al*. 2007). For tropical marine species, the impact of climate change on coral reefs is critical, not only because of the direct corals degradation through bleaching events, and the spread of coral diseases, but also because of the overall effects on coral reefs communities (Hoegh-Guldberg 1999; Hughes *et al*. 2003). How climate change already is or will affect other organisms directly associated with coral reefs and coastal environments (sea-grass beds and mangroves), fish for instance, have received much less attention and need to be addressed (Roessig *et al*. 2004; Munday and Holbrook 2006).

Climate change is expected to affect fish populations and communities through all life cycle stages. Potential impact on fish larval growth, dispersal and survival patterns, as well as ecological and genetic connectivity between populations has also been identified (Sale 1991; Cowen 2002; Munday et al 2008). Reef fish larvae are sensitive to changes in

environmental conditions, which most likely could affect species distribution and abundance of adult populations (Munday *et al*. 2007). Furthermore, climate change impacts on coral reef structure will have profound consequences for fish populations and communities. Recent episodes of coral bleaching from elevated sea temperatures (Wilkinson 2002), and the spread of coral associated pathogens have seriously degraded reefs around the world (Wilkinson 2002). As a consequence, a significant decline in reef fish species diversity and abundance has been already documented (Wilson *et al*. 2006; Pratchet *et al*. in press). There is a general uncertainty about the magnitude and direction of changes on reef fish species due to climate change (Munday *et al*. 2007); therefore, this information should be taken with great care. It is strongly recommended to develop research on specific climate change effects on Nassau Grouper populations throughout the Gulf of Honduras, to better understand future management challenges of this species.

In any case, the healthier the population of Nassau Grouper the better chances they will have to adapt to these uncertain changes. Similarly with reefs and other habitats used by groupers. Therefore protecting a network of key habitats and helping the grouper population to recover are two important actions to build resilience to climate change.

Management and conservation efforts, practices and lessons learned

Efforts in Belize

Carter and Marrow (1991) recommended the establishment of Marine Fishery Reserves in 20% of the Nassau Grouper spawning banks that would later increase to 30% of the barrier reef habitat. The 30% value was calculated based on the evidence that stocks that fall below 20% of the unexploited spawning stock biomass are likely to collapse. The remaining 70% of the marine habitat will be managed by traditional regulatory methods. Finally, Carter and Marrow (1991) recommended a permanent limited entry to the fishery to be set at 1991 levels.

Other proposed regulatory methods include the establishment of a minimum size limit of 30.5 cm or 12.0 inches standard length, at which 50% of the females become mature (Carter and Marrow 1991). Nassau Grouper become sexually mature at approximately 500 mm (20 inches) standard length, normally between 5 and 10 years of age. They can live from 15 to 20 years of age, and a single large female can produce 5 to 6 million eggs during a single spawning period (Green Reef Environmental Institute 2001).

Management recommendations were updated in 2001, including closure of SPAGs fishing, minimum capture size of no less than 20 inches or 50 cm, designation of SPAG sites as protected areas, and the development of alternative income earning activities for traditional fishermen affected by SPAGs fishing closures (Green Reef Environmental Institute 2001). Later on, in 2007 a recommendation for the inclusion of the precautionary principle was included in regards to the management of spawning aggregations as fragile systems crucially important for the maintenance of fish stocks (Heyman and Wade 2007).

Fisheries-independent counts revealed Nassau Grouper are still aggregating to spawn at several of the historical sites and may be showing some signs of recovery. Spawning has

been observed at northeast Glover's Reef Atoll and at Sandbore in Lighthouse Reef Atoll. Between 1,000 and 3,000 individuals have been counted at Caye Glory, with 2,500 on a single count in 2004 (Heyman and Wade 2007). Even so, there remains only a fragmented relict population of Nassau Grouper in Belize. Heyman and Wade (2007) recommend a full ban on the possession of Nassau Grouper, and invoking the precautionary principle, they further recommend continued and indefinite closure of the multi-species spawning aggregation sites in Belize. In order to evaluate the effectiveness of the closures over time, Heyman and Wade (2007) recommend continued and increased monitoring efforts for multi-species aggregations.

An analysis of the situation in Belize, conducted by Gibson (2007), indicated the need to provide more assistance for management and enforcement, public awareness, and alternative livelihoods. Additionally, it is crucial to sustain the political will at the highest levels to enforce the laws. Caribbean-wide actions supported by all countries may be the best hope for the recovery of the species (Gibson 2007). On the other hand, the enforcement provided by Friends of Nature at the Gladden Spit aggregation has resulted in Nassau Grouper and Cubera Snapper (*Lutjanus cyanopterus*) increase (Heyman and Wade 2007). Unfortunately, declines continue at most other sites, where enforcement has been less consistent (Heyman and Kjerfve 2008).

Protecting a spawning aggregation may not sufficiently protect groupers if they are being caught as they migrate, or if fishing rates are too high outside the spawning season. For example, there is a high rate of fishing mortality at Glover's Reef (Star *et al.* 2007). Close to 14% of the adult population is removed annually by year-round spear fishing at Glover's Reef (Sala *et al.* 2001). With the continued decline in numbers, the Working Group recommended that additional measures be introduced (Gibson 2007).

One of the key elements in Belize's successful efforts in protecting Nassau Grouper was the creation of the National Spawning Aggregation Working Group. The Belize National SPAG Working Group was established in July 2001, in response to a nationwide survey of spawning aggregations of the Nassau Grouper in early 2001 that revealed very low numbers of spawning fish. During 2002 a coalition of 7 NGOs worked successfully to protect 11 of the Nassau Grouper spawning sites, and to introduce a four-month closed season. Since early 2003, the Working Group was revitalized and has been meeting regularly on a bi-monthly basis to share data and develop management strategies. The SPAG Working Group's goal is "To manage spawning aggregation sites and gather data that can be used to develop strategies to maintain these as viable sites for the protection, conservation and sustainable use of the fishery." (http://collaborations.wcs.org/Default.aspx?alias=collaborations.wcs.org/spag).

Presently, the Working Group's members are representatives from 13 organizations: Belize Audubon Society, Belize Fishermen Co-operative Association, Belize Fisheries Department, Coastal Zone Management Authority and Institute, Friends of Nature, Green Reef Environmental Institute, Hopkins Fishermen Association, Placencia Fishermen Co-operative, The Nature Conservancy, Toledo Association for Sustainable Tourism and Empowerment, Toledo Institute for Development and Environment, University of Belize, Wildlife Conservation Society, and World Wildlife Fund.

Nassau Grouper protection at Glovers Reef Atoll is coordinated by the Belize Fisheries Department and WCS. The Nassau Grouper spawning aggregation site at Glover's Reef Atoll is located at the Northeast Point Site. The Seasonal Closure Zone, covers an area of 1,550 ha, and encompasses the Nassau Grouper spawning bank, located on the northeast corner of the atoll. In order to provide protection for the population of spawning Nassau Grouper, the zone is closed to fishing from 1 December to 1 March. This area also encompasses the Spawning Aggregation Site, established in 2003 (SI 161 of 2003) which is closed to fishing all year round.

Efforts in Honduras

The Nassau Grouper fishery in Honduras has received less attention. The grouper trap fishery in Utila coincides with strong winds and waves associated with the beginning of the year and the "northern" storms. Sustained periods of poor weather can prevent fishermen from setting their traps, but conversely can also prevent them from collecting them. An alternative to banning traps is to encourage fishermen to use degradable materials to tie the trap hatch closed, so that if the trap is left out for sustained periods this rots and the door opens and the trap does not become a ghost fishing gear.

Current legislation and regulations

Regulations in Belize

Belize regulations related to the protection of Nassau Grouper include the following statutory instruments (SI):

- Government of Belize. 2000, Chapter 210. Belize Fisheries Act. Among the regulations put in place by the Fisheries Act, several relate to Nassau Grouper fishing.
    - No person shall take any fish with a net of mesh size less than 3 inches, no use of long lines, trawlers or gill nets in a reserve unless authorized by the Fisheries Administrator
    - No commercial, sport or recreational fishing within the Conservation Zone
    - No setting of traps within 300 feet from the barrier reef
    - No setting of nets, weirs, or beach seines within a 2 mile radius of any inhabited locality
    - No spear fishing within marine reserves
    - No fishing without a valid license
    - No fishing using scuba gear

- Government of Belize. 2003a. Statutory instrument no. 161 of 2003. Fisheries (spawning aggregation site reserves) order, 2003. 161: 1–8.
    - Declares specific spawning aggregation sites as marine reserves, closed to fishing year-round: Rocky Point at Ambergris Caye, Dog Flea Caye at Turneffe Islands, Caye Bokel at Turneffe Islands, Sandbore at Lighthouse Reef, South Point at Lighthouse Reef, Emily or Caye Glory, Northern

Glover's at Glover's Reef, Gladden Spit, Rise and Fall Bank at Sapodilla Cayes, Nicholas Caye at Sapodilla Cayes, and Seal Caye at Sapodilla Cayes.

- Government of Belize. 2003b. Statutory instrument no. 162 of 2003. Fisheries (Nassau Grouper protection) regulations, 2003. 162: 1–2.
    - Prohibition of fishing and possession of Nassau Grouper between December 1st and March 31st, except for Nassau Grouper taken from Maugre Caye at Turneffe Islands and Northern Two Caye at Lighthouse Reef. Fishing at those 2 sites is allowed only with special license.

- Government of Belize. 2009. Statutory instrument no. 49 of 2009. Fisheries (Nassau Grouper & species protection). This legislation governs Nassau Groupers and was strengthened by requiring:
    - Fish caught should be no less than 50.8 cm in total length or greater than 76.2 cm in total length
    - Fish has to be landed whole.

Despite high expectations for the recovery of the reef banks as a result of regulations, the numbers have continued to decline and illegal fishing has been evident at several sites (Gibson 2007).

Regulations in Honduras

Fishing regulations in Honduras associated with Nassau Grouper are lacking. While it is commonly believed that traps are banned around the Bay Islands, there is no reference to such measure in the current fishery law. The PMAIB Project has not provided the rules that govern each zoned area and there are currently no restrictions on fishing besides those in the current Fishing Law and the 2011 regulations. The 2000 municipal decree banning fishing within 1 mile of Utila was lifted by the mayor in 2001, and has never been re-enacted. The local NGO BICA in Utila is conducting fishing patrols to enforce spear fishing, net and trap regulations around the island. Fishing at spawning aggregations in Cayos Cochinos, Honduras is forbidden, as per the approved management plan.

The 2011 fisheries resolution by DIGEPESCA for the protection of the spawning aggregation at Caldera de Diablo, as indicated before, was unfortunately placed in the wrong island. Other than that, the law to date does not provide protection for Nassau Groupers in Honduras.

A draft ministerial decree is being considered in Honduras, including several protection measures for Nassau Grouper. These include a closed season from December 1st to March 30th of each year, that also prohibits the fish export plants to buy and local commerce of the species during that time period (Calina Zepeda, com. pers.).

Fishing communities socioeconomic status and economic alternatives

Recent management strategies have drawn more attention to socioeconomic conditions as key component to achieve sustainability. More specifically, there is a great need to develop alternative income earnings activities for traditional fishermen communities affected by fishing regulations, such as SPAGs protection, fishing closure, and no-take zones. This section of the report provides an overview of the socio-economic status of local communities within the Gulf of Honduras, and offers potential recommendations as how to promote alternative income activities that better complement management strategies of the species. Creating and promoting new and complementary economic livelihoods requires an understanding of local socio-economic context as well as regional economic trends. Identifying activities that could take advantage of existing markets (e.g., labor, goods and service markets) is also a key step in developing alternative economic activities.

The Gulf of Honduras is part of the Mesoamerican Barrier Reef, the second longest barrier reef system in the world. Belize, Guatemala and Honduras not only encompass incredible marine biodiversity but also unique cultural diversity. Thousands of people from local communities along the Gulf of Honduras directly and indirectly depend on coastal and marine resources for their livelihood. Coral reefs are of critical economic value in the region where cultural traditions are closely related and in many cases directly depend upon local marine resources as it is the case of traditional fisheries. In recent decades, local communities have engaged in ecotourism business as either new or complementary livelihood alternatives, which have provided more local jobs and revenues for government coffers (McPherson 2006).

Regional population trends: demographics, development and economic indicators

A general overview of the regional demographics for the three countries is presented in the following section. The estimated population along the coasts of Belize, Guatemala and Honduras reached 1 million people (1,002,515) during the 2000 decade. The highest population density was reported in Guatemala with 35.70 person / km^2, and the highest population growth rate was 3.02% in Honduras (Table 3). Regional development and economic indicators such as those presented on Tables 4 and 5 are used as a development measure based on achievement in economic growth, education and health.

Uneven economic development characterizes communities in the region; agriculture and tourism are considered the main economic sectors for employment and earnings. On the other hand, fishing and fishing related activities are considered of relatively low importance when its regional employment and economic contribution are compared with the latter. In many coastal communities, however, fishing represents the main or only income activity and a traditional livelihood.

Specific communities within the Gulf of Honduras greatly depend on tourism as their most important income source such as the Bay Islands in Honduras, several communities in southern Belize and the town of Livingston in Guatemala. Current tourism trends in some of these localities already show signs of a consistent growth pattern for the near future.

Therefore, it is no surprise that governments and international organizations have plans to continue developing and extend tourism activities linked to coastal, marine and cultural resources in the region.

Ecotourism businesses in Belize have focused on adventure and experimental tourism activities directly related with coral reefs, rainforest and archeological resources (Tierney 1999). Hopkins and Placencia are two of the main important tourism destinations in southern Belize; Sapodilla Keys have also become a popular destination for Guatemalans as it is close to Puerto Barrios and it is a cheaper option to enjoy clear waters and optimal diving conditions. In 2004, 23.5% of Belize's GPD was linked to tourism activities, one of the highest tourism dependency rates in the Caribbean region (WTTC 2004). In the southern Belize districts of Stann Creek and Toledo, direct employment in tourism accounts for 8.5% and 15.5%, respectively. Guatemala shows a much lower tourism contribution to the country's GPD (2.6%) and total employment (2.6%). These values are expected to rise to 3.6% and 3.3%, respectively, in the next 10 years (WTTC 2005) (Table 5).

In Guatemala coastal municipalities represent a very low contribution to tourism at a national level. Livingston, a Garifuna community, is the most important destination for international, short term, and low-budget backpacking adventure visitors. During the past years cruise ships have become increasingly more important in Puerto Barrios (Table 6). In 2005, Honduras reported 8.5% of total employment and 4.4% of GPD to be associated to tourism activities. The Bay Islands (Utila, Roatán and Guanaja) represent the most important tourist destination within the coastal region, followed by Omoa, La Ceiba and Tela (Table 6).

Table 3. Municipal coastal demographic indicators by country (Source: CSO 2000; INE Honduras 2001; INE Guatemala 2002).

Country	Number of Municipalities	Estimated population (2005)	% average yearly population growth rate (intercensus period)	Estimated population density 2005 (per km2)	% population living in urban areas
Belize	4 (districts)	174,900	2.08	14.75	53.6
Guatemala	2	127,038	-.69	35.79	45.4
Honduras	22	700,577	3.02	25.63	66.3

Table 4. Regional development and economic indicators for coastal municipalities in Belize, Guatemala and Honduras (Source: CSO 2000; INE Honduras 2001; INE Guatemala 2002).

Country	% with sustainable access to	% with sustainable access to	% of population with no	% of population with only primary	% of population with secondary

	water	sanitation	education	education	education
Belize	79.4	91.4	26.8	50.7	18.1
Guatemala	85.1	82.6	25.1	52.8	18.6
Honduras	85.4	73.8	6.5	59.2	16.8

Table 5. Economic indicators in Guatemala, Belize and Honduras (summary by McPherson 2006).

Country	Average GDO per capita (US PPP)	Labor Force Participation Rate	% Reported Employment in the Agricultural Sector	% employment in Tourism Activities	Fisher and fish processing as a % of PEA	Hotel per Capita
Belize	n/a	60	20.1	6.2	3.7	45
Guatemala	n/a	36.7	39.7	17.6	3.8	n/a
Honduras	2520	36.5	n/a	n/a	n/a	n/a

Table 6. Selected tourism indicators for Belize, Guatemala and Honduras (McPherson 2005, IHT 2005).

Place	Overnight visitors 2003	Daily Tourist Population 2003	Projected Growth Trends (next 10 years)	Cruise Ships Visitors 2005
Belize				
Stan Creek (Hopkins/Dangriga)	15,642	300	n/a	n/a
Placencia	14,245	270	n/a	n/a
Toledo	12,000	50-100	n/a	n/a
Guatemala				
Livingston	40,000	220	n/a	n/a
Puerto Barrios	10-20,000	50-150	Growing cruise ship visitation	60,000
Honduras				
Omoa	63,076 (only 4,076 foreigners)	n/a	n/a	n/a
La Ceiba	6,866 (air arrival to Goloson)	n/a	n/a	n/a
Bay Islands	28,368 (air arrivals to	1.165	n/a	161,580 (Roatán)

Roatán)

Fishing and Fish Processing

Employment derived from fishing and fish processing in coastal communities throughout the Gulf of Honduras is relatively low compare to other job sources. Within Belize there are 1800 to 2000 small-scale commercial fishermen and about 66% of them come from Sarteneja village on the north side of the country. Even though Sarteneja village is not part of the Gulf of Honduras, they fish all along the Belizean coasts; more specifically they fish for Nassau Grouper around Glover's Reef. Only 200 fishermen are located in southern Belize from Monkey River area to Barranco. In 2004 fishing and fish processing represented 2.4% of the national EAP; 6.5% and 1.5% in Stann Creek and Toledo districts respectively.

In Amatique Bay, Guatemala, there are 1500 fishermen; fishing only accounts for 1.1% of the EPA in Puerto Barrios and 7.7% in Livingston (INE Guatemala 2002). The great majority of the fishing communities are artisanal fishermen; however, there is also a politically and economically important group of 60 semi-industrial shrimp trawlers based in Livingston. A significant amount of illegal fishing by Guatemalan fishermen is evident in Belizean waters from Gladden Spit and Glovers Reef to the Sapodilla Cayes.

Information on Honduras' fishing communities is lacking; estimates from year 2000 indicate that there are 647 fishermen in the coastal area from Rio Motagua to Tela (Heyman and Graham 2000). No records are available for the Bay Islands' communities and la Ceiba.

Local socio-economic status

Understanding the socio-economic status of local communities targeting Nassau Grouper provides the core foundation to realistically creating and promoting alternative earning activities supporting and maintaining Nassau Grouper conservation efforts. The following section focuses on the communities within the Gulf of Honduras known to target the species, providing information about their current demographic status and economic activities.

Belize

Although there are no communities within GSSCMR, the area has gained importance as a main tourism destination over the last decade. Whale shark associated activities have served as an attraction for many adventurous people wanting to see and snorkel with these creatures. In 1998 only 2 tour operators were active, by 2006 there more than 15. 2004 records indicate that 87.6% (2,807) of the visits were tourism related (snorkeling 44.7%, scuba diving 27.4% and kayaking 8.87%). It is likely that fishing activities in this area have become less productive and therefore less economically important due to restrictions and overfishing. This transition to a more tourism-based local economy has given these communities an alternative income source with great potential.

The area of GSSCMR directly receive the influence of 6 adjacent villages: Hopkins (Garifuna), Placencia and Monkey River (Creoles), where fishermen are known to target Nassau Groper, and Seine Bight, Sitte River and Independence. Population data and primary industries in which local communities from GSSCMR are employed are presented in Tables 7 and 8. Tourist industry had the highest employment percentage (24.5%), fishing and fish processing on the other hand was on fifth place (9.9%) after construction, and whole sale and retail trade repair. Besides these differences, gender-base showed to impact population differently: while the principal activity for women was related to tourism, the construction represented the main income source for men. These communities are an example of a transition from traditional fishing and agriculture based economies into tourism activities. In 2000 all of the 6 communities reported their employment source to be linked to tourism-related activities: 55.8%in Hopkins, 55.8% in Placencia, 40% in Sittee River, 61.1% in Seine Bight, 10% in Independence and 15.4% in Monkey River (McPherson 2006). Nevertheless, the amount of fishermen in these same communities has remained stable or in some cases declined (McPherson 2005). In 2000 at least 75% of the population reported having a fishery-related employment as their primary occupation; Hopkins for example, reported an average of 12%. We can conclude that fishing is still important but given the imminent transition and expansion to the tourist industry, overall fishing contribution will progressively decline. In many cases individuals are complementing traditional occupations with new activities, most of the tourism related. Placencia and Hopkins are currently the focal points to continue develop tourism in the area.

Table 7. Population in GSSCMR communities, from 2000 to 2004 (CSO 2000).

Community	Population 2000	Growth Rate 1991 to 2000	Population 2004
Hopkins / Commerce Bight	994	2.33%	1089.87
Mango Creek / Independence	2881	4.80%	3474.66
Placencia	458	2.48%	505.38
Seine Bight	831	5.71%	1037.82
Sitte River	312	0.14%	313.38
Monkey River	176	-0.61%	171.71
Total	5652	3.74%	6545.09

Sarteneja, Chunox and Coope Banks are communities located in northern Belize within the Corozal District. Even though they are outside the Gulf of Honduras area, the fishermen of these communities are known to fish everywhere within the country. Specifically, they are known to target Nassau Grouper around Glover's Reef area. Sarteneja is a proper community with a current population of 2,000 people (2009). Currently more than 90% of Sarteneja's residents base their income from fishing activities

earning a high reputation for having the country's most skilled fishing community. Sarteneja's fishermen sail on handcrafted vessels throughout Belize and as far south as Guatemala and Honduras fishing for the barrier reef and the outer atolls for conch, lobster, shrimp, and a variety of finfish species, including Nassau Grouper. The main markets to sell their catch are Belize City, San Pedro, and Chetumal. Chunox is an isolated town southwest of Sarteneja with 1,400 people (2009). Copper Bank is a small fishing village with a population of 525 people located on Laguna Seca (2009).

Table 8. Primary industries in which GSSMCR employed individuals work (2000) (Belizean Census 2000, CSO 2000).

Industry	Male	Percent	Female	Percent	Total	Percent
Tourism	202	17.1%	233	39.2%	435	24.5%
Construction	251	21.3%	9	1.5%	260	14.7%
Wholesale and Retail Trade Repair	130	11%	80	13.5	210	11.8%
Bananas	155	13.1%	41	6.9%	196	11.0%
Fishing and Fish Processing	137	11.6%	38	6.4%	175	9.9%
General Government Services Compulsory Social Security	76	6.4%	80	13.5%	156	8.8%
Community Social and Personal Service Activities	40	3.4%	70	11.8%	110	6.2%
Others	189	16.0%	43	7.2%	232	13.15
Totals	1180	100.0%	594	100.0%	1774	100.0%

Guatemala

Within the limits of the Punta de Manabique Wildlife Refuge there are 8 coastal and 3 terrestrial small villages, with a total of 1754 individuals. Common economic activities include fishing, agriculture, charcoal making, caretaking for summer homes, hunting and small commercial activities. By far the predominant and most important of them is small-scale commercial fishing. Records indicate at least 228 registered fishermen within the 8 communities suggesting the economic dependence on fishing activities. Interestingly, 10% of these registered fishermen are women (Table 9). Poverty and extreme poverty within Izabal Department reached 52.12% and 16.84% in 2002 respectively (MINUGUA 2003).

Economic activities seem to be specific for each of these communities. Guatemalan fishermen do not fish Nassau Grouper. The main species fished is manjua and the Caribbean Spiny lobster (*Panulirus argus*) mainly by Cabo Tres Puntas and San Francisco

del Mar fishers. Nassau Grouper catches are few and incidental in the area. Farming of rice, plantain, yucca and corn are for local consumption, and Cabo Tres Puntas community fishermen also harvest watermelons to sell in Puerto Barrios. Charcoal production is the primary economic activity for Santa Isabel, and complementary for families in la Graciosa and Estero Lagarto during the fishing low season. When charcoal production decreases during the winter months gathering and selling firewood supplement income for the Santa Isabel community. FUNDAECO provided training to 24 individuals in guiding nature tours; however, there is no current demand for these services. Tourism is not a major economic income for Punta de Manabique communities, less than 50 individuals visit the area every month. This suggests that tourism and related activities do not represent a current complement to their income, neither an economic alternative.

Amatique Bay area includes Puerto Barrios, the main port city of Guatemala on the Caribbean ocean and Livingston. Tourism in these areas does represent an important income source. Reliable information regarding the number of people working on tourism activities is lacking. Tourism business in Puerto Barrios focuses on national visitors and more recently, cruise-ship tourists (October to April). Currently there is a Puerto Barrios Tour Guides Association with at least 35 certified bilingual members.

Livingston is the preferred and traditional tourist destination in the Amatique Bay area. Even though the town receives between 3000 and 5000 visitors monthly, there is no professional guides association. As a result, higher income tourists generally prefer to visit the area accompanied with professional guides from Guatemala City. FUNDAECO and TIDE have trained locals (e.g., fly fishing, diving, and bird watching); however, more precise information regarding total number of involved people was unavailable. There is a need to develop marine-based tourism activities in the Caribbean coast of Guatemala.

Table 9. Communities and total population within the Punta de Manabique Wildlife Refuge (FUNDARY 2005).

Community	Location	Number of Households	Total Population	# of fishers
Cabo Tres Puntas	Coastal	71	304	69
Estero Lagarto	Coastal	18	73	16
Jaloa	Coastal	15	72	4
La Graciosa	Coastal	17	85	13
Punta de Manabique	Coastal	33	130	31
San Francisco del Mar	Coastal	59	244	50
El Quetzalito	Coastal	53	251	38
Santa Isabel	Coastal	13	59	6
Creek Grande del Mar	Terrestrial	30	173	1

Machacas del Mar	Terrestrial	31	181	0
Creek Negro del Mar	Terrestrial	32	182	0
Total		469	2278	228

Honduras

The municipality of Omoa encompass 80 villages with 33,630 people; 86% of the population lives in rural areas and only 14% lives in urban areas (Fiallos 2006).The main economic activities include agriculture (corn, rice and red beans), hunting and fishing, follow by commercial activities and in last place tourism, more specifically, hotels and restaurants. Artisanal fishermen, fishery cooperatives and commercial fisheries represent an important as an income source for the local population. More recently there have been some initiatives to promote Tilapia aquaculture projects as an alternative. Artisanal fishery still dominates the area, 574 fishermen and at least 350 fishing boats are known to regularly operate. Regulations allow local fishermen to fish 300 m offshore and further, between 6 p.m. and 6 a.m., and land catches reach 220,000 pounds (CCO, FUNDAECO, INCAE 2006).

Located approximately 50 km of the Honduran coast, the archipelago of the Bay Islands includes three main islands (Roatán, Guanaja and Utila), five minor islands (Barbareta, Santa Elena, Morat, Big Hog, Little Hog) and more than 60 small keys. Although they only form a small part of the coastal zone of Honduras, the Bay Islands have always been of strategic importance because of their location and have served as a base for the Honduran industrial fishing fleet since it began.

Administratively and politically, the department of the Bay Islands consists of four municipalities: Roatán and Jose Santos Guardiola in the island of Roatán, and the smaller populations of Utila and Guanaja. The population data on the bay islands is considerably out of date, from 2001, preceding the rapid growth of the islands that has occurred in the last decade due to rapid development for tourism. Accurate population estimates do not exist but it is estimated that the population has at least tripled since the census of 2001, based on energy demands and other scaling estimates). If that is the case it is believed that the Bay islands would have around 100,000 people distributed with 60,000 on Roatán, 21,000 in Santos Guardiola, 13,000 on Guanaja and 6000 on Utila.

A quick census of the Utila Cays was carried out in Early November 2010 by UCME. From a survey of ninety-two households it was determined that at present three hundred and thirty four people currently inhabit the cays. Approximately two-thirds of the population is comprised of adults (234 people), a person is considered to be an adult if they no longer attend school and are working full or part time, this may mean that some people are considered to be an adult despite being under eighteen years of age. The population of the Utila cays has four main ethnic groups they are, Cayan, Mainland Hispanic, Mainland Garifuna, and Foreign Resident (U.S. citizens). Cayans comprise the largest ethnic group comprising 65.3% of the population, mainland Hispanics comprises 24.6%, mainland

Garifuna 8.4%, and foreign residents 1.8%. A large percentage of children born on the cay, nine percent, have mainland Hispanic parents, if these children's ethnicity is considered to be mainland Hispanic and not Cayan, a large change in composition is observed, see figure 2b, Cayans now comprise 56.3% of the population and mainland Hispanics 33.5%, the remaining 10.2% consists of mainland Garifuna and foreign residents.

Utila has thirteen main sectors of employment. These employments include catering restaurants and those who make food stuffs to be sold in stores, construction, fishing, direct employment by the municipal authority, and boat captains on large vessels, generally employed by American companies.

Communities adjacent to Cayos Cochinos work as tour guides in Cayos Cochinos protected area, which receives between 5 to 4,000 visitors a year (2005). However, little to none formal local guide capacity has developed within these communities. There is only one certified dive-master and very few tourist operators. The majority of tours to visit the area are provided by external operators based in la Ceiba and Tela, who bring their own dive-masters and guides. Because tourism to Cayos Cochinos is managed by external tourist operators, local communities capture very few benefits. Some scientific and educational program like Operation Wallacea requires their students to stay overnight in the village providing some income to local communities. Information regarding demographics, economics and social information for these communities are lacking.

Nassau Grouper commercialization process and final markets

The commercialization process and final markets for Nassau Grouper fished in the Gulf of Honduras are unclear and hard to track, due mainly to the relatively low economic importance of this species in the Gulf of Honduras countries. As stated before, Nassau Grouper is not targeted in Guatemala by fishermen and its capture is incidental at best. In Belize, the reports of fish exports show a sharp drop in volume from 2000 onwards, which coincided with the closing of spawning aggregation fishing. Interviews with fishermen in Belize indicate that since closing of the spawning aggregation fishery, Nassau Grouper is no longer a species of economic importance. In Honduras the export of Nassau grouper declined since 2005, most likely due to extirpation of spawning aggregations, as in the case of La Caldera, documented in 1992. The US, a former major export market for the Gulf of Honduras' Nassau Grouper no longer can import.

In the past, and as recent as 2008, Honduras used to export Nassau Grouper to the US, as fresh whole fish. At least three packing plants, J.B. Seafood in Guanaja, Flying Fish in Roatán, and Caribbean Seafood in La Ceiba, used to export fresh fish to the US, including Nassau Grouper. These plants no longer export Nassau Grouper to the US market. On Utila fishermen sell their product to a local buyer who then ships it to La Ceiba and sells on to commercial buyers. They are likely selling it nationally as fillet grouper, at which point it is impossible to trace the species. Recently, fish buyers for the Cayman Islands and Jamaica are buying fresh fish from Honduras, and since the US market is closed to Nassau Grouper, it is likely that they are buying the Nassau. There are no export records

for these transactions and no one seems to be monitoring it. Nassau Grouper is now commercially extinct, and is only a marginal small scale fishery for a couple of communities. The grouper now being most highly targeted is the misty grouper from deep water, about which very little is known.

In Puerto Cortes' fish market, large groupers, including yellow fin and Nassau groupers are seen during February. The fish is being landed by Honduran fishermen early in the morning, potentially after a night of fishing in the waters of Belize. It is about a 3 hour trip each way from Puerto Cortes to Sapodilla Cayes and back, in a 30 ft long fiberglass boat with a 75 HP engine.

Nassau Grouper conservation in other countries

Conservation efforts for Nassau Grouper in other Caribbean nations and territories vary in their strength and success. For example, in Bermuda a moratorium on the fishing of all grouper species has been established. The same measure has been implemented in all federal and state waters of the US, including Puerto Rico and the US Virgin Islands. In Mexico grouper fishing regulations are based on Gulf of Mexico species, i.e. red grouper, *Epinephelus morio*. Closed season for groupers in the Mexican Caribbean runs from February 15th to March 15th of every year, a time period that may be missing the top spawning months for Nassau Grouper, December and January.

The Dominican Republic has a seasonal closure for grouper species, corresponding to each species' spawning season. During this time period, it is forbidden to fish and sale groupers, particularly gravid females. In Cuba management regulations include a quota system and size limit.

In Bahamas the Department of Fisheries has banned the taking, landing, processing, selling and offering for sale of fresh Nassau Grouper from the first of December to the end of February. This measure is a part of efforts to ensure that the commercial fishery for the Nassau Grouper in The Bahamas will be sustained for the benefit fishermen and consumers. Finally, in the Cayman Islands marine reserves protecting populations of Nassau grouper were set eight years ago. Nevertheless, this regulation protecting fishing at spawning aggregations is due to expire in October of 2011.

Maps of Nassau Grouper fishing communities and spawning aggregations in the Gulf of Honduras

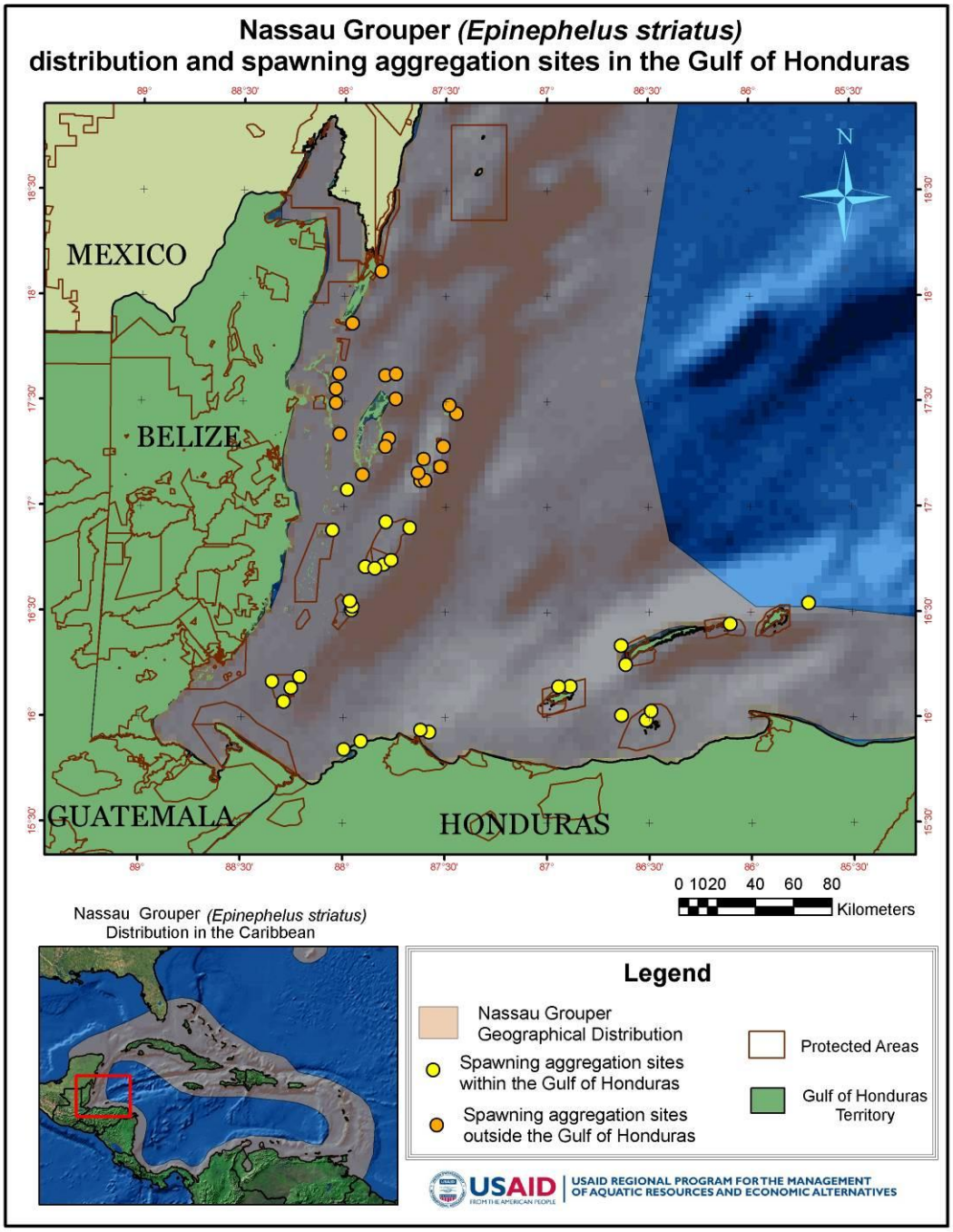


Figure 8. Nassau Grouper (*Epinephelus striatus*) distribution area and spawning aggregation sites within the Gulf of Honduras.

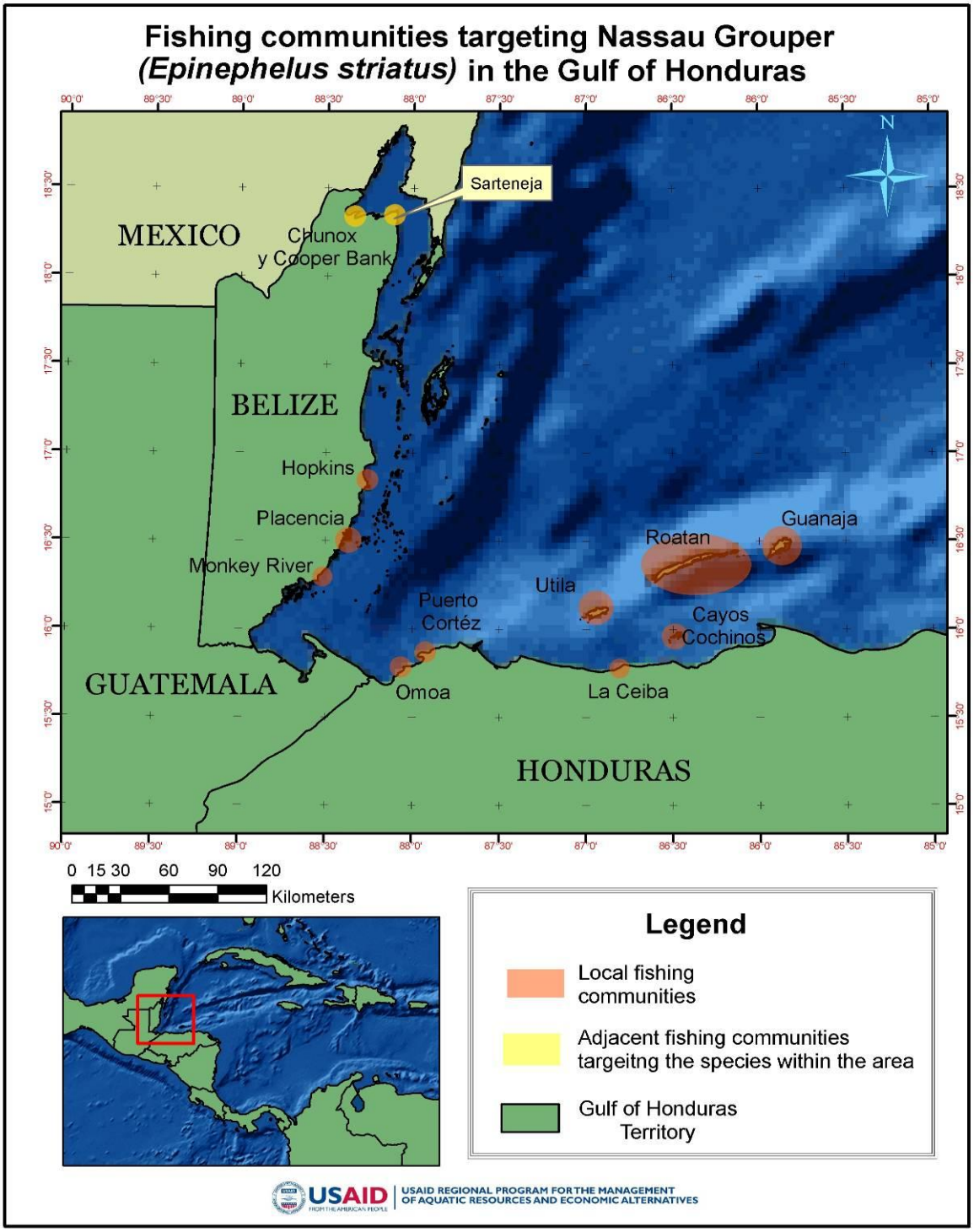


Figure 9. Fishing communities known to target Nassau Grouper in the Gulf of Honduras.

MANAGEMENT RECOMMENDATIONS

Given the fact that the Gulf of Honduras is a region shared by Belize, Guatemala and Honduras it is necessary to consider the creation of an international coalition of fishermen, managers, conservationist and scientists from the 3 countries to help address core aspects of fisheries, conservation and research of Nassau Grouper. A potential regional fisheries initiative to combine management, conservation plans and scientific efforts could be of great importance in the success of current and upcoming management strategies, perhaps they may be the best hope for the recovery of the Nassau Grouper.

Protection efforts should continue focusing on spawning aggregations sites throughout the Gulf of Honduras, which are the most vulnerable stage in the life cycle of Groupers. It is advisable to support more stringent regulations as to avoid fishing during spawning aggregations, as well as the establishment of permanent and long term monitoring programs on SPAG sites to maintain local accurate stock assessment statistics.

Gibson (2007) indicated the need to improve and enhanced the management and enforcement assistance, public awareness, and alternative livelihoods in Belize. All of these suggestions are valid and should be adopted in Guatemala and Honduras.

Conservation and management recommendations for Belize

Social behavior and migration patterns observations of Nassau Grouper populations inhabiting isolated atolls, such as Glover's Reefs, revealed that this species avoid swimming long distances over deep water and on the contrary, requires contiguous reef tracts to migrate. This information is of special importance for isolated reefs, given the previous findings, which suggest that replenishment of depleted populations may not occur via adult migration among isolated atolls, but would be entirely dependent upon larval recruitment. Identification, protection and monitoring of geographically isolated SPAG sites should be a priority.

Current management recommendations such as the closure of SPAGs fishing, minimum capture size of no less than 20 inches or 50 cm, designate SPAG sites as protected areas, and the development of alternative income earning activities for traditional fishermen affected by SPAGs fishing closure (Green Reef Environmental Institute 2001), and the inclusion of the precautionary principle (Heyman and Wade, 2007) should be maintained and enhanced if possible.

Heyman and Wade (2007) recommend a full ban on the possession of Nassau Grouper, and invoking the precautionary principle, they further recommend continued and indefinite

closure of the multi-species spawning aggregation sites in Belize in order to evaluate their effectiveness over time. Furthermore, they recommended continuing and increasing monitoring efforts for multi-species aggregations in the area (Heyman and Wade 2007).

Protecting a spawning aggregation may not sufficiently protect groupers if they are being caught as they migrate, or if fishing rates are too high outside the spawning season (Star et al. 2007). With the continued decline in numbers, the Working Group recommended that additional measures be introduced (Gibson, 2007).

Conservation and management recommendations for Honduras

The status, protection and management of the Nassau Grouper fishery in Honduras have received less attention. Management of the species in the country must concentrate on fish markets, monitoring local fishermen fish landings (e.g., fish size, sex, weight, etc.) and prohibiting the commercialization of Nassau Grouper during the closed season (December to March) as a direct mechanism to: (a) reduce illegal fishing in Belize; (b) enforce fishing legislation in Honduras; and (c) develop and establish a local Nassau Grouper stock assessment data bank. It is crucial that critical SPAG sites receive attention, ideally becoming no-take zones, allowing local Nassau Grouper populations to recover. Additionally, it is imperative to further promote research studies focusing on the population species status at both, known and potential, spawning aggregation sites in the area. This information is critical to establish a stock assessment baseline in the area; furthermore, it will support current and future fishing regulations and conservation initiatives, along with the sustainable commercialization of the species.

In Utila trap fishery is a common fishing practice to catch Nassau Grouper; however, traps can have negative effects on this species and groupers in general. Poor weather conditions might prevent fishermen from collecting the traps already deployed. Ghost traps are known to not only affect target species but also to deteriorate and damage coral reefs. A recent and promising option to diminish and decrease detrimental trap effects is the use of degradable material to tie the trap hatch closed and allow fish to escape if traps are left out for sustained periods.

Conservation and management recommendations for Guatemala

Since Nassau Grouper is not a target species in Guatemala, and the few catches are incidental, information on this species is nonexistent. Guatemala, however, is an important component of the system; therefore, information on Nassau Grouper local populations (including historical records), seasonal migrations through the area, and potential suitable nursery habitats for the species is of great importance. Furthermore, Guatemala should be included during regional fisheries management decision making process.

Nursery habitats and potential climate change effects

The Nassau Grouper utilizes multiple marine and coastal habitats throughout its life cycle including open ocean surface (eggs and larvae), mangroves and coarse rubble habitats as juveniles, reef crevices and abyssal depths as sub-adults and adults, and spur and groove

reefs after reaching sexual maturity. In order to protect and effectively manage the species the quality of the previously mentioned environments is imperative. Research studies support, monitoring programs establishment and actual protection are key to better understand current populations' dynamics, and connectivity processes among these habitats. Studies focusing on climate change and ocean acidification potential effects (e.g., larvae hatch and planktonic stage duration, life stages survival rates, feeding behavior, etc.) on Nassau Grouper populations in the Gulf of Honduras are strongly recommended.

Socio-economic component

The development of alternative and innovative income earning activities for traditional fishermen affected by SPAGs fishing closure and regulations is a vital piece in Nassau Grouper's protection and sustainable management in the Gulf of Honduras. To improve conservation efforts and support mid and long term programs success an active integration of local socio-economic components is recommended. Creating and promoting new and complementary economic livelihoods requires an understanding of local socio-economic context as well as regional economic trends. Identifying activities that could take advantage of existing markets (e.g., labor, goods and service markets) is also a key step in developing alternative economic activities.

CONCLUSIONS

Results from the present study indicate that the level of management and conservation of Nassau Grouper in the Gulf of Honduras varies from one country to another. To date, Belize has the most advanced level of knowledge and protection, while Guatemala has no fishery for this species in its coastal waters. An intermediate level of development is observed in Honduras, where Nassau Grouper had been of significant economic value, but due to the import prohibition by the United States, has since declined in importance.

There seems to be a consensus that some common ground can be found to develop and implement rules and regulations at the regional level. Following the example of Belize, Honduras and Guatemala can start by identifying the critical habitat for the species and protecting the spawning aggregations. Key factors driving the future of local Nassau Grouper populations include recruitment of larvae, location of source population, adequate coral reef habitat, and the increase in fishing effort due to human population increase.

Another important measure is the establishment of a regional closed season for the species, coinciding with the reproductive season, as it is in Quintana Roo, Mexico. Effective conservation of the Nassau Grouper requires the inclusion of migratory routes and deep reefs, in addition to the existing protection of shallow spawning sites (Star *et al*. 2007).The identification and protection of new SPAG sites in the area, especially in Honduras, should be considered a priority. Additionally, a permanent and long term monitoring program, along with more stringent management regulations such a no-take zone should be implemented. Summarizing management and conservation actions to protect Nassau Grouper these can be grouped in (i) closed areas (for spawning aggregations), (ii) closed season (for reproduction time), and (iii) minimum and maximum sizes.

Historical and more recent stock assessment and export records of Nassau Grouper have shown a decline in the species abundance throughout the Gulf of Honduras; moreover, several traditionally SPAG sites have been completely overfished. In the last decades the export and local markets value of Nassau Grouper have decreased and in some cases remained the same, promoting over-fishing of the resource to try to compensate income loss with an increase in the catch volume. The development of alternative and new income earning activities for traditional fishermen affected by SPAGs fishing closure should plays a critical role in the management strategies success of the Nassau Grouper.

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The following people were interviewed for the preparation of the report or participated during the workshops:

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