

## A spawning aggregation of Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) in the Mexican Caribbean

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### Synopsis

An annual spawning aggregation of Nassau grouper, *Epinephelus striatus*, observed off the southern coast of Quintana Roo, Mexico, on full moon days in December and January, was surveyed during the winters from 1991 to 1993. A fish aggregation had been appearing at one traditional site off Mahahual for more than 80 years, but currently it forms at undetermined sites far from the original site. Fish migration was northwards in the fore reef border along the 14 m isobath and isolated groups were observed. Through visual assessment fish aggregations were found to include 200 to 500 individuals. The fishing on Nassau grouper aggregations has been active since 1910 by using hook and line; however, recently fishermen used gill nets. It is necessary to continue the research on this aggregation and establish management guidelines to protect the species.

### Introduction

The Nassau grouper, *Epinephelus striatus*, is a common demersal fish in the Western Atlantic coral reefs and it is best known from its spawning aggregations, numbering many thousands of individuals at traditional sites on the reef. Nevertheless, the spawning characteristics of the species are poorly understood (Colin et al. 1987, Colin 1992). The distribution of Nassau grouper extends from Bermuda, south of Florida, Cuba and Virgin Islands throughout the Yucatan Peninsula to Venezuela (Bardach et al. 1958, Böhlke & Chaplin 1993). As a solitary predator it usually consumes fishes and invertebrates (Randall 1965, Silva-Lee 1974), and its reproduction is complex because of this fish exhibits some degree of protogynous hermaphroditism (Carter et al. 1994); however, protogyny in the species has not been accurately determined (Shapiro 1987).

The Nassau grouper is a commercially important food fish, providing a valuable income to local fishermen (Munro 1973). Although it is solitary most of the year, it aggregates during the annual reproductive season for spawning. A major proportion of the catches comes from the spawning aggregations, which have been known and exploited by generations of local fishermen at different spawning sites all around the Western Atlantic (Sadovy 1995). Aggregations may consist of large numbers of individuals (e.g. 2000–3000) (Colin 1992) with as many as an estimated at 100000 individuals (Smith 1972). The grouper reproduction is restricted both spatially, at defined spawning sites, and temporally, often occurring entirely within few days to a week each year (Shapiro et al. 1993). Nassau grouper aggregations form only during winter season on full moon days from November to February in several sites from the Western Atlantic (Shapiro 1987), although there is some geographic variation at different loca-

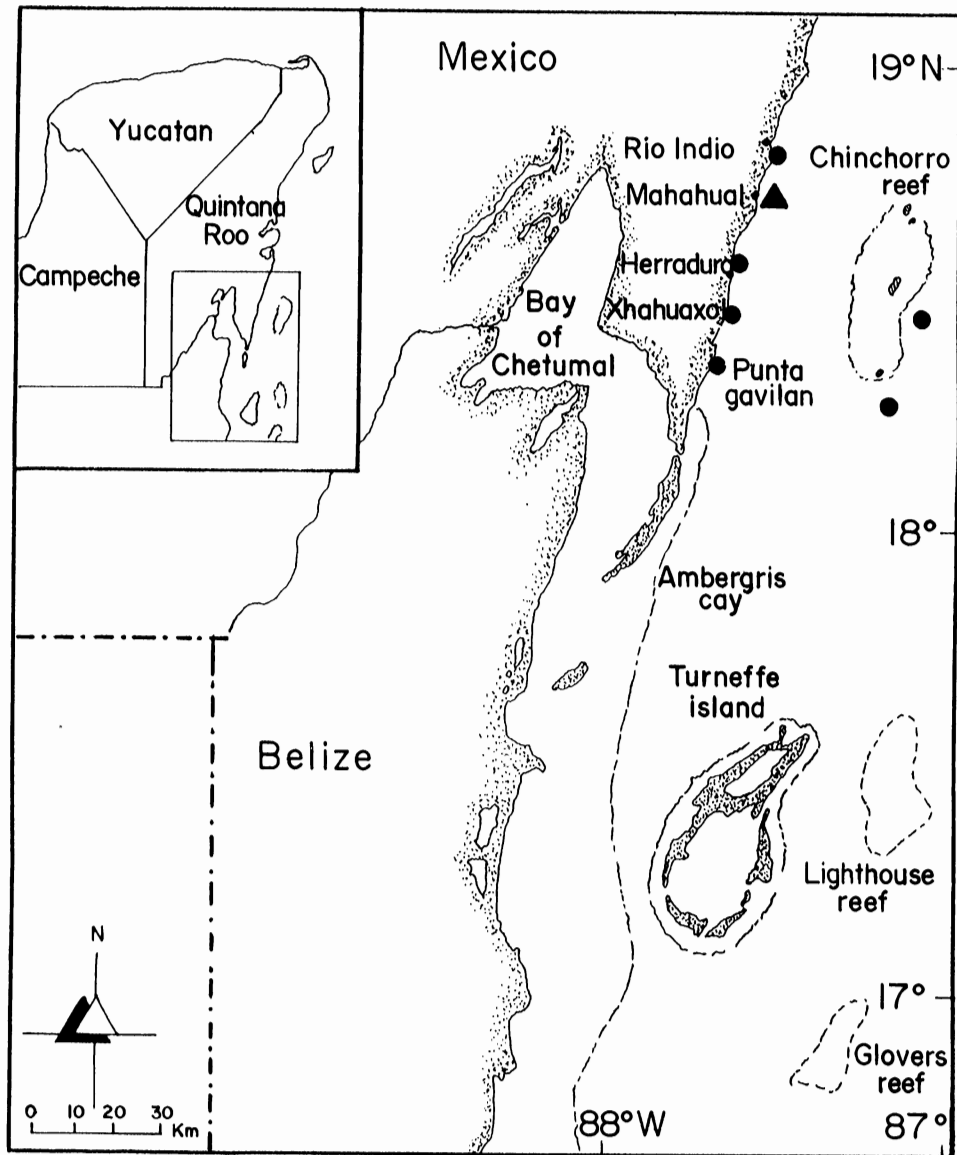


Fig. 1. Map of the southern coast of Quintana Roo, Mexico and the northern coast of Belize showing locations of Nassau grouper, *Epinephelus striatus*, aggregation sites. Black circles indicate previously undocumented sites and the black triangle indicates the aggregation site off Mahahual.

tions. In Bermuda the spawning aggregations form during May to June (Bardach et al. 1958) and during March to April in Jamaica (Thompson & Munro 1983).

Smith (1972) was the first to document characteristics of a spawning aggregation of Nassau grouper at Cat Bay, Bahamas. Subsequently other aggregations have been reported at different spawning sites

in the Western and North Atlantic, such as: Bermuda (Burnett-Herkes 1975), Virgin Islands (Olsen & LaPlace 1979), Cayman Islands (Colin et al. 1987, Tucker et al. 1973), Belize (Carter 1986, Carter et al. 1994), Bahamas (Colin 1992) and Quintana Roo, Mexico (Aguilar-Perera 1994). Although many spawning aggregations of *E. striatus* have sustained heavy fishing pressure constantly over time, some

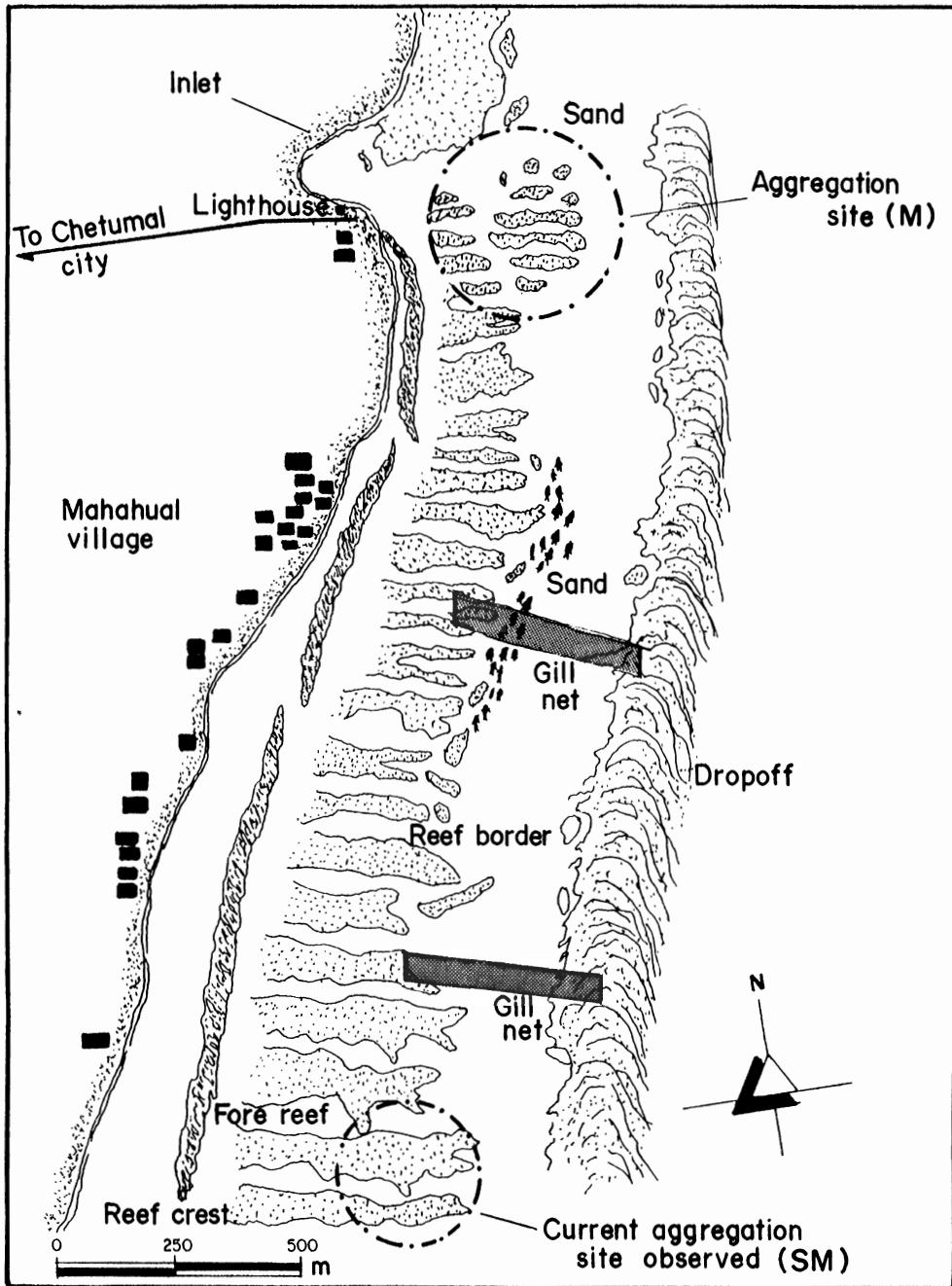


Fig. 2. View of the Mahahual coast showing coral reef morphology, the area of the traditional aggregation site and areas where fishermen deploy their gill nets to catch the migrating Nassau grouper. The reef border is followed northwards by the fish.

fish aggregations have apparently disappeared from their traditional aggregation sites (Sadovy 1995). The species is not one of the most commercially important fish in Mexico, as its closest rela-

tive, the red grouper, *Epinephelus morio*. However, the Nassau grouper constitutes the second most valuable fish in Belize (Carter et al. 1994) and the most important fish in the Bahamas (Colin 1992).

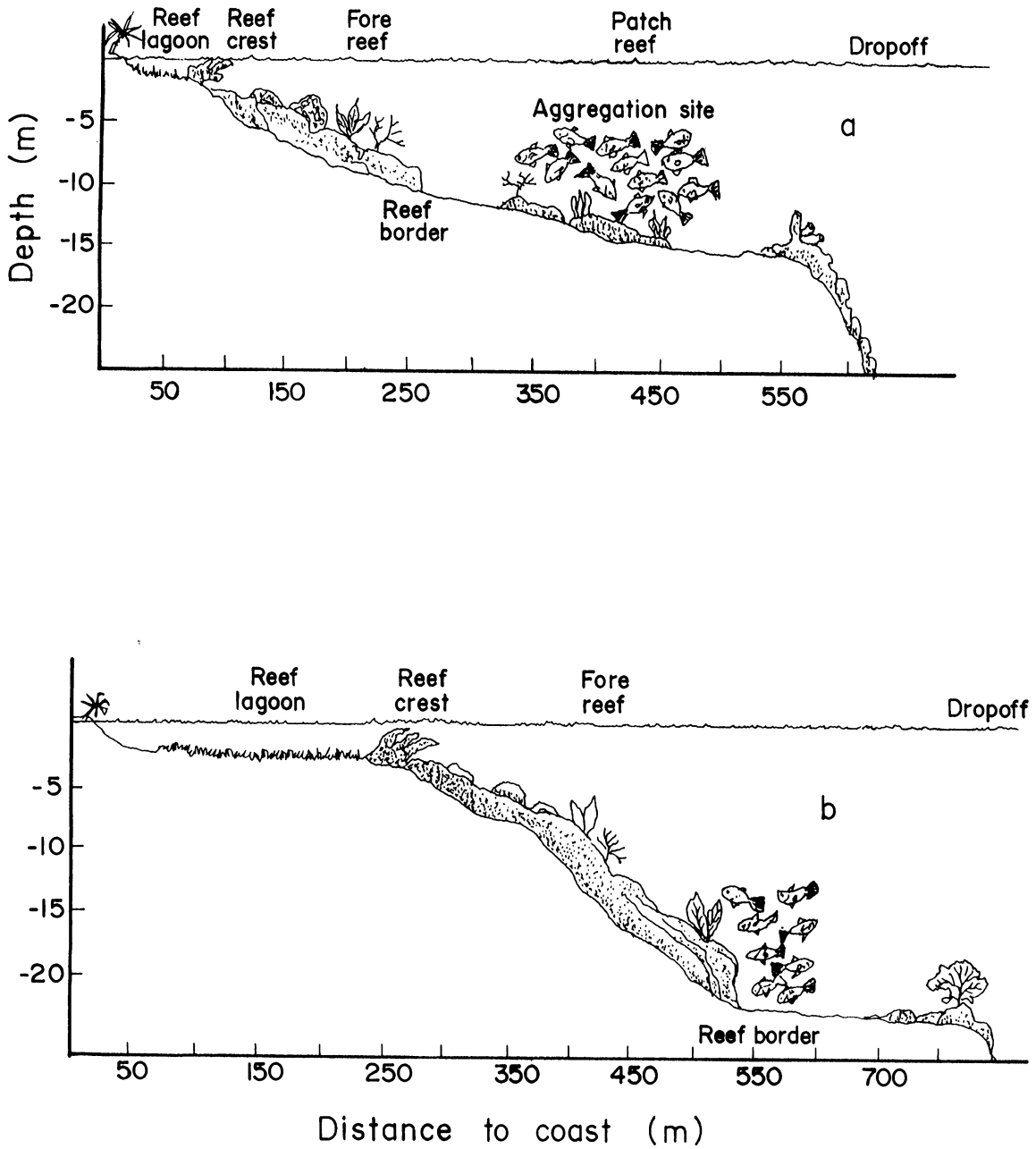


Fig. 3. a – Cross-section of coral reef at the aggregation site off Mahahual (M), showing depth and distance to coast. b – Cross-section of coral reef at the south of Mahahual (SM) aggregation site.

The only place in Mexico where spawning aggregations of *E. striatus* have been observed, at five to six sites in the coral reef, are located at the south and part of the central coast of Quintana Roo (Aguilar-Perera 1994). Data on ecology, biology and fishery

of the Nassau grouper aggregations are scarce. Only preliminary observations on ecology and some fishery aspects from aggregations at the site off Mahahual were available (Solís-Ramírez 1966, Miller 1982, Aguilar-Perera 1994, Sosa-Cordero & Cárde-

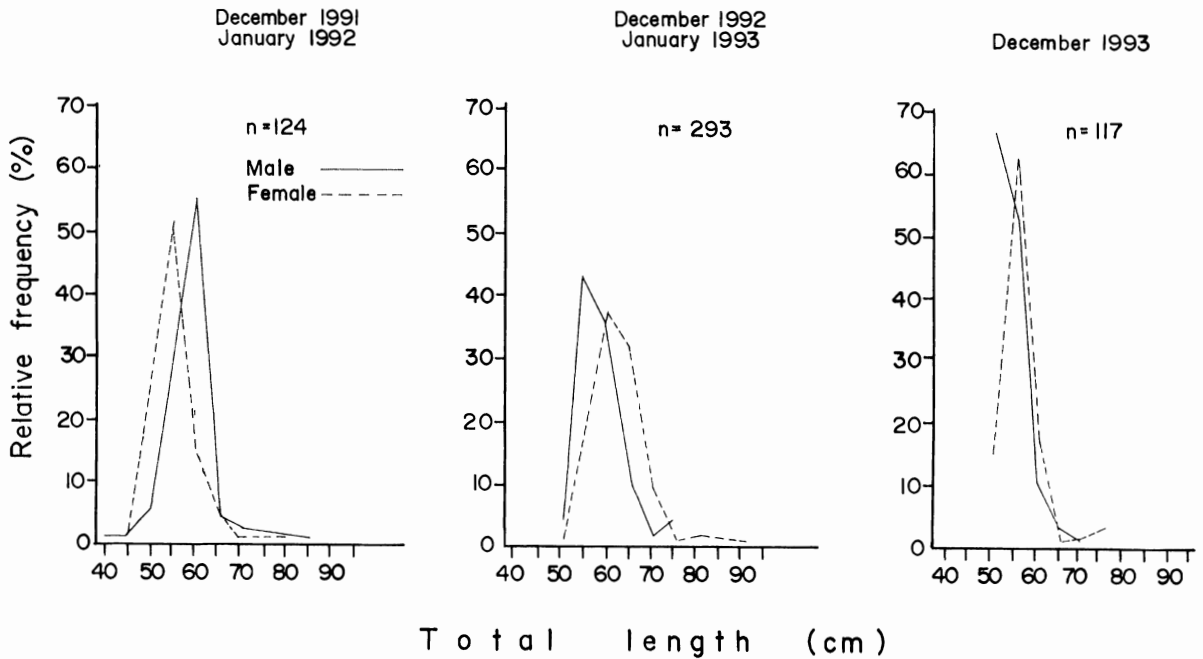


Fig. 4. Size-frequency distribution of adult Nassau grouper taken from the commercial catch off Mahahual, Quintana Roo, Mexico. Each reproductive season corresponds to the months of December and January, but the last one for December only. The fish not sexed were not included.

nas-Vidal 1995). The present paper describes the current condition of a spawning aggregation of *E. striatus* from a traditional aggregation site, off Mahahual, in the Mexican Caribbean and includes information on local sex ratios, size-frequency distribution, physical characteristics of the site, as well as observations on movements and reproductive behavior of the species during three reproductive seasons.

### Materials and methods

Field work was conducted at one offshore aggregation site, covering two complete reproductive seasons (December 1991–January 1992, December 1992–January 1993) and part of one more (December 1993). Field observations were made by SCUBA diving at the aggregation site and at adjacent areas, every morning, noon and afternoon (9:00, 12:00, 16:00 h), to characterize some aspects of the fish aggregation regarding movements and distribution along the reef. Commercial catches at Maha-

hual were sampled to obtain size-frequency data and sex ratios of the fish. Total length (TL) was determined to the nearest 1 cm and weight to the nearest 1 g. Time of sampling was derived by activities of fish at the aggregation site, with a range from five to six days per month during each reproductive season. Fish were sexed macroscopically, either by squeezing the abdomen to release gametes from the gonoduct (Colin et al. 1987) or more commonly once gutted by fishermen. During this survey, commercial fishing was carried out by four 25 feet fiberglass boats with outboard engines (40 and 75 hp). The gill nets (thread mesh) used were from 200 to 400 m long and 8 m wide (mesh size: 15 cm). Each boat used two nets. Nets were deployed in the afternoon (16:00 h) on the fore reef, perpendicular to the barrier reef, in natural drainage grooves. Part of the nets reached the reef border near sandy areas. Early in the morning, at noon and afternoon (5:30, 12:00, 16:00 h) the nets were visited by fishermen for recovering the fish caught.

Table 1. General data from specimens sampled during the season 1991–1992.

	December 1991		January 1992	
	n = 58		n = 166	
	males	females	males	females
×	16	42	61	105
	58.6	57.9	58.2	59.8
range	52–65	49–71	39–86	47–86
mw	3606	3450	3568	3931
range	2300–4600	2000–5000	1300–8100	1800–9600
f:m		2.62:1		1.72:1

× = mean size cm TL. mw = mean weight g. f:m = female:male.

## Results

### *Characteristics of the spawning site*

The aggregation site off Mahahual (M) (18°43' N, 87°42' W), a coastal village in the southern part of the state of Quintana Roo (Fig. 1), is located at the fore reef and almost 350 m off the coast, while the shelf edge is 500 m seaward. The substrate at the aggregation site consists of low relief patchy hard corals interspersed with plexaurids and gorgonians. Hard corals present are mountain coral *Montastrea annularis*, and leaf coral, *Agaricia* spp., growing between sandy areas (Fig. 2). Depth ranges from 6 to 20 m, with the shallower part located on the fore reef. All of the site has a flat geomorphology without a significant slope (Fig. 3). There is another site that was occasionally occupied by fish during part of the reproductive season. It is located almost 2 km to the south of Mahahual (SM), 500 m off the coastline (Fig. 2), with geomorphological characteristics differing from those of the M site. This second site con-

sists of a set of grooves with significant relief on a gentle slope with a depth range from 15 to 25 m, and with the shelf edge seaward by 1000 m (Fig. 3). The currents were slow during all the dives on both sites and visibility was greater than 30 m. There are other aggregation areas located in different spots of the southern coast of Quintana Roo, such as: Río indio, Herradura, Xhahuaxol, Punta gavián and two sites at Chinchorro, a reef complex located almost 30 km offshore (Fig. 1). Neither the ecological characteristics nor the biological aspects of Nassau grouper aggregations at these sites are known.

### *Aggregation movements and coloration*

Aggregations at the M site formed variously, two or three days before or after the full moon phase, during December and January. However, the aggregation has disappeared from this traditional, of more than 80 years old, aggregation site. During December 1989 an aggregation appeared at the site two

Table 2. General data from specimens sampled during the season 1992–1993.

	December 1992		January 1993	
	n = 170		n = 123	
	males	females	males	females
×	71	99	55	68
	57.4	58.0	61.32	60.7
range	46–74	50–71	52–88	52–76
mw	no data	no data	no data	no data
f:m		1.4:1		1.24:1

× = mean size cm TL. mw = mean weight g. f:m = female:male.

days after the full moon (full moon, 12 Dec), at a point of the fore reef located 1 km southward from M (Aguilar-Perera 1994). In December 1991, 50 to 60 individuals were observed (10:00 h) two days after the full moon (full moon, 21 Dec) at the same site. This small aggregation was moving northwards along the reef border, just where the sand area meets the reef (14 m isobath). During January 1992 three groups were observed at SM: one group was comprised at 500 individuals, the other two of 200 individuals each. In December 1992 a group estimated of 500 individuals was observed between SM and M (8:00 h). All of the aggregations moved northward along the reef border. However, at the traditional site (M) there were no fish. During January 1993 other group of 600–800 individuals were observed two days before the full moon (full moon, 8 Jan at SM (11:30 h). Only 15 individuals were observed in December 1993, near to the shelf edge to 25 m (14:00 h). In January 1994 (full moon, 27 Jan) the strong winds from northeast (20 to 30 km per h) and from southeast (35 to 40 km per h) did not permit fishing or diving activities. During all the underwater observations, neither the ritual courtship nor the gamete release (spawning) described by Colin (1992) were found.

Coloration of Nassau grouper were observed during the aggregations into two of the four different patterns described by Colin (1992) in Bahamas and observed by Carter et al. (1994) in Belize. Colin (1992) defines the patterns as: (1) barred (normal), (2) white belly, (3) bicolor and (4) dark phase. The

Table 3. General data from specimens sampled during the season 1993.

December 1993		
	n = 117	
	males	females
	57	60
x	54.75	55.45
range	49–69	49–72
mw	3456.1	3660.8
range	2200–6700	2300–7770
f:m		1.05:1

x = mean size cm TL. mw = mean weight g. f:m = female:male.

barred pattern (normal among non-aggregating periods) was observed in the aggregating fishes at M during the morning. The white belly phase was exhibited by the fish early in the morning and at noon, and it was the most common color phase observed; during this phase the barred pattern is modified so the abdominal area is pale without the bars descending onto that area. The bicolor and dark phase were not observed.

#### Population structure and sex ratio

The length, weight, and sex of reproductively active fish were determined from the commercial catch of the local fishermen obtained by gill nets during the three reproductive seasons. The selectivity of this fishing gear has been not determined in detail, however, in this study, all of the sample of fish taken by

Table 4. Summary of size and sex ratio of *Epinephelus striatus* in different localities of the Caribbean.

Localities	Sex ratio f:m	Size (SL*, cm)		Source
		male	female	
Virgin Islands	1:1, n = 571	58.5	58.9	Olsen & La Place (1979)
Cayman Islands	1.9:1, n = 95	50.2	51.6	Colin et al. (1987)
Belize	2.4:1, n = 485	42.0	41.8	Carter et al. (1994)
Cuba	4:1, n = 330	not available		Claro et al. (1990)
Mexico	1.4:1, n = 634	57.6**	58.7**	Present study
	1.5:1, n = 70	59.6**	60.8**	Sosa-Cordero & Cárdenas-Vidal (1995)
Jamaica	0.72:1, n = 38	not available		Thompson & Munro (1983)
Bahamas	5:1, n = 136	not available		Colin (1992)
	3:1, n = 175			

\* SL = Standard length; \*\* = Total Length in cm.

Table 5. Reports summarized on spawning aggregations of *Epinephelus striatus* in the Caribbean.

Geographic area	Months	Depth (m)	Fishing (start)	Fishing gear*	Source
Bahamas (Cat Cay)	January	29–38	1960	T	Smith (1972)
Bermuda	May-August	33–37	–	T	Burnett-Herkes (1975)
Virgin Islands	January February	40	1910	H.T	Olsen & LaPlace (1979)
Cuba	December January	29	–	H.T.S	Claro et al. (1990)
Cayman Islands	January	25–30	1925–26	H	Colin et al. (1987)
Belize	December February	40	1920	H.T.S	Carter et al. (1994)
Bahamas (Long island)	November February	20–30	1900	T	Colin (1992)
Mexico	December January	6–20	1910	H.S.N	Aguilar-Perera (1994)

\* T = Traps, H = Hook and line, S = Speargun, N = Gill nets.

gill nets had a size ranges from 39 cm to 86 cm TL, thus the nets catch a wide range of sizes for both sexes. We assume a non-selective fishing regarding both the size and sex. A total of 775 individuals were sampled, with 634 individuals sexed, 374 females and 260 males (Fig. 4). Total length (TL) was obtained for all individuals; however total weight and sex could not be determined from already-gutted fish. Among fish that could be sexed the ratio of females to males was approximately: 1.9:1 ( $n = 224$ ) in 1991–1992 (Table 1), 1.3:1 ( $n = 293$ ) in 1992–1993 (Table 2) and 1.05:1 ( $n = 117$ ) in December 1993 (Table 3). A total sex ratio of 1.4:1 was calculated from 634 individuals. Sex ratios and size data from the Mexican Caribbean and other areas are summarized in Table 4. Both smallest mature male and female weighed 2000 g with 39 cm TL and 2000 g with 49 cm TL respectively. Both largest male and female weighed 8100 g with 86 cm TL and 9000 with 86 cm TL. The interactions between size, sex and month were tested with a two-way ANOVA ( $\alpha = 0.05$ ). Assuming that each reproductive season was formed by two samples (e.g. December 1991 and January 1992), then a total of five samples was obtained, because of the third reproductive period corresponds to the sampling of December 1993 only. There was a significant difference between size and month ( $n = 5$ ,  $F = 19.502$ ,  $p < 0.001$ ) and there was not a significant difference between size and sex ( $n = 2$ ,  $F = 2.195$ ,  $p > 0.05$ ). However, a one-way ANOVA with data of three reproductive seasons taken together, showed a significant difference between sexes ( $n = 634$ ,  $F = 5.633$ ,  $p < 0.01$ ); the females were larger than males (Tukey test for

means). There was not a significant difference of abundance per sex ( $n = 634$ ,  $F = 1.745$ ,  $p > 0.05$ ). The length-weight relationship equation (for both sexes combined) was  $W = -0.0711 \times TL^{2.423}$  ( $n = 340$ ,  $r^2 = 0.874$ ).

#### The aggregation fishing pressure

Interviews with local fishermen have revealed that the grouper aggregation at M has been known and exploited using hook and line since 1910 (Table 5). In the early 1960s, the fishermen used dynamite as the fishing method, which the aggregation totally disappeared for one reproductive season; however, reproductive activities were apparently normalized in subsequent seasons. Before the 1960s, fishermen were catching grouper using hook and line only. They kept the fish alive in special wire-mesh holding pens near the beach, until they could move them to the market, and sold them alive or salted to Belize and Guatemala. After the 1960s, the speargun replaced the hook and line, and it was the only gear used. However the speargun was recently prohibited (December 1993) by fishery authorities. At the present time, the gill nets are the only fishing method permitted over non-aggregating areas (Fig. 2), far from the M site.

#### Discussion

The spawning aggregations of the Nassau grouper, *E. striatus*, in the Mexican Caribbean are mostly ob-

served on the continental shelf, conversely to other aggregations of the species in the Western Atlantic whose locations are near or at the ends of islands or on seaward projections of the reef (Colin et al. 1987). However, two aggregation sites are present at the Chinchorro reef, 30 km from the mainland in the Mexican Caribbean (Aguilar-Perera & Aguilar-Dávila 1993). The aggregation area described in the present study was discovered and exploited by local fishermen more than 60 years ago. Other aggregation areas of the species, at the same southern coast of Quintana Roo, have been reported by fishermen, but these areas have not yet been surveyed. Nonetheless, in only two of these sites is the fishing currently active (Xhahuxaol and Chinchorro reef).

The traditional aggregation site (M) is located in shallow waters (6–20 m) differing from other aggregation sites described for the species in the Western Atlantic (Table 5). At this site there was an evident change related to the presence of the annual Nassau grouper aggregations. In December 1988 an aggregation estimated at 1000 to 1500 fish was found at M (Aguilar-Perera 1994), during next reproductive seasons the aggregation had disappearing from this site. Only a few fish in small groups were found over the reef border and other aggregation was observed at SM. The characteristics of the shelf edge of the reef border of the M and SM have different geomorphologies. The aggregation has not been observed again in SM, thus it was apparently migrating northwards over the reef border to reach the M site. The disappearing of the Nassau grouper aggregation from M must be related to some disturbing factors that have been not yet determined. All of the aggregating fish observed had distended abdomens suggesting an imminent spawning, however during the reproductive periods there was no evidence, based on limited observations, of courtship or spawning. Apparently the aggregation moves to deep waters near the reef to find a proper site to spawn. This assumption needs to be confirmed. Shapiro et al. (1993) commented that the grouper aggregation, in fact, allows males and females to find mates. Aggregation sites represent convenient gathering spots but do not necessarily comprise unusual physical characteristics. Coloration in the Nassau grouper is important in reproductive behav-

ior. Colin (1992) comments that the white belly phase is exhibited among suspected females with heavy and prominent abdomens. However, most of the fish observed in aggregation during the reproductive seasons in this study presented the white belly phase. Individuals taken by commercial fishing displaying this phase were from both sexes.

There may be some connection between Mexican aggregations to those in Belize (Fig. 1), since fish were seen to be migrating northward. Carter (1989), in a survey involving attachment of ultrasonic tags to Nassaus, captured two groupers at Rocky Point, Ambergris Cay, Belize prior to the spawning season of 1986. More than a year later he recovered one transmitter from a grouper taken at the central part of the Yucatan Peninsula (off Quintana Roo). The grouper reached more than 240 km from where it was tagged. There are approximately 56 km between the most northern aggregation site to the most southern site known by fishermen over the Mexican coast of Quintana Roo. It is probable that there may also exist connection between sites from those to the north. This suggests a possible relationship among Nassau grouper aggregations; however there is no evidence supported in more detail to confirm such possibility.

Despite the scarcity of long-term databases on the fisheries of the Western Atlantic, there is no doubt as to the vulnerability of the Nassau grouper to intensive fishing pressure (Olsen & La Place 1979, Sadovy 1995). Aggregation fishing removes reproductively active fish from the spawning site and thus may have a detrimental effect on future fish catches (Shapiro 1987). Of the aggregations of *E. striatus*, known and exploited for many years by local fishermen, many have disappeared, possibly due to overfishing (Colin 1992). In Belize an aggregation has disappeared from its traditional aggregation site in the last years (Carter et al. 1994). Similar trends have been noted for the species at Jamaica, Florida and Virgin Islands (Sadovy 1995). In the Mexican Caribbean, overfishing on the aggregations has been not evaluated. Disturbing evidence has been noted due to both disappearance from the site and decrease in abundance of aggregating fish estimated visually. In relation to the disappearing aggregation, there is the possibility it moves to

other sites far from fishing pressure influence, to northern sites or to others undiscovered sites. This assumption needs some more investigation.

The knowledge of the ecology and reproductive behavior is important for management and conservation decisions. Several countries have taken actions to protect the spawning aggregations of *E. striatus*. In Belize, two marine parks have been established (Carter 1988). In Cayman Islands only fishing by hook and line is permitted (Sadovy 1994). In the Mexican Caribbean coast fishing at the aggregation site has been prohibited. Fishing with gill nets in other non-aggregating areas is permitted (Aguilar-Perera 1994), however these are areas where aggregations have an obligated passage. Currently, fishing regulations are necessary in Mexico regarding protection of the aggregations. At the same time, a set of socio-economic implications must be considered, specially regarding management guidelines; this means that total prohibition of fishing has implications to fishermen. It is important to establish a monitoring of the aggregation to identify declines in the fish stock. A capture-mark-recapture program should be designed between Belize and Mexico to monitor migrating Nassau groupers among different aggregation areas from the Western Atlantic.

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