STATUS REPORT ON NASSAU GROUPERS

FOR BELIZE, CENTRAL AMERICA

A Scientific Report of the Green Reef Environmental Institute[1]

Written By:

Guillermo Enrique Paz and Thom Grimshaw

JULY, 2001

[1]San Pedro Town, Ambergris Caye, Belize
Phone (501) 26-2833, Fax (501) 26-2766, e-mail: greenreef@btl.net

ACKNOWLEDGEMENTS

We wish to acknowledge & thank the Toledo Initiative for Development & The Environment (BZ); the Audubon Society (BZ Chapter); The Belize Department of Fisheries; the Hol Chan, Bacalar Chico & Glovers Reef Marine Reserves (BZ); Scripps Institute of Oceanography (US), the Wildlife Conservation Society (US), the University of York (UK), and The Nature Conservancy (BZ Chapter) for their assistance with the execution of this study.

We also wish to acknowledge & thank the numerous team members who collected field data, and/or otherwise contributed greatly to completion of the survey. These person include, from the Green Reef Team at Dog Flea Caye: Tony, Arturo & Victor Lara, Fishermen; Dan Wagner, Videographer; Joe Miller, Photographer; and Dan Ellison, OTP/VSO Volunteer; from the Rocky Point Team at Ambergris Caye: Miguel Alamilla, Hol Chan Director/Team Leader; Isaias Majil, Bacalar Chico Biologist; Brandon Kitagawa, Peace Corps Volunteer; Francisco Arceo, Fisherman; Jill Hepp, Peace Corps Volunteer; Edgar Badillo, Hol Chan Ranger; Gilmaldo "Gizmo" Acosta, Hol Chan Ranger; Jason Edwards, Bacalar Chico Ranger; and Victor Alegria, Bacalar Chico Manager; from the Nature Conservancy Team at Caye Glory, Gladden Spit & Caye Bokel: Will Heyman, Team Leader; Nicanor Requena, University of Belize Student; Eloy Cuevas, Fisherman; Rachel Graham, University of York; Dan Castellanos, Fisherman; Richard Foster, Videographer; and Carol Foster; from the Toledio Iniative for Development & the Environment Team at Sapadillo Caye: Karl Castillo, Team Leader; Matthew & Alfonso Avila, Fishermen; Matthew Nicolas, Fisherman; and Horack Arnold, Fisherman; from the Audubon Team at Half Moon Caye: Julianne Robinson, Team Leader; Andy Stockbridge, Dive Videographer; Ashley Hutchens, Diver; Uriah Rhaburn, Boat Captain; Phillip Young Jr. Fisherman; and Brian, Deck Hand; and from the Sandbore Caye Team: Jamie Lee Chanona, Team Leader; Auriol Samos, Diver; Marciano Gutierrez, Boat Captain / Diver; Ivan Young, Fisherman; Phillip Young Sr., Fisherman; and Efrain, Deck Hand.

Ken Mathus & Yvonne Sadovy reviewed the manuscript and provided many helpful comments. The field survey was funded by Grant No BZE 98 G52 – PRO 03 from the United Nations Development Program - Global Environmental Facility (UNDP/GEF).

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INTRODUCTION

The Serranidae are a circum-global family of apex predators, which in the greater Caribbean include Sea Bass, Basslets, Hamlets & Groupers (see **Table 1**). The smaller members of this family are often sought by collectors for the aquarium industry, and the larger members are highly prized as food fish throughout the world. The Nassau Grouper (*Epinephelus striatus*) is a commercially important member of this group of fishes that has been declining throughout its range for at least the past decade (Auil-Marshalleck, 1993, Sadovy, 1993), which in turn has led to IUCN red-listing the species as endangered.

The primary reason for the Nassau Grouper's decline has been attributed to selective over-fishing of its highly synchronized & site specific spawning aggregations, which occur during the period following the 1st full moon of either December or January each year (cf. Sadovy & Eklund, 1999). These aggregations have experienced near total collapse from over-fishing in Puerto Rico, Cayman Islands, Bermuda, US Virgin Islands, Mexico, and the Dominican Republic (Sadovy, 1993).

During the 1950's, annual grouper catches in Belize were as high as 100,000 lbs (McField *et al,* 1996), and during the 1960's, Nassau Groupers were fished a rate of about 2 tons per day from a single aggregation site on Belize's barrier reef (Craig, 1969). As late as 1994, groupers comprised more than 30 % (38,383 Lbs) of the total finfish exported from Belize, of which, 64 % (24,764 Lbs) consisted of Nassau Grouper. More recently in 1999 & 2000, a long known aggregation site located at Glovers Reef was surveyed by the Wildlife Conservation Society and found to be comprised of just 3,100 adults, from which fishermen removed 219 individuals during the same season (Salas & Ballesteros, 2001).

The declining catch of Nassau Grouper has led to the common belief that this Serranid no longer aggregates at most of the localities from which it was formerly known in Belize. However attempts to close the fishery have failed because the few fishermen who continue to fish Nassau Grouper from aggregation sites argue that this species is not declining, but capricious in its movements, and simply relocates its aggregation site from year to year. These circumstances clearly identified the need for a national survey of Nassau Grouper aggregation sites, and so funding was sourced from UNDP/GEF & the Oak Foundation to develop a Research & Advocacy Plan for the species. One component of this initiative called for a national survey of locally known aggregation sites, and the findings of the first phase of this initiative are reported here.

METHODOLOGY

Interviews were conducted with fishermen from San Pedro Island, Ambergris Caye; and Hopkins Village on the mainland of Belize during the month of October 2000 in an attempt to develop a location map of all known Nassau Grouper aggregation sites in Belize. These interviews resulted in the identification of 13 sites shown in **Illustration 1**. A short-list of 7 sites were elected for survey during the 2000 – 2001 aggregation period based on historical records, the recommendations of retired fishermen, and the knowledge that Wildlife Conservation Society would survey the well known aggregation site at Glover Reef. One additional location at Caye Bokel, Turneffe Reef was also surveyed because the site demonstrated similar characteristics to other aggregation sites, but had no reputation as an aggregation site with fishermen.

TABLE 1

NATIVE SERRANIDAE OF THE WESTERN ATLANTIC[1]

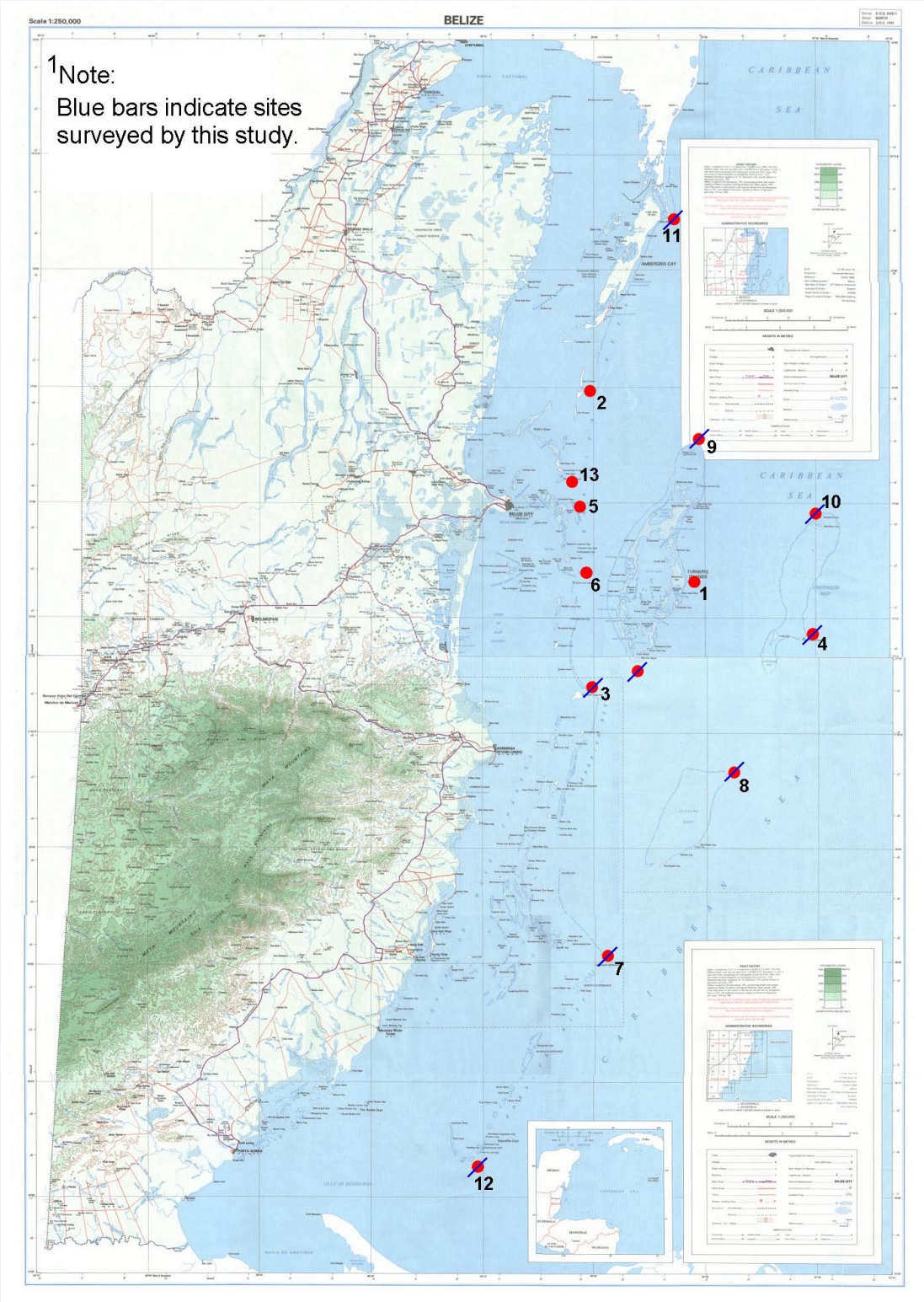
(Adapted from Bohlke and Chaplin, 1968)

COMMON NAME	SCIENTIFIC NAME	SIZE (CM)
BASS, BASSLETS & PERCH		
Swissguard Basslet	*Chorististium rubre*	9
Candy Basslet	*Chorististium carmabi*	5
Ridgeback Basslet	*Chorististium mowbrayi*	8
Coney	*Cephalopholis fluvia*	30
Graysby	*Petrometopon cruentatum*	30
Toothless Basslet	*Schultzea beta*	11
Sand Perch	*Diplectrum formosum*	30
Lantern Bass	*Serranus baldwini*	6
Harlequin Bass	*Serranus tigrinus*	10
Chalk Bass	*Serranus tortugarum*	8
Tobaccofish	*Serranus tabacarius*	17
Orangeback Bass	*Serranus annularis*	8
HAMLETS		
Orange Hamlet	*Hypoplectrus gummigutta*	13
Shy Hamlet	*Hypoplectrus guttavarius*	11
Indigo Hamlet	*Hypoplectrus indigo*	14
Butter Hamlet	*Hypoplectrus puella*	7
Black Hamlet	*Hypoplectrus nigricans*	12
Hamlet	*Hypoplectrus unicolor*	10
Mutton Hamlet	*Alphestes afer*	30
GROUPERS, HINDS & JEWFISH		
Snowy Grouper	*Epinephelus niveatus*	120
Misty Grouper	*Epinephelus mystacinus*	90
Red Grouper	*Epinephelus morio*	90
Nassau Grouper	*Epinephelus striatus*	120
Rock Hind	*Epinephelus adscensionis*	50
Red Hind	*Epinephelus guttatus*	50
Jewfish	*Epinephelus itajara*	240
Yellowmouth Grouper	*Mycteroperca interstitialis*	75
Tiger Grouper	*Mycteroperca tigris*	75
Black Grouper	*Mycteroperca bonaci*	120
Yellowfin Grouper	*Mycteroperca venenosa*	90

[1]Species $\geq$ 30 cm are taken to belong to the food fishery; species < 30 cm are taken to belong to the ornamentals fishery.

ILLUSTRATION 1

MAP OF NASSAU GROUPER SPAWNING AGGREGATION SITES IN BELIZE, CENTRAL AMERICA[1]



The survey included the following sites (locality numbers are shown in parentheses):

Lighthouse Reef:

Sandbore Caye (10)
Half Moon Caye (4)

Turneffe Reef:

Dog Flea Caye (9)
Caye Bokel (Control)

Barrier Reef:

Ambergris Caye (11)
Caye Glory (3)
Gladden Spit (7)
Sapodillo Caye (12)

The survey plan called for the organization of locally experienced divers into teams that would simultaneously survey the seven sites planned for 2000 – 2001 evaluation. Each team consisted of one Dive Master, a minimum of two dive-certified assistants, a boat captain, and one or more local fishermen as assistants (~5 persons). Dives were planned to commence on the day before the full moon of January 8, 2001, and to be continued through January 16. Two dives per day were established as maximum to allow for decompression time.

Each team was equipped with hand-held, underwater video cam-corders, and a generalized data collection scheme was established that included recording of locations with GPS, measurement of aggregation depth using scuba pack gauges, visual estimation of aggregation number & color-phase expression; notation of any specific behavioral activities such as gauges, aggression and/or spawning; measurement of water temperature using scuba pack instruments; estimation of current direction, speed, & vertical and horizontal visibility (if different); estimation of coral cover & condition (predominant species, $\pm$ bleaching); and the variety & number of any other schooling or aggregating species that may be present.

Between and/or after dives, each team interviewed fishermen, and collected information on their home villages & fishing effort, number of years fishing aggregation banks, market sold to, anticipated price, and any available anecdotal information regarding the trend of the fishery at each bank; in addition to fork length, weight, sex & egg weight on the daily catch.

RESULTS

Lighthouse Reef

This reef faro is located approximately 55 miles from Belize's mainland, and is the outermost of three such formations east of the Belize Barrier Reef (see **Illustration 1**). The faro is approximately 41 x 21 miles in expanse, with its long axis running NNE – SSW. Five Cayes lie within the reef lagoon. Northern & Sandbore Cayes lie at the northern end; Half Moon Caye lies at the southeastern margin of the lagoon, adjacent to an extended promontory in the reef; and Long & Hat Cayes lie within the southwestern region of the lagoon. Interviews with local fishermen on Ambergris Caye established that two localities had been traditionally fished at Lighthouse Reef, one location near to Sandbore Caye; and the other near to Half Moon Caye. Both sites were monitored during the 2001 spawning assessment.

Sandbore Caye

Seven observation dives conducted at this site established the presence of a previously un-studied aggregation of 4,000 – 6,000 Nassau Grouper. The aggregation site was approximately 1 mile from the reef crest over a low (2 – 4 meter) spur & groove formation. The aggregation itself held position between 20 & 30 meters depth. Twenty to thirty Nassau Grouper were present at the site 1 day prior to the full moon of January 8, but they began arriving in bigger schools from both the north & south on Days 1 & 2 after the full moon. The aggregation peaked at 4,000 - 6,000 animals on or before Day 5 after the full moon. By Day 7 less than 40 Nassau Grouper occupied the site.

No mass spawning activity was directly observed during monitoring dives, possibly because spawning occurred closer to sunset after divers had left the area due to visibility constraints (see below). Peak spawning was estimated to have occurred on Day 4 & 5 after the full moon based on population numbers & roe collected from fishermen. Color phases were predominantly cryptic (~60 %) & light (~30 %) the day before & first three days after the full moon, with few dark (~5 %) or bicolor (~ 5%) phases observed. Some circular swimming was observed on the day before the full moon. Most animals demonstrated a bicolor phase (70 %) on the fourth day after the full moon; and were evenly (50 %) divided in expressing bicolor & cryptic coloration patterns by Day 5 after the full moon. The observed aggregation peak is closer to the full moon & of less duration than that reported by Sala & Ballesteros (2001) for Glovers Reef during the 1999 - 2000 spawning event, suggesting that the spawning moment may not be rigorously fixed.

Currents ran north to south, from surface to aggregation depth, at speeds up to 5 knots. Visibility was generally poor due to suspended organics, and seldom exceeded 7 meters at aggregation depths even during morning dives. No stratification of either currents or visibility was apparent. Water temperature was 28.3 $\pm$ 3.3 ^{o}C (n = 7) at the surface; and 28.2 $\pm$ 2.8 ^{o}C (n = 7) at spawning depths (mean $\pm$ sd). Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. Predominant species present were *Montastrea cavernosa*, *M. annularis* and *Porities asteroides*.

Three fishermen captured approximately 130 Nassau Grouper using traps over a period of 30 man-days during the aggregation week for a CPUE of 130/30, or 4.3. The three fishermen have lived on Sandbore Caye for about 27 years attending the lighthouse for which the reef is named. They claim populations of 20,000 to 30,000 Nassau Grouper were present at the site in the mid 1980's, despite the fact that the fishing effort has not changed from that presently in use. This observation supports the widely held belief that aggregations can decline for reasons other than site-specific fishing pressure. A sub-sample of 66 specimens was taken from the catch for sex, (fork) length, & weight evaluation, the findings of which are shown in **Illustrations 2** & **3**.

The sub-sampled catch consisted of 56 female & 10 male Nassau Groupers, indicating a ratio of 5.6:1, female to male in the larger population. This ratio closely follows the light/dark phase ratio observed before spawning. The relationship between sex & size class is shown in **Illustration 2**. Although sample sizes were small in lower & upper size classes, distinct differences in the ratio of female to male Nassau Groupers were clearly pronounced in the 55 – 74 cm size range. The size range corresponds to individuals between 5 & 13 years of age (Sadovy & Eklund, 1999).

TABLE 2

SUMMARY OF DATA COLLECTED DURING 2001 SURVEY OF NASSAU GROUPER AGGREGATION SITES IN BELIZE

PARAMETER	Sandbore Caye, Lighthouse Reef	Half Moon Caye, Lighthouse Reef	Dog Caye, Turneffe Reef	Caye Bokel, Turneffe Reef	Ambergris Caye, Belize Barrier Reef	Caye Glory, Belize Barrier Reef	Gladden Spit, Belize Barrier Reef	Rise & Fall, Belize Barrier Reef
ENVIRONMENTAL PARAMETERS								
Depth Range	20.7 - 27.4	30.0 - 38.0	24.4 - 39.6	25.9 - 39.6	25.0 - 45.7	30.5 - 44.2	32.0 - 38.1	19.8 - 23.5
Visability	≤ 7	15 - 20	24.4 - 36.6	19.8 - 21.3	15.0 - 30.0	15.2 - 24.4	18.3 - 30.5	1.5 - 15.0
Mean Temperrature	28.2 ± 2.8	25.8 + 0.4	25.4 + 0.5	---	26 + 0.6	---	---	25 + 0.9
Current Direction	180	210 - 270	000 - 090	090	000	000	330	090 - 180
Deviation from Surface	?	0	0	0	0	---	---	0 - 90
Current Speed (Knots)	1 - 2	1 - 2	1 - 3	2.5	3 - 4	0.25	0	0.002
Bottom Feature	Low - Relief Spur & Groove Reef	High - Relief Spur & Groove Reef	Low - Relief Spur & Groove Reef	High Relief Spur & Groove	Hard Substrate (with sparse coral)	Low - Relief Spur & Groove Reef	Sand Floor with Low Profile Mound	Low - Relief Spur & Groove
NASSAU GROUPER OCCURRENCE								
Individuals, Day 1-am	20	2	30					1
Individuals, Day 1-pm		0						2
Individuals, Day 2-am	3,250	2	55		0			1
Individuals, Day 2-pm					0			3
Individuals, Day 3-am		2	85		0	12		
Individuals, Day 3-pm		0	20					2
Individuals, Day 4-am	3,250	13	30		0		9	2
Individuals, Day 4-pm		1					22	5
Individuals, Day 5-am	4,000		40		0		107	6
Individuals, Day 5-pm						7		2
Individuals, Day 6-am	2,000		30	13	0			3
Individuals, Day 6-pm		1	30				49	4
Individuals, Day 7-am	1,725	1	30	2				2
Individuals, Day 7-pm		0	100			21		
Individuals, Day 8-am			35				90	
Individuals, Day 8-pm			18				90	
Individuals, Day 9-am								
Individuals, Day 9-pm						8		
BEHAVIORIAL PARAMETERS								
ORIENTATION	360	360	Random	Random	---	Random	Random	Random
COLOR CHANGES	Yes	No	No	Yes	---	Yes	Yes	No
COURTSHIP	Yes	No	No	Yes	---	No	Yes	No
FISHING EFFORT								
Catch	120.0	0.0	261.0	0.0	0.0	18.0	6.0	0.0
Man - Days	30.0	0.0	70.5	0.0	0.0	25.0	16.0	0.0
CPUE	**4.0**	**0.0**	**3.7**	**0.0**	**0.0**	**0.7**	**0.4**	**0.0**
OTHER GROUPERS								
Black	1 - 40	3 - 25	1 - 5	23	5	19 - 60	9 - 40	1
Tiger	1 - 5	1 - 6	1 - 2	5	0	0	0	1 - 7
Yellow	0	1	0	0	0	2	2 - 9	2
OTHER AGGREGATING / SPAWNING SPECIES								
Dog Snapper		75 - 200		100 - 300		~ 600	800 - 1,500	
Mutton Snapper				200 - 500				
Marget, Black or White		50 - 100			3,000 - 4,000		30	
Horse-eye Jacks		~ 100		~ 500	75 - 100			
Permit								
Trunkfish						20 - 80	35 - 50	
Jolthead Porgy						215	40 - 60	

Observations made during monitoring dives indicate that Nassau Grouper appearing at the site during Days 1 to 3 following the full moon were 10 - 20 Cm in length, while those present during Days 4 & 5, when peak spawning activity was assumed to be taking place, were larger at 30 - 40 Cm. Whether the late-arriving, larger size class interacted with the smaller size class, or disbursed them from the aggregation site was unclear, but the larger size classes' presence was clearly later & shorter than that of the smaller size class. Length-weight relations for captured fish shown in **Illustration 3** do not reflect this observation however.

ILLUSTRATION 2

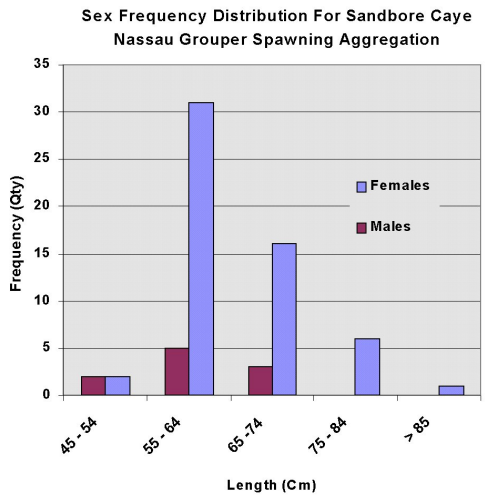
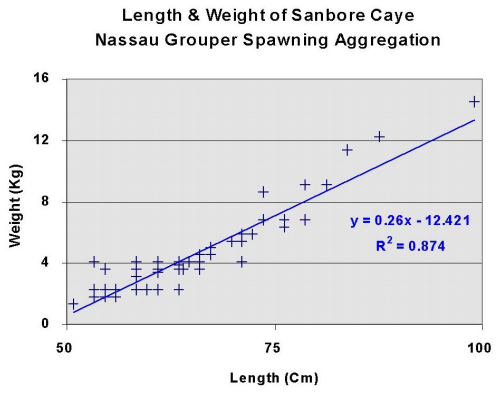


ILLUSTRATION 3



Other Serranidae observed during monitoring dives included 10 to 40 Black Grouper (*Mycteroperca bonaci*) of approximately 1.0 meter in (total) length; and 1 – 5 Tiger Grouper (*Mycteroperca tigris*) of approximately 0.2 meters in (total) length. Non-Serranid species occurring during the aggregation included Creole Wrasse (*Clepticus parrai*) swimming head to tail in a 'parade' formation; and Yellowtail Snapper (*Ocyurus chrysurus*), which schooled near to the growing aggregation of Nassau Grouper on the 1st day after the full moon.

Half Moon Caye

This site was approximately 0.25 miles from the reef crest over a high (12 meter) spur & groove formation at approximately 24 meters depth. Ten survey dives were conducted at the site, during which time it had been visited by either solitary or small groups of Nassau Grouper. The largest group of Nassau Groupers observed during a single dive was thirteen. Most animals appeared to be moving north, and either stopped briefly at a cleaner station, or just moved on. Most were between 40 & 50 Cm in total length, although a few larger individuals between 50 & 90 Cm were also observed.

Currents ran south to southwest at speeds of 1 -2 knots at depths of 30 – 38 meters, and were observed to be present when surface currents were zero. Visibility was fair, but seldom exceeded 20 meters at dive depths due to suspended organics. No stratification of either currents or visibility was apparent. Water temperature was 25.8 $\pm$ 0.5 ^{o}C (n = 5) at the surface; and 25.8 $\pm$ 0.4 ^{o}C (n = 6) at dive depth. Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. The predominant coral species present was *Montastrea faveolata.*

Other Serranidae observed during monitoring dives included 3 - 25 Black Grouper (*Mycteroperca bonaci*) of approximately 50 – 90 Cm in (total) length; and 1 – 6 Tiger Grouper (*Mycteroperca tigris*) of approximately 20 - 80 Cm in (total) length. Non-Serranid species occurring during the aggregation included 75 – 200 Dog Snapper (*Lutjanus jocu*); and 50 – 100 White Marget (*Haemulon album),* which at times schooled together with the Dog Snapper. Dog Snappers exhibited some spiraling & nudging, taken to indicate pre-spawning activity. Horse-Eye Jacks (*Caranx latus*) were also present in schools of ~100 individuals; and exhibited nudging & following behavior, also taken to indicate pre-spawning activity. Other schools present included ~75 Schoolmasters (*Lutjanus apodus*) which came in & left during 1 dive session, ~20 Ocean Triggers (*Canthidermis sufflamen*), ~30 Surgeonfish (*Acanthurus* sp.), and ~ 50 Jolt head Porgy (*Calamus bajonado*). Three Reef Sharks (*Carcharhinus springeri*) were observed on Day 2 after the full moon.

Turneffe Reef

This reef faro is located approximately 19 miles from Belize's mainland, and is the innermost of Belize's three such formations (see **Illustration 1**). The faro is approximately 31 x 5 miles in expanse, with its long axis running NNE – SSW. A number of large & small cayes & mangrove islands lie within the reef lagoon. Interviews with local fishermen on Ambergris Caye established that Nassau Grouper were known to aggregate near to Dog Flea Caye at the northern end of the reef; and at eastern margin of the faro near to Blackbird Caye. The Dog Flea Caye site, along with another site near to Caye Bokel were monitored during the 2001 spawning assessment.

Dog Flea Caye

Twelve observation dives conducted at this site established the presence of a previously un-recorded aggregation of 300 - 400 Nassau Grouper. The aggregation site was approximately 0.5 miles from the reef crest over a low (2 - 3 meter) spur & groove formation between 27 & 40 meters depth. Approximately 30 Nassau Grouper were present at the site 1 day prior to the full moon of January 8, but one fisherman had reported capture of about 100 Lbs (~ 25 individuals) the day before the survey commenced. New individuals arrived at the site on the day of the full moon & the first day following the full moon, raising the number of Nassau Grouper present to 85 individuals. Most of these individuals were 30 to 60 Cm in total length, with smaller & larger individuals occasionally present. By late afternoon however, the aggregation numbered only 20 individuals due to heavy fishing pressure at the site.

The number of Nassau Groupers present at the site varied between 30 & 40 animals between the morning of Day 2 and Day 5 following the full moon. In the afternoon of Day 5, the aggregation had abruptly increased to approximately 100, larger (50 – 70 Cm) individuals arriving from deeper waters in cryptic coloration, but the number of Nassau Grouper present at the site had fallen again to 35 individuals on the morning of Day 6, and then to 18 individuals on Day 7 following the full moon, presumably in response to the continued, unrestrained fishing pressure at the site. Fishermen at the site had expressed some familiarity with difference between morning & evening size classes in their catch, and suspected that the larger fish were coming up from deeper waters to feed. Few bi-color phase individuals & no spawning activity were observed during monitoring dives at this site. Color phases were predominantly cryptic (~73 %) the day before the full moon, with only 2 dark & bicolor individuals (each, ~ 7 %) and 4 light phase individuals (~13 %). On the first day after the full moon, about 35 % showed cryptic coloration; 40 % showed light phase coloration; 20 % showed dark phase coloration; and about 5 % were bi-color.

Between Day 1 & 5 after the full moon, approximately 50 % of individuals present were in cryptic coloration; 40 % were in light phase coloration; 5 % were in dark phase coloration; and 5 % were bi-color. The school of approximately 100, larger individuals arriving from & departing to deeper waters below the aggregation site on Day 5 were all in cryptic coloration; as were all Nassau Grouper present on Days 6 & 7 after the full moon.

The sequence of coloration changes & date of peak aggregation number during the aggregation event at this site were similar to those observed at the Sandbore Caye aggregation site, with the most notable difference of light, dark & bicolor phase proportions likely to have been strongly influenced by fishing at the site. Another notable similarity with the Sandbore aggregation was the late arriving presence of larger individuals from deeper waters when the aggregation number was anticipated to peak on Day 5 after the full moon. The two observations seem to indicate that larger and presumably older Nassau Grouper wait at lower depths for an aggregation of younger animals to form before participation in spawning.

Currents at aggregation depth were easterly when they occurred, and generally not greater than 1 knot when present, the exception being however when currents rose to 3 knots on Day 5 after the full moon only. Visibility was generally very good and between 24 & 37 meters. No stratification of either currents or visibility was apparent. Water temperature was 26.0 $\pm$ 3.3 ^{o}C (n = 12) at the surface; and 25.4 $\pm$ 0.5 ^{o}C (n = 12) at aggregation depths. Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. Predominant coral species present were Montastrea sp.

Fishermen working from 3 – 6 boats captured 261 Nassau Grouper over a period of of 62 man-days during the week of January 8 for a CPUE of 4.2, which is close to that of Sandbore Caye. These fishermen were primarily from Turneffe Reef & Belize City, and have traditionally fished the reef for their livelihoods. Fishermen reported that the aggregation had moved south from Mauger Caye (approximately 4 miles) in recent years; and one fisherman reported having fished some 2,000 individuals from the aggregation in the previous year. A sub-sample of 13 specimens were taken from the total catch & examined for sex; and the entire catch was measured for length & weight, the findings of which are shown in **Illustrations 4** & **5**. The sub-sampled catch consisted of 11 female & 2 male Nassau Groupers, suggesting a female/male ratio of 5.5:1, which again closely follows that observed at Sandbore Caye. Egg content varied among females with weight; and a mean egg content was estimated at 8 % $\pm$ 2 % of total weight, was could be derived from mean fish weights, and egg weight per number female fish.

Size classes captured by trap (Sandbore) & hook (Dog Flea) are shown **Illustration 4**. The size class capture of the two catches are similar in their higher frequency of 55 – 64 Cm individuals. As with Sandbore Caye, the age classes for the catch at Dog Flea Caye is probably 5 to 13 years old, based on data from the Bahamas reported by Sadovy & Eklund (1999).

Comparison of the length-weight relationships between the two sites suggests the Dog Flea Caye aggregation (slope = 0.271) may have been slightly more fit than the Sandbore Caye aggregation (slope = 0.260), but the two slopes were not statistically distinct and so can only endorse the similarity of the two sites (see **Illustration 5**).

ILLUSTRATION 4

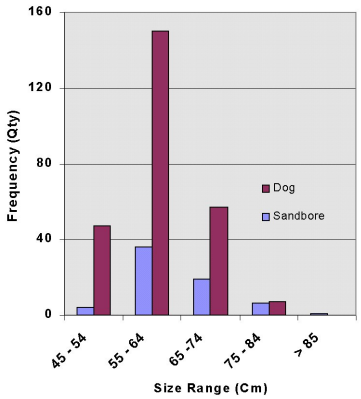
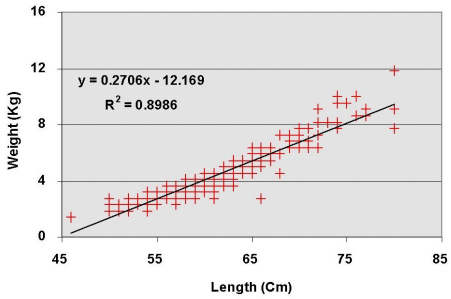


ILLUSTRATION 5



Other Serranidae observed during monitoring dives included 1 to 5 Black Grouper (*Mycteroperca bonaci*) of approximately 0.3 - 0.6 meters in (total) length; and 1 – 2 Tiger Grouper (*Mycteroperca tigris*) of approximately 0.4 meters in (total) length. Non-Serranid species occurring during the aggregations included Creole Wrasse (*Clepticus parrai*) swimming head to tail in a parade formation; and Bermuda Chub (*Kyphosus sectatrix*), which schooled near to the site on the 7th day after the full moon.

Caye Bokel

This site was approximately 80 meters from the reef crest over a high (8 - 12 meter) spur & groove formation at approximately 24 meters depth. Only two survey dives were conducted at the site on Days 5 & 7 following the full moon. Thirteen Nassau Grouper 30 – 60 Cm in total length were observed at the site on Day 5, and only two small (20 – 30 Cm) individuals were observed on Day 7. These individuals demonstrated both mating coloration and courtship, which suggests that this site may indeed have once supported greater aggregation activity. No fishing activity was observed at the site.

Currents were strong (i.e. 2.5 knots) and southward at this site, flowing along both the east & west sides of the faro and meeting at the dive site. Visibility varied between poor (~ 5 meters) due to suspended organics & good (~ 20 meters) at dive depths of 25 – 40 meters. No stratification of either currents or visibility was apparent. Coral condition at dive depths was good to excellent, and no indications of bleaching were apparent. Predominant species present were *Montastrea faveolata, M. cavernosa, Siderastrea spp., and Diploria spp.,* along with scattered sea rods, sea plumes, and other Gorgoniacea.

Other Serranidae observed during monitoring dives included 23 Black Grouper (*Mycteroperca bonaci*) of approximately 35 - 110 Cm (50 Cm average) in (total) length on Day 5; and 5 Tiger Grouper (*Mycteroperca tigris*) of approximately 40 Cm (total) length on Day 7 after the full moon. Black Groupers expressed color changes and parallel swimming, as did the Tiger Groupers, which expressed white 'Polka-Dot' coloration. Non-Serranid species schooling or aggregating at the site included 100 - 300 Dog Snapper (*Lutjanus jocu*); 200 - 500 Mutton Snapper (*Lutjanus analis);* and a school of approximately 500 Horse-Eye Jacks (*Caranx latus*). A single Hammerhead Shark (*Sphyrna lewini*) was observed on Day 5 after the full moon.

Glovers Reef

This reef faro is located approximately 28 miles from Belize's mainland, and is the southernmost of Belize's three such formations (see **Illustration 1**). The faro is approximately 20 x 10 miles in expanse, with its long axis running NNE – SSW. Only one Nassau Grouper aggregation is known from this reef, and the population has been studied for a number of years (Carter, 1986). Salas & Ballesteros (2001) reported the population to be highly threatened by fishing rights granted to traditional fishermen, despite the aggregation site being located within a specifically designated protected area. The 1999 – 2000 population was estimated at approximately 3,100 individuals, of which 219 were captured by local fishermen using hook & line.

The aggregation site is situated approximately 300 meters from the reef crest & consists of high spurs with bisecting sand channels. Interestingly, while the most frequently captured size classes were similar to those of Sandbore & Dog Flea Cayes (i.e. 55 – 65 Cm), the CPUE estimate for the Glovers Reef aggregation was reported at 9.1, or nearly twice that observed at Sandbore & Dog Flea Cayes. The 1999 – 2000 Glovers Reef aggregation assemblage coalesced over a longer period of time (~ 10 days); and peaked on Day 7 following the full moon, two days later than observed at Sandbore & Dog Flea Cayes. It is also interesting to note that dark & bi-color phases dominated the spawning aggregation at Glovers Reef and that the female to male sex ratio was only 3:1; whereas white & bi-color phases dominated at Sandbore & Dog Flea Cayes; and the female to male sex ratio was twice that observed at Glovers Reef.

The Wildlife Conservation Society (WCS) maintains a research station at Glovers Reef, and has been monitoring the Glovers Reef aggregation site annually from 1999 to the present. Consequently, the site was not surveyed by the present initiative, and we await the official findings of the 2000 – 2001 WCS survey. Sadly, reports indicate that the 2000 – 2001 population was estimated by visual inspection at only 2,700 individuals, of which some 300 individuals were captured by five local fishermen over a period of 50 man-days using hook & line. The 2000 – 2001 CPUE estimate for the Glovers Reef reflects these impacts, in falling to 6.0.

Barrier Reef

The Belize Barrier Reef runs along a north-northwest to south-southwest axis, extending from the southern coast of the Yucatan peninsula some 140 miles south and 10 - 20 miles east of the Belize mainland, ending in the Gulf of Honduras (see **Illustration 1**). A number of sand & mangrove islands lie along the barrier reef, as well as within the Barrier Reef Lagoon. Interviews with local fishermen on Ambergris Caye and at Hopkins Village established that at least eight locations along the barrier reef were thought to have at one time supported Nassau Grouper spawning aggregations. North to south, these sites include reef segments or promontories near to Ambergris Caye; Caye Caulker; St. Georges Caye; Gallows Point; Goffs' Caye; Caye Glory; Gladden Spit; and Sapodillo Caye(s). Four of these sites were monitored for Nassau Grouper aggregations during the January 2001 spawning assessment, and these included Ambergris Caye; Caye Glory; Gladden Spit & Sapodillo Cay(s).

Ambergris Caye

This site was approximately 1 mile from the reef crest over hard substrate with sparse coral, gorgonians and sponges at approximately 35 meters depth. Six survey dives between 35 & 39 meters depth were conducted at the site, during which time no Nassau Grouper were observed; and no fishing activity was observed at the site. Discussions held with Gil Gonzales, a local fisherman who originally found the site in the early 1980's, confirmed that the survey location was correct, corroborating that Nassau Grouper were no longer aggregating at the site.

Currents were strong & generally ran northward at speeds of 3 - 4 knots from surface to dive depths of 35 - 39 meters. Visibility was good, varying from 20 - 30 meters at dive depths. No stratification of either currents or visibility was apparent. Water temperature was 26.2 $\pm$ 1.3 ^{o}C (n = 6) at the surface; and 26.0 $\pm$ 0.6 ^{o}C (n = 6) at dive depth. Coral cover was sparse, but no indications of bleaching were apparent. The predominant species present was *Monastrea annularis*.

Other Serranidae observed during monitoring dives included five Black Grouper (*Mycteroperca bonaci*) seen on the day of the full moon (only). Non-Serranid species occurring in groups or schools included 5 – 10 Dog Snapper (*Lutjanus jocu*); 3,000 - 4,000 Black Marget (*Anisotremus surinamensis)* at approximately 60 meters depth; and 75 - 100 Horse-Eye Jacks (*Caranx latus*) with visible spawning grooves.

Caye Glory

Four survey dives were conducted at this site. The location observed was a reef promontory situated approximately 420 meters from the reef crest over a low (2.4 meter) relief, spur & groove formation having approximately 30 % coral cover at 30 meters depth. Twelve Nassau Grouper were observed on Day 1 after the full moon; seven were seen on Day 3; 21 were seen on Day 5; and eight were seen on Day 7. A few bi-color individuals were observed, but no spawning activity took place. The low population number and lack of spawning behavior suggests there were too few individuals present to catalyze a spawning event. Taken together, these observations indicate that this site, which at one time harbored an aggregation in the tens, if not hundreds of thousands, may now be extinct as an aggregation site for Nassau Grouper.

Currents at aggregation depth were southerly at < 1/4 knot. Visibility was between 15 & 25 meters. No stratification of either currents or visibility was apparent. Water temperatures were not monitored during survey dives. Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. Predominant species present were *Agaricia* sp., *Monastrea anularus*, *Monastrea cavernosa*, and several *Diploria* sp..

Five fishermen working from two boats captured 18 Nassau Grouper with hook & line over a period of 25 man-days during the aggregation week for a CPUE of 1.4. These fishermen were primarily from Hopkins Village and have traditionally fished the reef for 2 – 3 generations (~ 40 – 60 years), and one fisherman had reported fishing this site for 50 years. None of the captured fish were assayed for sex, length or weight.

Other Serranidae observed during monitoring dives included 19 - 60 Black Grouper (*Mycteroperca bonaci*) between 0.3 & 1.1 meters in (total) length; and 2 - 50 Yellow Fin Grouper (*Mycteroperca venenosa*) between 0.6 & 1.1 meters in (total) length. Non-Serranid species occurring in groups or schools included approximately 600 Dog Snapper (*Lutjanus jocu*); some 215 Jolt Head Porgy (*Calamus bajonado*); 20 to 80 Trunkfish (*Lactophrys trigonus*); 40 Bermuda Chub (*Kyphosus sectatrix*); and 35 Ocean Triggerfish (*Canthidermis sufflamen*).

Gladden Spit

Six survey dives were conducted at this site. The location observed was a reef promontory situated approximately 80 meters from the reef crest over sand with a low profile mound formation of about 5 x 12 meters expanse at approximately 40 meters depth. Twelve Nassau Grouper were present at the site on Day 2 after the full moon of January 8. On the following day, 107 were present during a morning dive, but on Day 4, only 49 individuals were observed at the site. A total of 90 individuals were observed on Day 6 after the full moon, and these animals expressed both cryptic & mating colorations. Approximately 52 Nassau Grouper expressed cryptic coloration; 20 expressed light phase coloration; 10 expressed dark phase coloration; and 8 were bi-color. Most individuals were 40 to 55 Cm in total length; but the total range in sizes spanned 25 to 65 Cm in total length.

The sequence of coloration changes & date of peak aggregation characteristics of this site were intermediate between those observed for Sandbore & Dog Flea Cayes to the north; and Glovers Reef to the south. Color changes followed a sequence & light/dark ratio similar to those of Sandbore & Dog Flea Cayes in that they appeared to be light-phase dominant, but the aggregation peak was later than observed at Sandbore & Dog Flea Cayes, and closer to that observed at Glovers Reef.

Currents at aggregation depth were southwesterly, and generally below 1 Knot. Visibility was less than 5 meters to a depth of approximately 9 meters due to suspended organics; but abruptly increased to approximately 20 meters below 9 meters depth. Water temperatures were not monitored during survey dives. Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. Predominant species present were *Montastrea* & *Diploria* spp., along with sea rods and other Gorgoniacea.

Five fishermen working from three boats captured just 6 Nassau Grouper over a period of 16 man-days during the aggregation week for a CPUE of 0.4; however, all 6 fish were taken by sharks prior to landing. These fishermen were primarily from Hopkins Village and have traditionally fished the reef for 2 – 3 generations (~ 40 – 60 years).

Other Serranidae observed during monitoring dives included 9 - 40 Black Grouper (*Mycteroperca bonaci*) of 0.3 – 1.1 meters in (total) length; and 2 – 9 Yellow Fin Grouper (*Mycteroperca venenosa*) of 0.3 – 1.0 meter in (total) length. More than 200 Red Hind (*Epinephelus guttatus*) were also captured by fishermen during week following the January 8th full moon. Both the Yellow Fin Groupers & Red Hind were seen in shallower waters, approximately 50 meters above the Nassau Grouper aggregation depth. Non-Serranid species occurring in groups or schools included approximately 800 to 1,500 Dog Snapper (*Lutjanus jocu*), the peak schools for which appeared on Days 4 & 6 after the full moon; some 40 - 60 Jolt head Porgy (*Calamus bajonado*); 35 to 50 Trunkfish (*Lactophrys trigonus*); and 30 White Marget (*Haemulon album).* Five Bull Sharks (*Carcharhinus leucas*); and 6 Bottlenose Dolphin (*Tursiops truncatus*) were seen in the vicinity of the Nassau Grouper aggregation on Day 6 after the full moon.

Sapodillo Caye

This site was approximately 5 miles from the reef crest over a low (1 meter) spur & groove formation between 19 & 24 meters depth. Twelve survey dives were conducted at the site, during which time 1 - 6 Nassau Grouper were observed. No fishing activity was noted at this site.

Currents generally ran to the south-southeast at the surface, and east to south at dive depth. Current speed was very strong at 4 – 6 knots. Visibility was generally poor due to suspended organics, varying from 1 - 8 meters at dive depth. No stratification of either currents or visibility was apparent. Water temperature was 25.5 $\pm$ 0.9 ^{o}C (n = 12) at the surface; and 25.0 $\pm$ 0.9 ^{o}C (n = 10) at dive depth. Coral condition at spawning depth was good to excellent, and no indications of bleaching were apparent. The predominant species present was *Montastrea faveolata.*

Other Serranidae observed during monitoring dives included one Black Grouper (*Mycteroperca bonaci*) seen on the day of the full moon (only); 1 - 7 Tiger Grouper (*Mycteroperca tigris*); and 2 Yellow Fin Grouper (*Mycteroperca venenosa*). Red Hind (*Epinephelus guttatus*) were reported by fishermen & observed by the dive team to be aggregating 5 miles north of the Sapodillo Caye site. Non-Serranid species occurring in groups or schools included 30 – 40 Horse-Eye Jacks (*Caranx latus*); 10 - 30 Yellowtail Snapper (*Ocyurus chrysurus*); and approximately 20 Dog Snappers (Lutjanus jocu).

DISCUSSION

Life History Considerations

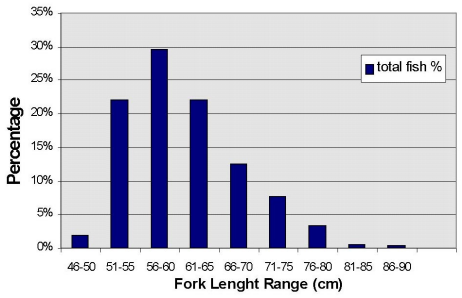
The findings of this study have shown that six of nine Nassau Grouper aggregation sites surveyed during the week of January 8th 2001 in Belize remain in use (see **Illustration 6**). Two of these sites (Caye Bokel & Glory) had less than 50 individuals demonstrating reproductive coloration & behavior, and have been classified as being *critically threatened* with extinction. Two sites (Dog Flea Caye & Gladden Spit) had less than 500 individuals demonstrating reproductive coloration & behavior, and these sites have been classified as being *threatened* with extinction because they continue to be fished. Two sites (Sandbore Caye & Glovers Reef) had several thousand individuals demonstrating reproductive coloration & behavior, and these sites have been classified as being *at risk* because they also continue to be fished. Local fishermen at the Sandbore Caye site had noted that Nassau Grouper attendance at the annual aggregation event was declining independently of fishing effort; and the Dog Flea Caye site may actually have been fished to extinction during the survey.

A total of 715 Nassau Grouper were captured with traps, and hook & line using 183 man-days during the January 8th 2001 aggregation event, for an national CPUE of approximately 3.9 fish/man-day (including the 2001 catch from Glovers Reef).

The size frequency of 391 individuals from the Sandbore & Dog Flea Cays catch is shown in **Illustration 7**. Age/size data summarized by Sadovy & Eklund (1999) for Caribbean Nassau Grouper suggest that Belize's 2001 catch may largely have consisted of animals between 5 & 13 years of age.

The sex ratio of 79 individuals sampled from this catch was female dominant by a factor of approximately 6:1. This ratio also corresponded very closely with the light/dark phase ratio observed at the Sandbore Caye aggregation site; and the general observation of light phase dominance at all four aggregation sites surveyed.

ILLUSTRATION 7

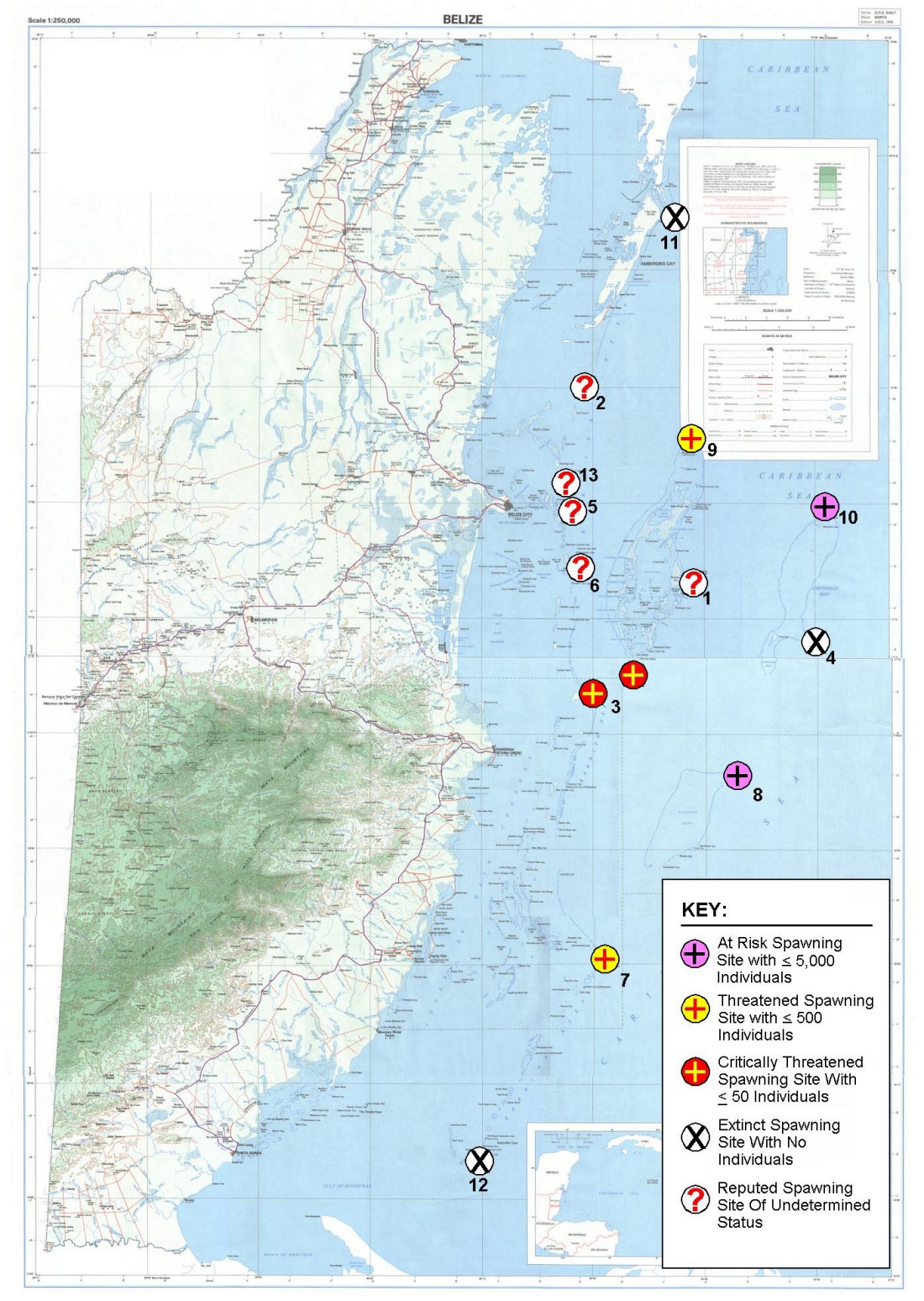


These observations are decidedly different from those reported for 1999 – 2000 Glovers Reef aggregation by Salas & Ballesteros (2001), which demonstrated twice the CPUE, nominal light phase expression; high levels of dark & bi-color expression; and lower female dominance of 3:1.

We interpret these differences as indicating that dark phase Nassau Grouper are probably male, despite Colin's (1992) speculation to the contrary. It follows from this conclusion that both sexes arrive at aggregation sites in cryptic coloration, and briefly express their biological sex by female Nassau Grouper demonstrating light phase coloration and males demonstrating dark phase coloration. If sufficient male coloration is expressed, female Nassau Groupers commence vitellogenesis (egg hydration), and signal either the onset or completion of this process with bi-color expression, and behaviorally by nudging males. If sufficient bi-coloration & nudging occurs, spawning follows. Fishing probably impacts this process by lowering male abundance first, which is consistent with the notion of male abundance influencing CPUE estimates (cf. Carter *et al* 1994).

ILLUSTRATION 6:

SITES & STATUS MAP OF NASSAU GROUPER SPAWNING AGGREGATION SITES IN BELIZE, CENTRAL AMERICA



This interpretation of the quatro-phasic coloration characteristics of Nassau Grouper is consistent with an adaptive strategy for coping with the selective pressures of predation & energy scarcity. In the first instance, bi-coloration is widely recognized as being adaptively cryptic for the open water column; while light-phase coloration would be adaptively cryptic for a background of sand. Light phase expression would of necessity have to be limited to female Nassau Grouper that have not yet ascended into the water column because its cryptic value as camouflage would probably be compromised against the darkness of the abyss during crepuscular spawning.

Male Nassau Grouper however, are likely to be well camouflaged in either normal or dark phase expression against the background of reefs & the abyss, but loose some degree of camouflage when seen in the open water column against background light from the surface. This brief window of exposure has likely supported some degree of adult predation (probably by sharks), and contributed to naturally low levels of male abundance over evolutionary time, reinforcing the harem behavior that is typical of Nassau Grouper. Predation-aversion has probably influenced the timing of the spawning event as well, since temporal proximity to one of two northern-hemispheric tropical winter solstices (November & February) when twilight is extended; and temporal proximity to sunset both serve to lower male predation risk.

Why then do female Nassau Grouper express *tri*-phasic coloration, and males only *bi*-phasic coloration? We propose that the capacity to signal a change in vitellogenic state probably lowers predation risk to male Nassau Grouper during spawning, by minimizing male exposure time in the open water column. Female Nassau Grouper might also benefit from this behavior if pre-hydrated eggs can be re-adsorbed and their energy content salvaged, since hydrated eggs are likely to be expelled, and their energy content forfeited if spawning is aborted for any reason. Hence, the capacity to reserve the commitment to spawn until the last possible moment would be highly adaptive for both sexes from the standpoint of predation-avoidance *and* energy economy.

The appearance of larger & presumably more 'fit' Nassau Grouper from deeper water late in the aggregation sequence supports a strategy of predation aversion; but may further genetic diversity if the late-arriving, larger & 'older' animals conditionally participate in spawning with the smaller & 'younger' aggregation only when a sufficient number of individuals (or males) are present. This seems to have been the case at Dog Flea Caye, where late-arriving, larger Nassau Groupers appear to have departed the aggregation, rather than joining in to reinforce the event as was done at Sandbore Caye.

The type of male/female signaling envisioned for Nassau Grouper by this study has not been described for other Serranid species. Black (*Mycteroperca bonaci*), Tiger (*Mycteroperca tigris*) and Yellow Fin Grouper (*Mycteroperca venenosa*) have been observed to demonstrate variable coloration during aggregations, but the reasons for such variation between species has yet to be described.

All of the aggregation sites surveyed during the 2001 aggregation period shared the physical attributes of sand floors, or spurs with sand channel grooves, and close proximity to the abyss. The relatively few sharks observed at most aggregation sites however, is likely to be a greater reflection of their over-exploitation by commercial fishing, rather than lack of interest in Nassau Grouper as prey. Shark fishing in Belize has increased dramatically in recent years and has, in an obtuse way, probably slowed the demise of Belize's Nassau Grouper aggregations by reducing predation mortality during spawning.

It is interesting to note in this regard that the Gladden Spit aggregation site lacked a spur & groove formation; and was the only aggregation site where sharks were both reputed to make diving hazardous (cf. Salas & Ballesteros, 2001) & recorded (during this study) to take the Nassau Grouper catch of fishermen. Nassau Grouper fidelity to this site in particular, and less camouflaging sites in general, would seem to imply that an aggregation sites' camouflage value may not outweigh other influences, such as the value of currents for dispersing offspring, in reinforcing aggregation site fidelity.

This conclusion is consistent with the notion that reef fishes spawn at sites, which maximize seed-dispersal characteristics (e.g. Johannes, 1978, Thresher, 1984 and Domeier & Colin, 1997). However, the potential for specialist predators to reduce reproductive success (such as Whale Sharks (*Rhincodon typus*), which are known to frequent the Gladden Spite site), would certainly mandate that dispersing currents were of sufficient magnitude & proximity to the spawning arena as to be immediately accessible to newly or recently fertilized eggs.

Most of the aggregation sites surveyed during the 2001 aggregation period shared the physical attributes of moderate to strong currents, as well as high environmental quality as indicated by coral condition; but temperature, the concentration of suspended organics, and current direction varied between sites. Consequently, these latter characteristics probably have less influence on reinforcing aggregation site fidelity, because tolerance of their variation would be selected for during the long process of dispersal.

A wide range of aggregation activity, involving both other Serranids, such as Black, Tiger & Yellow Groupers (Salas & Ballesteros, 2001), Red Hinds (*Epinephelus guttatus*); and Non Serranids, such as Dog Snapper (*Lutjanus jocu*), Black Margets (*Anisotremus surinamensis*), White Margets (*Haemulon album*), and Horse-Eye Jacks (*Caranx latus*) either co-occurs with Nassau Grouper aggregation activity, or takes place at other times of year at Nassau Grouper aggregation sites in Belize (personal observation). Such phenomena suggests that suitable aggregation sites may be uncommon and therefore, critical to protect from anthropological disturbances such as pollution and/or physical-mutilation, as well as species-specific over-fishing.

Economic Analysis

The economic value of the 2000 – 2001 Nassau Grouper catch in Belize is largely derived from the local market price for fillets and roe, as little is exported due to low & irregular availability. Grouper fillets sell for US $ 2.50 - $ 3.50 per pound, with high-end prices being paid by restaurants in the tourism sector. Grouper roe sells for US $ 3.50 - $ 5.00 per pound, with high-end prices being paid by the fishing community at San Pedro, Ambergris Caye. Assuming a fillet yield of 32 %, roe yield of 8 %, a mean whole weight of 4 Kg; and sex ratios as indicated for the various survey sites; we estimate the national catch for 2000 – 2001 to have a value of approximately US $ 7,000 for fillets plus US $ 1,000 for roe, for total value of US $ 8,000. This earning was divided between 38 fishers as the principal beneficiaries of the catch, for an average value of approximately US $ 210 per fishermen; or US $ 40 per fisherman-day, which is about 4 times minimum wage in Belize, and represents the primary incentive for fishermen to catch Nassau Grouper in Belize.

Given the size and income value of the fishery, is seems reasonable to propose that tourism viewing of aggregation sites might offer a viable economic & conservation alterative to fishing; particularly because there are few semi-skilled occupations in Belize which can offer an equal or greater return than this level of income/day. Assuming that at least four aggregation sites identified by this study remain in use by Nassau Grouper, and that there are probably < 3 days/year with tourism value for viewing a Nassau Grouper aggregation, the four sites might offer 4 x 2.5 or 10 days of tourism visitation per year. However, Nassau Grouper appear to be quite sensitive to human presence immediately prior to spawning, and so tourism visitations should probably not exceed two persons + one guide per visitation.

Consequently, at a maximum visitation rate of perhaps 4 dives per day (8 tourist visitations per day); the 4 aggregation sites together might be expected to support about 80 visitations per season. At this level of usage, tourists would have to be willing to pay > US $ 100 per visitation (each) for tourism to provide a viable economic alternative to the fishing of Nassau Grouper from their aggregation sites in Belize (in 2001 dollars).

Management & Research Recommendations

Coleman *et al* (1999) have recently argued that the life-history characteristics of many reef fishes, including Nassau Grouper, render them unsuited to typical fisheries management policies, such as total allowable catches (TAC's), size restrictions & seasonal closures; and conclude that spatial closures in the form of strict, no-fishing, marine reserves are probably best suited to the management of Nassau Grouper & other fishes with similar life-history characteristics. We concur with these recommendations, but would add the qualification that such reserves not be singular in number, and that they should specifically identify the individual location of each aggregation site, the species by which it is used, and time-frame during which that species may not be fished.

The findings of this study clearly establish that fishing pressure on Belize's Nassau Grouper must be stopped in the immediate near term as a first priority if the existing aggregations are to be afforded any chance for recovery. To this end, we recommend a minimum 5-year moratorium on fishing of Nassau Grouper in Belize, during which time no Nassau Grouper of any size should be held, sold or exported during the months of November 15th to January 15th; and no Nassau Grouper having less than 20 inches (500 mm) in standard length should be held, sold or exported at any time. The confirmed aggregation sites identified by this study should also be designated as species-specific protected areas to reinforce their exclusion from the commercial & recreational fishing of the seasonal spawning aggregations.

Concurrently with this moratorium however, alternative economic activities for displaced fishermen should be developed & put in place; community & tourism education programs should be developed & put in place; and Belize's remaining known aggregation sites should to be further surveyed & monitored for species presence & activity.

Alternative activities should include, but certainly not be limited to training fishermen for tourism related viewing of Nassau Grouper (and other species) during aggregation events; and continued involvement in future Nassau Grouper assessments & research. Key parameters to be monitored should include color phase expression during each day of aggregation; day of peak aggregation number; and the presence/absence of spawning activity should be verified. The typical suite of environmental parameters should also be monitored, inclusive of GIS location; depth; water temperature; current speed & direction; visibility; and perhaps photo-intensity. Electro-magnetic fields in the vicinity of aggregation sites might also be worth monitoring.

Continued investigations should also be conducted into traditional knowledge of aggregation sites, with the deliberate intention of permanently recording & evaluating these sites for management needs. Invitational research should also be solicited & supported in the areas of recruitment, migration, DNA & age assessments.

CONCLUSIONS

A national survey of Nassau Grouper aggregation sites in Belize has established that 6 of 9 sites visited during the 2000 – 2001 aggregation period were visited by reproductively active individuals, and 5 of these sites are severely threatened by commercial fishing. The largest aggregation consisted of 4,000 – 6,000 individuals; and the remaining five aggregations consisted of approximately 2,700; 400; 200; 45; and 20 individuals each (before the fisherman's catch).

These observations indicate that Belize's Nassau Grouper aggregation sites are critically threatened with extinction. Five historical Nassau Grouper aggregation sites remain to be surveyed. The importance of recording traditional knowledge in this regard cannot be underestimated, as this knowledge has proven to be the single most important link to the identification & protection of what may be Belize's last intact Nassau Grouper aggregation site.

Belize urgently needs to close its known aggregation sites to fishing for a minimum period of 5 years to afford its Nassau Grouper stocks some opportunity for recovery. It will be critically important during this period to develop alternative income opportunities for fishermen, continue monitoring the country's aggregations sites, and to develop a long term strategy & action plan for management of the fishery. Perhaps more importantly however, it will be important to increase public awareness of the Nassau Grouper's current struggle for survival on both a local & international level.

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