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Contribution to the Theme Section 'Range-wide status and conservation of goliath grouper'

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Characterization of the goliath grouper *Epinephelus itajara* fishery of southern Belize for conservation planning

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ABSTRACT: The goliath grouper *Epinephelus itajara* (Lichtenstein, 1822) is an integral part of traditional coastal fisheries in Belize; however, recent anecdotal reports suggest declining catches, mean size and abundance, particularly of large adults. Quantifying goliath grouper abundance in the waters of Belize is an important first step in developing management plans that can protect stocks of the species as well as local fishing communities. To characterize the status of the goliath grouper in southern Belize, we used a 2 yr market survey, fishery-dependent collections and passive tagging. Market surveys revealed that the vast majority (98% or 1412) of 1441 goliath groupers examined at a fish market comprised juveniles. Eight of the 64 interviewed fishers were responsible for most of the catches (67.2%). Size distributions of goliath grouper collected from coastal to outer reef areas using setlines, longlines and drumlines confirmed the overall paucity of adults in local populations. Specifically, a 90-fold difference in catch rates was observed between adults (n = 1425) and juveniles (n = 16). Of 209, 45 (21.5%) tagged individuals were recaptured during assessments, observed in marketed catch or reported, with 39.3% taken from the Port Honduras Marine Reserve. Fishing mortality was estimated at 0.27, while the specific growth rate was 0.29% d^{-1}. These results, together with documented loss of known spawning aggregations, suggest that goliath grouper in southern Belize are overfished. To allow population recovery, strict management and enforcement measures are required. Such a plan would have minimal impact on fishing communities, since no fishers are solely reliant on the species.

KEY WORDS: Goliath grouper fishery · Marine protected area · Tag-recapture

INTRODUCTION

The goliath grouper *Epinephelus itajara* (Epinephelidae, formerly Serranidae) is the largest grouper (>2 m) in the Western hemisphere and is widely distributed throughout the Caribbean, Gulf of Mexico and central eastern and western Atlantic (Heemstra & Randall 1993). The species was previously reported from the central eastern Pacific; however, recent molecular analyses have shown that population to be a sister species, *Epinephelus quinquefasciatus* (Craig et al. 2009, this Theme Section). The species is among a group of epinephelids that are extremely vulnerable to overfishing because they are long-lived, slow growing, late maturing and form relatively small (<100 ind.) and brief seasonal spawning aggregations (Sadovy & Eklund 1999). Size at maturity is reported as 110 to 115 cm total length (TL) for males and 120 to 135 cm TL for females (Bullock et al. 1992).

Goliath grouper exist in a range of marine and estuarine habitat types, with juveniles typically found in shallow waters in association with well-structured mangrove habitat (Koenig et al. 2007). Adults occupy areas around shipwrecks, coral or rocky reef crevices and overhangs down to 45–55 m. Both juveniles and adults show high seasonal site fidelity, although there is evidence of long distance migrations for both life history stages (Graham 2008, Pina-Amargós & González-Sansón 2009, this Theme Section).

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Goliath grouper are traditional members of local and regional fisheries throughout their range and, like their congeners, are vulnerable to a wide variety of gear types (Sadovy & Eklund 1999, Graham 2008). More recently, goliath grouper have become an important component of the dive tourist industry, particularly where large individuals still exist (W. Sterns pers. comm., F. Pina-Amargós pers. comm.). Unfortunately, goliath grouper populations have experienced substantial declines following decades of overfishing at and away from spawning aggregation sites (Sadovy & Eklund 1999). Adults, in particular, are now regionally rare and the species is commercially extinct in many areas (NMFS 2006). As a result, in 1996 and again in 2007, the IUCN Species Survival Commission characterized goliath grouper as Critically Endangered (CR A2d), implying that no regional population recovery has been shown.

In the USA, goliath grouper is still considered overfished by the National Marine Fisheries Service (NMFS) following a 1990 catch moratorium (NMFS 2006). Although some moderate increases in catch per unit effort (CPUE), mean length, and abundance of juvenile goliath grouper have been observed in the USA since the 1990 moratorium, insufficient data still exist to allow fishing to resume (Cass-Calay & Schmidt 2003, NMFS 2006, Porch et al. 2006). Adults still appear to be scarce, and large (50 to 100 ind.) spawning aggregations of goliath grouper are exceedingly rare within the species' distributional range, yet, due to population increases among juveniles, the species was de-listed as a Species of Concern (NMFS 2006).

In other regions of the Atlantic, anecdotal reports suggest severe declines of goliath grouper; however, there is little reliable fisheries data available to support these claims or on which to base management decisions. For example, recent efforts to sample goliath grouper from West African coastal mangroves and fish markets resulted in no sightings (Craig et al. 2009), and there are no known recent reports from nearshore fishing vessels. In Latin America and much of the wider Caribbean, adults are infrequently observed in markets or in the wild. Few spawning aggregation sites are known and, of those previously reported, several are now extirpated, including English Caye, the only site recorded in Belize where goliath grouper are no longer caught or recorded during dives (Sadovy & Eklund 1999, Paz & McField 2001, M. Paz pers. comm.). In addition to impacts from overfishing, the species is likely experiencing population-level declines from the coastal mangrove destruction, both from rapidly increasing development and recent natural events (e.g. Hurricanes Iris and Mitch).

Despite the relative importance of goliath grouper in fisheries and tourism, little is known about populations outside of the USA and US territories on which to base management decisions, such as landings data or population demography. Until recently, details of the species' larval biology (Lara et al. 2009, this Theme Section) or juvenile habitat requirements were unknown (Koenig et al. 2007). The sexual pattern for goliath grouper — either as gonochores or protogynous hermaphrodites — has not been established, in part because of an inability to obtain sufficient sample sizes of adults (Sadovy & Eklund 1999). Spawning has not been observed, although recent evidence suggests spawning occurs nocturnally (Mann et al. 2009, this Theme Section). Management is sparse outside the USA and Brazil, even though anecdotal reports of population declines are sufficient to support immediate implementation of precautionary management.

In Belize, goliath grouper have been a traditionally favored target among coastal fishers due to their large size and predictable behavior. Goliath grouper are captured using a variety of gear types, including spear, line (set line, longline and handline), net and trap. Similar to other areas, anecdotal evidence from Belize suggests a historical decline in both abundance and mean length. While such traditional ecological knowledge is not infallible (e.g. Tibby et al. 2008), it is still widely regarded as useful in management in lieu of historical records (e.g. Ruddle 1996, Johannes 1998). In spite of declines and fish spawning aggregation loss, no management exists for the species outside incidental placement in no-take national parks or marine reserves where gear bans exist. Thus, there is a need for improved management, as well as baseline fisheries and population data to establish its status in Belize.

Reductions in mean size, age or size at sexual maturity within populations, or accelerated rates of growth are often responses of populations to overfishing (Grift et al. 2003, Olsen et al. 2004, 2005). These changes reflect efforts by populations to maintain reproductive output in compensation for the loss of spawning stock, particularly larger, more fecund females (Sadovy 2005). To gauge whether such changes are occurring, some preliminary estimates of size distribution, growth and size at sexual maturity are needed. In addition, to target management appropriately, details of the fishery are generally required, including documentation of size at capture, fishing gears and targeted areas.

The primary objective of the present study was to establish a baseline record for the goliath grouper fishery in southern Belize where no quantitative information currently exists. To accomplish this, we used a combination of market assessments, anecdotal fisher information, fisheries-dependent collections, and tag-recapture to assess the size structure of the goliath grouper stocks in southern Belize.

MATERIALS AND METHODS

Study site. Southern Belize encompasses a range of habitats from coastal fluvial, estuarine and mangrove ecosystems to inshore and offshore seagrass, patch reef and barrier reef sites. The present study focused on a trans-boundary area encompassing >4665 km^2 of coastal, estuarine, reef and lagoon habitat (Fig. 1). To the south, the study was delineated by a line from the Sarstoon River (15.89168° N, 88.91395° W) to the Sapodilla Cayes (16.07706° N, 88.29895° W), to the east along the Belize Barrier Reef linking the Sapodilla Cayes to the northernmost boundary of the South Water Marine Reserve to the north (16.94632° N, 88.05228° W). The northernmost boundary ran from the northern end of the South Water Caye Marine Reserve to the mouth of the Sittee River. Within this area are 4 marine reserves (South Water Caye, Gladden Spit, Sapodilla Cayes and Port Honduras) and 3 national parks (Laughing Bird Caye, Payne's Creek and Sarstoon Temash) (Fig. 1). In Belize, national parks are completely closed to fishing, whereas fishing bans in marine reserves only take place in designated no-take zones. Recreational and commercial fishing using setlines, handlines and spears takes place in the remaining general use zones of Belize's marine reserves. Active patrols occur primarily within the Payne's Creek National Park and Port Honduras Marine Reserve where the present study was primarily focused.

Market survey. Data were collected on goliath grouper landed at the Punta Gorda fish market Monday through Saturday during the key market hours of 07:00 to 10:00 h from 30 December 2005 to 31 December 2007. The market is closed on Sundays. Data collected include total fish length (nearest 0.5 cm), weight (nearest 100 or 250 g depending on the size of the fish) and degree of processing prior to evaluation (gutted, whole, skinned, caudal fin removed). All weights were

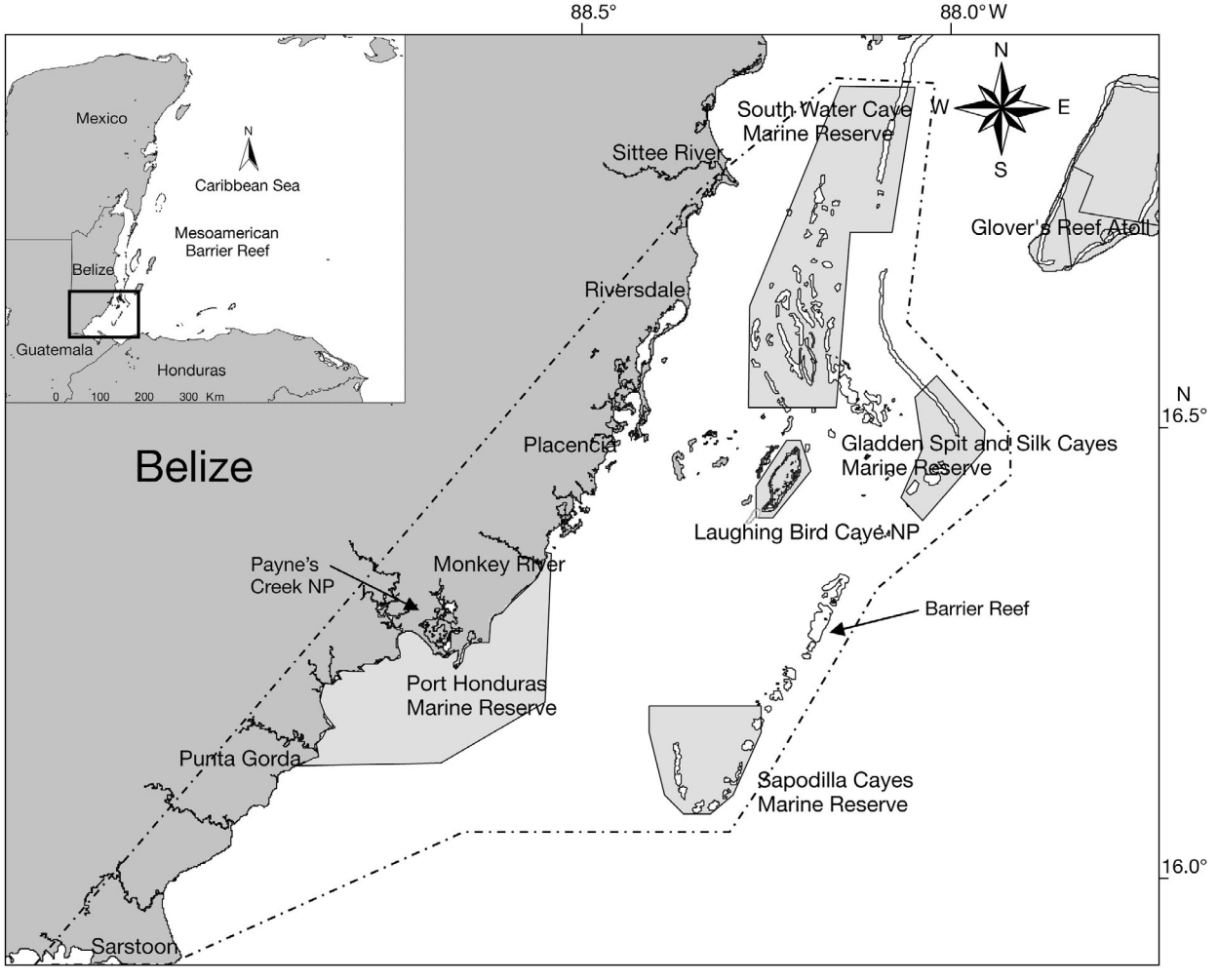

Fig. 1. Location of the project site (– · –) and marine protected areas (solid lines, lighth grey) in southern Belize. NP: National Park

taken using a Chatillon spring balance (Model IN-025M, 100 g increments for fish up to 12.5 kg, Model IN-050M, 250 g increments for fish up to 50 kg). When available, gonads were examined macroscopically for signs of sexual maturity and reproductive activity, based on previously published criteria for the species (Bullock et al. 1992). Brief opportunistic fisher interviews were conducted at the time of landing, with fishers asked to identify their village of origin, catch location, gear (and bait used, if applicable) and total number of goliath grouper taken. No information on fishing costs or total fishing time was taken. All gonads from individuals above the reported size at sexual maturity (>1150 mm total length, TL, males; 1200 mm TL, females; Bullock et al. 1992) and a subsample of those presumed to be juveniles were retained for future microscopic analysis. Finclips, dorsal spines, otoliths and tissue samples were collected as available for future analysis of populations, age and growth and heavy metal contamination, respectively. Rates in instantaneous fishing mortality were determined using Jobling's (1994) formula (see 'Field surveys') for comparisons to those previously reported (e.g. Sadovy & Eklund 1999).

Field surveys. Four community meetings and 2 workshops (held in Punta Gorda and Placencia) brought together members of 7 coastal communities in southern Belize in December 2005 and May 2006 (Fig. 1). These events provided a means of presenting the scope of the project to local stakeholders and an opportunity to request traditional and historical knowledge from local fishers on goliath grouper distribution, size and abundance. Semi-structured group discussions centered around maps of southern Belize and basic questions of fish distribution, seasonality, gear and bait preferences, and areas of high capture rates provided information on key habitats and favored fishing grounds for goliath grouper juveniles and adults. The group discussions and subsequent one-on-one interviews with 27 patriarch fishers provided the basis for selecting sampling sites that covered all coastal and marine habitat types in southern Belize (coastal mangroves, mangrove cayes, mud bottom, seagrass, reef patches, back-reef and fore-reef). Sites were sampled using a variety of recommended gears for each habitat and life history stage. The timing of field sampling was determined to coincide with favorable weather conditions in the dry season. Twelve local fishers assisted with field sampling. Based on interviews, setline sampling was conducted in rivers lined by red mangrove *Rhizophora mangle* Lichtenstein, and along coasts and cayes within and adjacent to the Port Honduras Marine Reserve during the main months of the dry season (January to April) (Fig. 2). All field work was conducted in accordance with institutional, national and international guidelines concerning the sampling of endangered species. High current flow and fast-moving debris precluded setline sampling within these waterways during the rainy season (June to December). Setlines consisted of a single-snap clip that was attached to the mangrove and linked to 3 m of 140 kg (300 lb) test monofilament line fitted with a single circle hook (Mustad 16/0). Set lines deployed between 08:00 and 14:00 h were left to soak for a minimum of 3 to 4 h, while those set later were left overnight for pick-up the next morning. Soak times for all gears varied somewhat within and among days and seasons, such that CPUE estimates are reported as the number of captures per 100 hooks and not the number of captures per unit soak time. Mean (±SE) soak times are nonetheless provided.

Longline and drumline sampling was distributed between January and October in habitats ranging from rivers and estuarine areas as well as mud-bottom sites to 43 km away from coastal mangrove habitats. Based on fisher information on adult habitat types and fishing

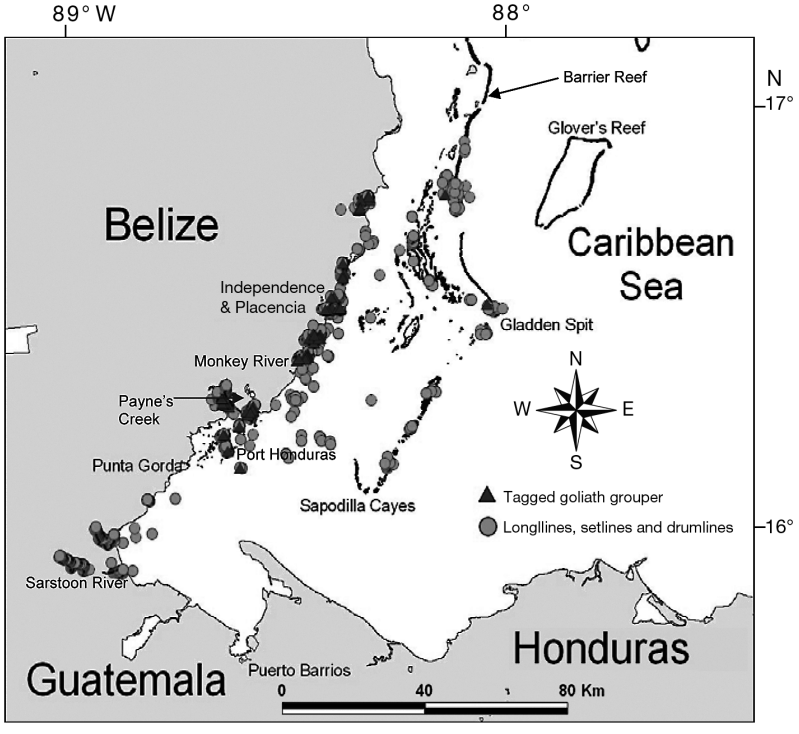

Fig. 2. Location of all hook deployments and goliath grouper captures in southern Belize between January 2006 and December 2007

areas, longlines and drumlines were deployed in outer bank areas and some mid-lagoon locales. Longlines were deployed in mud- and rocky bottom sites, reef passes, reef patches and back- and fore-reef areas spanning from Riversdale and Tobacco Caye in the north to the Sapodilla Cayes and the Moho River in the south. Illegal gillnet deployment by local fishers precluded longline placement near the Sarstoon River (Figs. 1 & 2). Longlines consisted of 25 to 50 hooks per line (4 m gangions with Mustad 16/0 circle hooks), while drumlines were single hook (Mustad circle 16/0) rigs attached to a float and anchored by a mooring. All drumlines were deployed in narrow reef passes where longlines were inappropriate. On advice by local fishers, all setline and longline hooks were baited primarily with mullet *Mugil cephalus*, and drumlines were baited with lutjanids. Setline, drumline and longline positions, along with waypoints for fish capture, were recorded using a Garmin 76® GPS and mapped using ArcView 3.2 (ESRI).

Length and weight were taken as above for all captured fish. All fish captured in good condition, were tagged with a 15 cm long numbered, nylon-core conventional dart-type spaghetti tag (Hallprint) inserted into the musculature near the dorsal fin spines. Each tag was printed with a unique identification (ID) number on either end of the shaft, with contact information printed in between. This printing method allowed ID numbers to remain legible for most fish even when tags were broken close to the dart tip.

Released fish were categorized as excellent, good or poor upon release, based on the manner of hooking and general activity level. Fish in poor condition were typically slow to descend and had been gill hooked or swallowed a hook with subsequent esophageal tears or bleeding. Fish in good condition may have been lip-hooked or have swallowed a hook, but the hook was cleanly removed with no large esophageal tearing. Fish in excellent condition had typically been lip-hooked and, therefore, more quickly processed. Both good and excellent condition fish were active, rapid swimmers upon release. To assess growth rates, recaptured tagged fish were re-weighed and re-measured. Specific growth rates (G = instantaneous growth rate × 100) for recaptured fish, expressed as percentage growth per day, were determined using the formula:

$$G = [(\ln W_2 - \ln W_1)/(t_2 - t_1)] \times 100$$

where W_2 is the weight in kg at recapture, W_1 is the weight at first capture, t_2 is time at recapture and t_1 time at first capture (Jobling 1994).

For fish re-captured with broken tags, the tags were replaced to ensure unambiguous identification during subsequent recapture. All recaptured tagged fish had legible tag numbers. Recaptured fish marketed in Punta Gorda were measured and weighed by the market landings coordinator. Fishers returning tagged fish were given a monetary or T-shirt reward. All other recaptures were included only if the fisher provided whole tagged fish.

RESULTS

Market landings analysis

A total of 1441 goliath grouper were examined from marketed catches during 625 of 731 possible sampling days. The remaining 106 d were dedicated to field sampling or associated with Sundays or national holidays when markets were closed. Sixty-four fishers were sampled, 3 of whom were responsible for 54.1% of the total sampled catch, with 8 fishers contributing 67.2% of the total landings.

Goliath grouper examined during market surveys ranged from 0.3 to ~135 kg with a mean (±SE) weight of 4.5 ± 0.1 kg, range of 23.5 to 200.5 cm TL and total landings of 6416.5 kg. Only 16 of 1441 fish (1.1% of the total) were above the size of sexual maturity reported for the species from the Gulf of Mexico (mean = 63.6 ± 0.4 cm TL) (Fig. 3). No signs of reproductive activity were observed for any gonad examined macroscopically, regardless of size.

Conventional tag-recapture

Setline sampling was conducted over a total of 50 d during the 2 yr study period (29 d: 4 January to 5 April 2006; 21 d: 13 January to 9 April 2007). During this period, a total of 4087 hooks (1887 in 2006 and 2200 in 2007) were deployed, resulting in the capture of 220 goliath grouper (1 per 18.2 hooks or 5.5 fish per 100 hooks). Of those captured, 204 fish were tagged and released in good to excellent condition, 8 fish escaped during pick-up and 6 fish were found dead. Two fish were not tagged owing to poor condition. Soak time varied between years and averaged 9 h, 51 min overall (range = 0.85 to 23.9 h; 2006: 11 h, 52 min; 2007: 8 h, 4 min). Lengths of captured goliath grouper from setlines ranged from 18.0 to 125.0 cm TL (mean = 60.4 ± 1.0 cm TL), with fish weighing from 0.3 to 23 kg (mean = 4.5 ± 0.2 kg). Based on macroscopic gonad analyses, no reproductively active individuals were captured and >99% were below the minimum size of reported sexual maturity.

Longline and drumline sampling was conducted throughout southern Belize (Fig. 2) both in riverways and offshore over a total of 54 d (4 January to 13 October 2006). A total of 12 285 longline hooks and

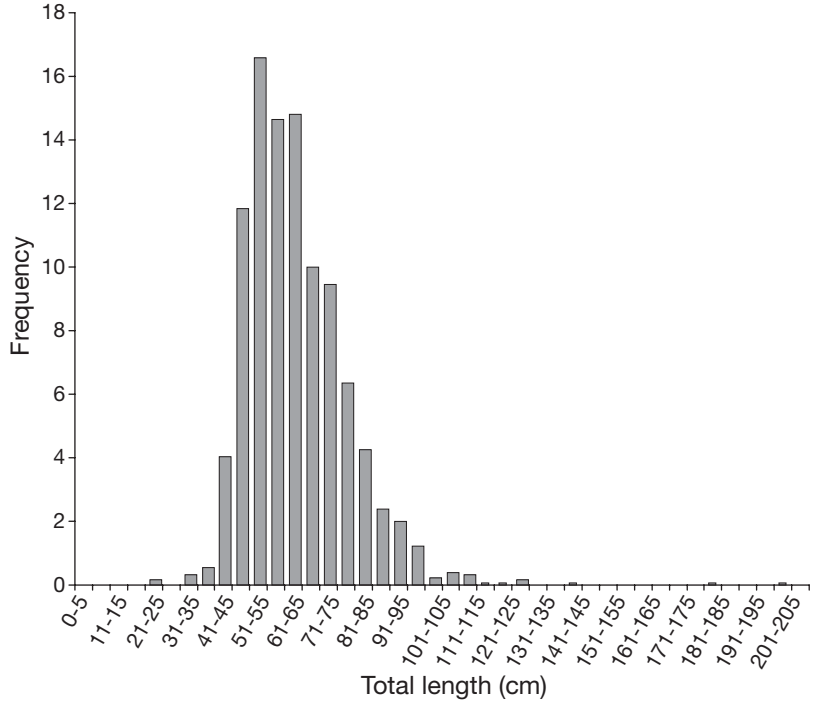

Fig. 3. *Epinephelus itajara*. Length frequency distribution of whole, marketed goliath grouper in the Punta Gorda, Belize, fish market. Marketed fish with tails removed were not included

166 drumline hooks were deployed for a total soak time of 37 353 h or a mean of 180 min per hook. Comparisons in soak time and CPUE between years was not conducted since these were not standardized during collection periods. A total of 5 goliath grouper were captured (1 per 2490 hooks) by longline, ranging from 72.0 to 181.0 cm TL (mean = 136.9 ± 52.53 cm TL) and 7.0 to 13.5 kg (mean = 10.25 ± 4.6 kg). Weights could not be determined in the field for the 3 larger individuals due to difficulties in handling. One individual above the reported size at sexual maturity was captured in February by longline, but was not reproductively active. Similar to weights, reproductive assessments by cannulation were not possible for larger in-water animals. No goliath grouper were captured using drumlines.

Recaptured goliath groupers

Of the 209 goliath grouper tagged, 33 (16% of the total) were recaptured between 25 April 2006 and 23 December 2007, while an additional 12 fish were reported by fishers who did not provide the fish for measurement. The recapture rate was 22.1% of all fish tagged fish, with an instantaneous rate of fishing mortality (F) of 0.27.

Anecdotal reports provided no length information and were therefore not included in the growth analysis. Of the 33 ind. available for assessment following recapture, 20 recaptures provided no length, weight or catch location data owing to sale or extensive processing. This provided us with robust data for a total of 13 ind.: 2 recaptured during setline sampling and 11 that were observed at markets. All 13 ind. were taken within the Port Honduras Marine Reserve, with the lengths provided forming the basis of growth estimates (Table 1). The median specific growth rate (G) was calculated at 0.29% d^{-1}. No population estimates were attempted owing to the small

Table 1. *Epinephelus itajara*. Tagging data and growth rates for 13 recaptured goliath grouper in southern Belize. TL: total length

Sample	TL at tagging (cm)	TL at recapture (cm)	TL change (cm)	Weight at tagging (kg)	Weight at recapture (kg)	Change weight (kg)	Days at liberty	Growth (cm d^{-1})	Growth (kg d^{-1})	Specific growth (weight, % d^{-1})
1	45.00	84.00	39.00	1.70	9.09	7.39	466	0.084	0.016	0.429
2	48.00	61.70	13.70	2.00	1.82	−0.18	172	0.080	−0.001	0.000
3	48.00	54.50	6.50	1.90	2.75	0.85	351	0.019	0.002	−0.046
4	53.50	61.40	7.90	2.50	3.70	1.20	305	0.026	0.004	0.060
5	57.00	77.00	20.00	3.10	8.00	4.90	303	0.066	0.016	0.525
6	61.00	66.30	5.30	4.25	4.55	0.30	114	0.046	0.003	−1.070
7	61.00	73.00	12.00	3.90	5.50	1.60	245	0.049	0.007	0.192
8	61.50	73.66	12.16	4.30	6.82	2.52	150	0.081	0.017	0.616
9	63.50	84.00	20.50	4.40	7.70	3.30	465	0.044	0.007	0.257
10	64.00	73.00	9.00	4.50	6.75	2.25	352	0.026	0.006	0.230
11	65.00	74.40	9.40	5.00	6.50	1.50	169	0.056	0.009	0.240
12	70.50	82.00	11.50	6.10	9.00	2.90	351	0.033	0.008	0.303
13	78.00	84.40	6.40	8.25	8.36	0.11	110	0.058	0.001	−1.977
Mean	59.69	73.03	13.34	3.99	6.20	2.20	273	0.051	0.008	0.289

number of animals captured, the heavy bias towards juveniles and the single resampling interval.

DISCUSSION

Punta Gorda fish market surveys provided the first record of the goliath grouper fishery in southern Belize. Findings reveal a fishery dominated by juvenile catches taken from red mangrove areas known to be critical habitat, primarily those within and adjacent to the Port Honduras Marine Reserve. It is currently unclear whether the targeting of these habitats is due to the apparent paucity of adults in nearshore and offshore habitats or the reduced costs and ease of access associated with fishing in nearby coastal areas. If the adult portion of the goliath grouper populations is indeed small, as suggested by combined fisheries-dependent findings and anecdotal reports, continued fishing of juveniles is likely to further reduce goliath grouper populations and impact fishing communities dependent on them, both through reduced fishing success and delayed population recovery.

Among gear types used by local fishers and recorded during the market surveys, setlines and spearfishing are favored and highly successful methods of capturing juvenile goliath grouper within coastal habitats. As reported by Cass-Calay & Schmidt (2009, this Theme Section), the release of fishing pressure on juveniles can propel full population recovery assuming pressure is also reduced on adults. Nonetheless, 18 yr after the catch moratorium in the USA, adults are still rare, suggesting that improvements to the adult population in Belize are unlikely without management intervention.

The apparent rarity of adult goliath grouper in southern Belize is reflected in both market analyses and fisheries-dependent surveys and is supported by anecdotal reports from southern Belize fishers, market owners and restauranteurs who collectively perceive a widespread diminution of both adults and spawning aggregations (R. T. Graham unpubl. data). These combined findings correspond closely to those reported elsewhere where overfishing of the species has occurred (e.g. Sadovy & Eklund 1999, Cass-Calay & Schmidt 2009, McClenachan 2009, this Theme Section). Based on our findings, goliath grouper appear to be in need of a range of management solutions to allow recovery of adult populations, as well as full protection of mangrove nursery habitats.

Total landings versus market-based landings

Although total landings of goliath grouper in southern Belize (Punta Negra to the Sarstoon River) are unknown, previous countrywide fisher surveys (R. T. Graham unpubl. data) suggest that most of the commercial catch in the area passes through the Punta Gorda fish market. Although 1 additional landing site exists by the side of the road in Punta Gorda, the volume of fish is reportedly small. Other sources of goliath grouper may include occasional direct sales to restaurants or personal consumption. Nonetheless, it is unlikely that the size composition of catch outside of the Punta Gorda market is dissimilar to that observed during the present survey, particularly for adults, which provide far greater income to fishers than juveniles and likely appear in marketed catch.

Loss of critical habitat

Red mangroves have been identified as critical nursery habitat for goliath grouper (Frias-Torres 2006, Koenig et al. 2007). In 1990, mangroves constituted 3.4% of land cover in Belize, but declined to 0.7% by 1992 (Murray et al. 2003). Recent rapid and uncontrolled coastal development and mangrove loss from Hurricanes Keith and Iris in 2000 and 2001, respectively, have severely reduced juvenile goliath grouper habitat. Both fishing and development pressures are increasing on remaining tracts of coastal and caye mangrove communities. Development-promulgated dredging and sediment dispersal have further impoverished goliath grouper mangrove habitats and impacted seagrass and coral reefs. Loss of mangroves not only affects goliath grouper habitat needs, but also impacts a range of other commercial and reef-associated species, several of which are considered mangrove-obligates during a part of their life cycle (Mumby et al. 2004). While habitat loss was not cited as a major factor in goliath grouper decline in Florida (NMFS 2006), other studies have definitely shown that goliath grouper juveniles are heavily reliant on mangroves and associated habitat (e.g. Frias-Torres 2006, Koenig et al. 2007, Frias-Torres & Luo 2009, this Theme Section). Indeed, recent surveys among adjacent yet varying coastal habitats in the USA clearly showed suboptimal goliath grouper catches from locales where mangroves are absent or reduced (e.g. Cass-Calay & Schmidt 2009). Thus, continued reductions in mangrove habitat and increased fishing pressure will further reduce catch and limit the potential for population recovery.

Life history analyses

Recaptured goliath grouper provided some insight into growth rates for the species in southern Belize.

Mean growth rates recorded from fish recaptures were within the range of Bullock et al.'s (1992) otolith-derived growth rates for fish younger than 6 yr old (>100 mm yr^{-1}). Reproductive seasonality, reported as June to August, could not be confirmed from macroscopic examination of gonads, since no reproductively active individuals were observed and few adults were sampled. No known active spawning aggregation sites for goliath grouper were identified through market landings, fisher interviews or field surveys in southern Belize. Further work is clearly needed to identify spawning sites and ascertain reproductive life history for goliath grouper. High growth rates recorded in juveniles suggest that goliath grouper in southern Belize are growing rapidly, perhaps in response to the sustained fishing pressure.

Fishing pressure

A heavy reliance on juvenile goliath grouper was observed within the southern Belize fishery and likely reflects the demographic profile of the goliath grouper population. Nonetheless, other factors may have biased our findings, such as the proximity and ease of access to coastal mangrove habitat, reduced fishing time and costs and increased predictability of catches. Regardless, these data are worrisome given the apparent lack of adults in the population, the reduction in critical habitat and the increasing fishing pressure on goliath grouper from trans-boundary fishers from Guatemala. Among the 64 fishers identified as either targeting or occasionally fishing goliath grouper, 2 of the 3 top fishers by catch volume were Guatemalan. Since it is unlikely that the number of fishers entering the Belizean fishery will decrease, increases in abundance for goliath grouper can only come from additional protective measures.

Based on the present survey, estimated fishing mortality appeared low in comparison to the overall mortality (Z) estimates provided by Sadovy & Eklund (1999) of 0.85. Assuming natural mortality for goliath grouper is similar to other species at $M = 0.15$, and the instantaneous rate (F) for southern Belize goliath groupers is 0.27, $Z = 0.42$ overall. While this is approximately one-half of the fishing mortality expressed in the northern part of its range, estimates from the Gulf of Mexico were based largely on fish >11 yr of age (~1500 cm TL) (Bullock et al. 1992), which are likely far older than any fish captured during the present survey. However, fishing mortality of southern Belize goliath grouper approximates that of the overfished Nassau grouper ($F_{OVERALL}$ = 40; $F_{ACOUSTIC}$ = 0.20), that have been tagged conventionally and tracked at glover's Reef Atoll by Starr et al. (2007). Unfortunately, none of the 5 ind. larger than the size at reported sexual maturity were recaptured in the present study; thus, adult F could not be examined. However, it is likely that fishing mortality increases with size and reproductive ability, as suggested by Bullock et al. (1992). Further assessment will be needed to fully understand total mortality for goliath grouper in the region.

Management of goliath grouper in Belize

Belize has passed legislation to specifically protect 4 finfish species: the recreationally lucrative bonefish *Albula vulpes*, permit *Trachinotus falcatus*, and tarpon *Megalops atlanticus* and the commercially important, but endangered, Nassau grouper *Epinephelus striatus*. While a fishing ban fully protects bonefish, Nassau grouper are protected only during their reported spawning season, 1 December to 30 March (GoB 2003a). In addition to species-specific legislation, area protection is provided to 11 multi-species spawning aggregation sites that host a range of commercially important reef-fish species (GoB 2003b). Of these sites, only the Gladden Spit and Silk Cayes Marine Reserves are enforced, with fishing for some aggregating species still allowed (Graham et al. 2008). Declines in abundance for aggregating species such as Nassau grouper continue even under the current regulations (Sala et al. 2001) due to both a lack of enforcement and the use of small-scale Marine Protection Areas (MPA) that provide insufficient protection for migrating individuals during reproductive periods.

Currently there is no directed legislation to protect goliath grouper, even though anecdotal information suggests the species is heavily overfished. Unfortunately, there are no historical fishery records for the species from which to document the perceived decline in goliath grouper catch and size. However, Thompson (1944, p. 12) made reference to goliath grouper as a fish that 'does not appear to dry-salt very successfully under local methods and it is usually disposed of fresh, though its flesh is not highly esteemed.' The lack of historical interest in large-scale commercial harvesting of this species in Belize could explain why populations persist today.

During the final community meeting of the southern Belize goliath grouper assessment held in June 2007, fishermen were keen to find a management solution to the perceived decline in abundance and size of goliath grouper. Suggested management strategies included a slot limit that would allow the release of large fecund individuals and the smallest juveniles, with enhanced enforcement of site-based fishing closures. However, the data provided from the present and other studies (e.g. Sadovy & Eklund 1999, Cass-Calay & Schmidt in press) suggest that the best current solution is to pro-

vide full protection for the species through a catch and sales moratorium to allow the adult population to recover. A ban would not impact the fishing community widely, as only 8 fishers were found to target goliath grouper in southern Belize, and these individuals also fish several other species. Unfortunately, enactment of a sales and catch moratorium under the current levels of enforcement and management would likely be ineffective due to insufficient controls over the fishery and landings. Alternatively, a no-take area closure with effective enforcement could be used to protect juveniles, with a ban on catch or sale of individuals above the reported size at sexual maturity. Stakeholder discussions that include fishers, market and restaurant owners and reserve managers, such as the Belize Department of Fisheries and numerous local NGOs, may produce viable management alternatives.

Additional fieldwork and market data from northern Belize are needed to provide data for the development of a national management plan for goliath grouper. Meanwhile, continued dialogue with stakeholders, including trans-boundary fishers, towards a temporary management solution, such as slot limits, with continued market monitoring may allow more stringent measures to be adopted under an adaptive management agreement. Regardless, it is now apparent that some level of management for the species is needed if populations are to persist in southern Belize. Moreover, human health concerns in association with the elevated mercury levels found in many goliath grouper — both juveniles and adults — sampled from southern Belize (Evers et al. in press, this Theme Section) may provide further impetus to curb fishing pressure and protect this species. Further inaction and continued habitat loss will likely result in the demise of the species and further erode the fishery in southern Belize.

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