Project Report

Status of Goliath Grouper in Port Honduras Marine Reserve, Payne’s Creek National Park, Deep River 2014

Results of 2014 landing site surveys & comparison with previous studies

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Project Report:

Status of *Epinephalus itajara* (Goliath Grouper) in Port Honduras Marine Reserve, Payne’s Creek National Park, Deep River:

Fisheries Dependent Landing Site Study 2014

Conducted by Toledo Institute for Development and Environment, Belize
Funded by U.S. Fish & Wildlife Service

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Acronyms:
BFD               Belize Fisheries Department
BL                Body length
CPUE              Catch per unit effort
PCNP              Payne’s Creek National Park
PHMR              Port Honduras Marine Reserve
TIDE              Toledo Institute for Development and Environment
TL                Total length
TPPL              TIDE Private Protected Lands
WCS               Wildlife Conservation Society
1. Abstract

In 2014, the Toledo Institute for Development and Environment (TIDE) conducted a U.S. Fish and Wildlife Service funded project to determine the status of Goliath grouper populations in Port Honduras Marine Reserve (PHMR). Results of the landing site survey research project are presented here, showing size distribution in total length, body length and weight, and comparing mean size variations over time with earlier studies. Mean size has not varied significantly since 2007, being skewed towards juveniles, probably due to PHMR, PCNP and Deep River being a key nursery area for the species. Gut content, otolith extraction and gonad analysis also took place where possible. The findings of this study support previous studies recommending changes in legislation to improve protection of the species, showing that PHMR, Payne’s Creek and Deep River continue to provide unique and ideal habitat as a Goliath grouper nursery, and that population structure in the study area is likely permanently skewed towards younger animals for this reason rather than gear types selecting in favor of juveniles. 100% of the catch surveyed was less than minimum size at maturity, showing limits are needed to begin effective management of the species to increase its chances of long-term survival in Southern Belize. Tagging studies by WCS in 2007-2010 proved Goliath groupers from PHMR migrate at least as far as Mexico. This study supports greater protection of the species in one of the only known nursery sites in the MAR region, and which may be supplying the majority of the population found in the region. In light of strong historical resistance among fishers to impose a moratorium, or a proposed 40-inch (101.6cm) size limit, other management options are suggested to improve buy-in for protection rules that could result in an increase in abundance and overall maturity, but that also work economically for fishers, a crucial factor for success in protecting the species in the long term in an area with significant enforcement challenges, and a better alternative than no change to the existing situation. With a population percentage-based size limit that protects the smallest 75% of the resident population from fishing pressure, 25% of the population would still be available to fishers, with improvements seen in 5-10 years. Special management zones in PHMR giving full protection to Goliath grouper, even modest sized, permanent or seasonal, may significantly reduce their exposure time to fishing pressure during their residency as juveniles in PHMR. Goliath grouper as a means to control or mitigate the invasive lionfish is discussed in light of discovery of spines penetrating the stomach of a large specimen floating dead in PHMR.

2. Introduction

The critically endangered Goliath grouper (Epinephelus itajara) has been overfished throughout its range. In the USA and in Brazil, there are fishing moratoriums in place, yet in Belize, no species-specific legislation exists.

The Punta Ycacos Lagoon/Deep River estuary area in southern Belize, situated between Payne’s Creek National Park (PCNP) and Port Honduras Marine Reserve (PHMR), is thought to be one of only three major nurseries for E. itajara remaining in the world and is restocking populations throughout the Mesoamerican Reef (Graham 2009; Graham et al. 2010) (Fig. 1). Yet, this nursery is being fished at a significant rate and juvenile E. itajara are frequently sold in markets in southern Belize. Of 1,441 Goliath groupers observed on sale at Punta Gorda fish market, only 1% were sexually mature (Graham et al. 2009). Legislation is urgently required to reduce fishing pressure, especially on juveniles.

TIDE co-manages PHMR and PCNP with the Belize Fisheries Department and Forest Department, respectively. The Fisheries Department uses data collected by TIDE to formulate policy, for example, recently deciding to apply Managed Access fisheries management in all Belizean MPAs, based, in part, on information supplied by TIDE. The Department has stated its willingness to consider TIDE’s recommendations regarding legislation to protect Goliath grouper so long as there is sufficient evidence that such legislation is warranted. Initial dialogue with local fishers suggests they would also support at least one regulation to protect the species, namely a size limit.
Fig. 1: The upper panel shows the Maya Mountain Marine Corridor, TIDE’s geographical focal area in southern Belize, which is comprised of the Port Honduras Marine Reserve and the six watersheds that drain into it. Punta Gorda Town can be seen in the southern corner. The lower panel shows a Google Earth image of the goliath grouper nursery area at Deep River Estuary and the Punta Ycacos Lagoon. Wetland areas appear dark green.
3. Background/Rationale

Goliath groupers (*Epinephelus itajara*) are found throughout the Atlantic waters of Florida, the Caribbean, the Gulf of Mexico and south to Brazil. The full range and abundance of adult populations are unknown. However, in populations that are known, there has been an 80% decrease in the last 40 years, covering three generations (IUCN 2013).

Adult Goliath groupers inhabit both nearshore and offshore structures, such as coral reefs or shipwrecks, while juveniles prefer mangrove habitat, but also inhabit seagrass and estuarine habitats. Juveniles show high site fidelity and remain in nursery areas for 5-6 years (Koenig et al. 2007). The largest of the Western Atlantic groupers, they can grow to lengths exceeding 2 meters. The size at sexual maturity in the Gulf of Honduras is between 110cm - 115cm in length for males and 120cm – 135cm for females (Bullock et al. 1992).

The Goliath grouper, known for its consumption of venomous prey (Mumby et al. 2011), may be a natural regulator of the invasive lionfish (*Pterois volitans*). The Exuma Cays Land and Sea Park in the Bahamas has been closed to fishing for over 20 years and grouper biomass there is in the top 1% throughout the Caribbean. Within the marine park, lionfish biomass is significantly negatively correlated with grouper biomass, suggesting that groupers play a role in controlling lionfish (Mumby et al. 2011). While lionfish have been found in the guts of the Nassau grouper (*Epinephelus striatus*) and tiger grouper (*Mycteroperca tigris*), gut analyses of Goliath groupers are still underway in some areas (Frias-Torres 2012).

The Goliath grouper has been listed as critically endangered on the IUCN Red List since 1996, and is vulnerable to a number of threats. Its life history characteristics make it susceptible to overexploitation, with long life span, slow growth rate, late maturity and limited reproductive output as a result of small, brief spawning aggregations (Sadovy & Ecklund 1999). Overfishing is widely recognised as the largest threat to Goliath grouper, with habitat destruction another significant factor. Juvenile Goliath groupers spend much of their time within mangrove habitats, but in areas north of PHMR, shrimp farms and housing and hotel development are destroying important habitat (Graham 2009).

In southern Belize, Goliath grouper spawning is known to occur offshore in deep water, during the rainy season, in small aggregations and with no fixed location. Hence, local fishers pose little threat to reproductive success of individuals as aggregations cannot be easily targeted (Frias-Torres 2012). This information is helpful in eliminating this as a potential threat in the area.

Red mangrove habitat in the area encompassing the Punta Ycacos Lagoon and Deep River estuary (Map 1) is still intact and constitutes a vital nursery ground for Goliath grouper, believed to be one of only three major nursery grounds remaining in the world (Graham et al. 2009). Results from tagging exercises show that individuals from this area travel as far as Mahahual, Mexico, and La Ceiba, Honduras (Graham et al. 2009, 2010). Thus, this nursery could be critical in restocking the whole Mesoamerican Reef Complex. The area spans Payne’s Creek National Park (PCNP), the Port Honduras Marine Reserve (PHMR) and Deep River Forest Reserve and so it is protected from development, with the possible exception being made for oil exploration and drilling proposals by Providence Energy Ltd. The majority of the Punta Ycacos Lagoon system lies within PCNP, in which all fishing except for catch-and-release sport fishing is prohibited. Yet, the lagoon estuary and the Deep River estuary lie within PHMR, where hand-line fishing and set lines with single hooks are allowed. Set lines are the main method used to catch Goliath grouper and these estuaries are known locally as excellent fishing grounds for the species (Williams pers. comm.).

Goliath grouper abundance in the Punta Ycacos / Deep River estuary appears to be declining. Dr Rachel Graham of WCS found that over a five year period, 2006-2010, Goliath grouper catch per unit effort in the Deep River estuary declined by 50% (Graham et al. 2009). PHMR fishers also report declines in abundance and size of Goliath groupers over recent years. Dr Graham also conducted market landing surveys in Punta Gorda over a two year period, 2005-2007, and found that 99% of all landings had not reached the size of sexual
maturity (Graham 2009). Just three fishermen were responsible for catching over 50% of the Goliath grouper observed (Graham 2009). Landing surveys by TIDE at the Punta Gorda fish market (as part of a wider fisheries stock assessment) have also revealed an average Goliath grouper length of 66.3 cm, far below the minimum size at sexual maturity. In fact, of 209 Goliath groupers measured over the four-year period 2009-2012, only one was above the minimum adult length at sexual maturity.

Moratoriums on catching Goliath grouper have been in place in the continental USA since 1990; in the US Caribbean since 1993 and in Brazil since 2002, but so far there have been no specific protective measures in Belize. The need for immediate management of the Goliath grouper nursery in Belize was recommended in 2010 by Dr. Graham but, crucially, Fisheries Department support was lacking (Graham et al. 2009). Now, with the support of the Fisheries Department, TIDE intends to reopen the dialogue on legislation to protect the Goliath grouper. Preliminary discussions with fishers suggest size limits may be the most acceptable option. This would also be relatively simple to enforce since this regulation can be enforced at the landing site and/or market as well as on the water and the Fisheries Department already conducts routine inspections at Punta Gorda market.

The **long term outcome** of this project will be the sustainable management of Goliath grouper in Belize. This is attainable through the **overall project objective** of assisting the Belize Fisheries Department to introduce legal measures to protect Goliath grouper based on sound scientific evidence.

The specific **project objectives** are:

1) **To present the Belize Fisheries Department with sufficient evidence to inform national policy regarding sustainable management of Goliath grouper by means of three sub activities:**

   1.1 Literature review of current status of Goliath grouper
   1.2 Data collection – catch surveys at landing sites in Punta Gorda
   1.3 Report summarizing findings of sub-activities 1.1 and 1.2

2) **To establish legal protection for the Goliath grouper and formalise legal changes.**

3) **To make the majority of Belizean fishers aware of and adhere to any new legislation to protect Goliath groupers.**

This report aims to fulfill the requirements of Activity 1.3, and includes a summary of data collection activities carried out in fulfillment of Activity 1.2.

The objectives of Activity 1.2 were to:

i) Verify that existing data from the Punta Gorda fish market is representative of the situation throughout southern Belize;

ii) Provide further evidence that the fishery is unsustainable;

iii) Determine whether or not enforcement would be required at additional market places besides Punta Gorda fish market.
4. Methods

Fisheries Dependent Landing Site Surveys:

Data were collected by TIDE’s marine biologist, research assistant and community researchers on Goliath grouper landed at the Punta Gorda fish market and the informal landing site near to the UNO gas station 1-3 days per week over a four month period during opening hours of 7-10am between March and June 2014. For each specimen found, data were collected on numbers of fish, total length (TL) as the greatest length between the tip of the head and the tip of the tail, body length (BL) as the greatest length between the tip of the head and where the body meets the tail fin, total weight and gut content where possible. Gender analysis was attempted but unsuccessful due to gonads being in premature stage for most fish. Weights were recorded using the scales available and used by fishers at each landing site, and later converted into metric units. Gonads were removed where possible, photographed for maturity estimations to be made via communication with experts, and later weighed using a SciTech microbalance. Otoliths were extracted where possible, cleaned and stored for future analysis of the relationship between length, sexual maturity and age. The majority had no identifiable gonad development, probably due to their young age.

Size frequency distributions and mean values (+SE) for TL, BL and weight were calculated and are presented in this report. No population estimates were attempted owing to the small number of individuals sampled and the heavy bias towards juveniles.

While trained and experienced staff were already available to collect this data from landing sites in Punta Gorda from the beginning of the project, new staff had to be recruited and trained to carry this out at landing sites in Monkey River. This required waiting until the 2014 community researcher training program was completed in May 2014. This phase is now complete and data collection in Monkey River has begun. This will be incorporated into the study for comparison between sites once this dataset is large enough for statistical analysis.

Fisheries Independent Observations:

Two large dead floating Goliath groupers -
Additionally, during the market survey phase, PHMR ranger staff inadvertently discovered two large mature Goliath groupers floating dead in PHMR on separate occasions. While these could not be included in the market survey data as they did not represent catch by fishers, measurements were taken and subsequent results included and discussed in this report to provide further insight into the status of Goliath groupers in PHMR and surrounding areas (Figs. 9, 10).
Fig 2: Showing examples of data collection activities at landing sites in Punta Gorda. Through cooperation with local fishers who target Goliath grouper, TIDE was able to acquire data on total length, body length, weight, gut content, gonads and otoliths for 21 fish over the study period. TIDE now has a team of experienced community researchers capable of carrying out this work without causing negative impact to the market value of the meat:

From top right:

a) Researchers collecting data.

b) All Goliath groupers found in market surveys were under size at maturity.

C) Willie Caal, TIDE community researcher using his training to extract otoliths from Goliath grouper heads.

d) Example Goliath grouper catch from one fisher.

e) Tanya Barona (TIDE marine biologist) and Marty Alvarez (TIDE research assistant) taking measurements.

f) Goliath groupers at one Punta gorda landing site.

g) James Foley, TIDE science director performing gut content analysis.

h) Otolith of Goliath grouper extracted for later age/size: maturity studies.
5. Results

Fisheries Dependent Landing Site Surveys

A total of 23 Goliath grouper were examined between March and June 2014. Of these, 21 were found in landing site surveys in Punta Gorda, and 2 much larger individuals were found floating dead in Port Honduras Marine Reserve. All but three (18 total) of the marketed specimens surveyed were reported as caught in PHMR. Of these, 5 can be pinpointed to Deep River / Garobo Point area within PHMR. The remaining 3 were reported as caught in the Temash River area, south of Punta Gorda.

The two specimens found floating dead were not included in length and weight frequency analysis or mean calculations, as these constitute fisheries independent data while the focus of this study was on fisheries dependent market data.

Mean total length (TL) 2007-2014:

• **Mean total length remained statistically stable throughout studies between 2007-2014:** While there was an apparent overall increase in mean TL between 2007 and 2010 (Graham 2010), followed by an apparent decrease in 2014 (Foley & Alvarez 2014), there was no statistically significant difference between mean sizes in any year where sampling took place. This supports Graham’s (2010) conclusion that PHMR, Payne’s Creek and Deep River continue to function as a Goliath grouper nursery.

• While mean TL was identical (60.3cm) in both 2007 and 2014, greater standard error in 2014 compared with 2007 is likely due to the smaller sample size collected to date in 2014, and should reduce as market surveys continue.

![Mean total length captured Goliath Grouper 2007-2014](image)

Fig 3: Mean total length (TL) (+SE) fisheries dependent Goliath grouper catch data. 2007-2010 data from Graham’s WCS annual research report. 2014 data from this study (Foley & Alvarez 2014). No data are known to have been collected by any entity between 2011 and 2013 on Goliath grouper landings.
Total length (TL) % frequency distribution:

- Goliath grouper examined during market surveys had a total length (TL) between 35.5cm to 82.2cm with a mean (+SE) of 60.3 ± 2.9cm.

- 100% of the surveyed catch had TL less than minimum size at maturity of 110cm - 115cm for males and 120cm – 135cm for females (Bullock et al. 1992), compared with 99% in an albeit larger sample size by Graham in 2005-2007 (Graham 2009).

Fig 4: Total length (TL) % frequency (5cm size classes), fisheries dependent Goliath grouper catch data 2007-2014. Black dotted line is 40-inch size limit proposed but not yet enforced by Belize Fisheries Department in 2013; green and orange bars are size at maturity ranges for males and females respectively (Bullock et al. 1992). 2007-2009 data from Graham’s WCS annual research report (blue). Data not available for Graham 2010 TL % frequency. 2014 data (red) from this study (Foley & Alvarez 2014). No data are known to have been collected by any entity between 2011 and 2013.
Fig 5: Same data as in Fig. 4 for total length (TL) % frequency (5cm size classes), fisheries dependent Goliath grouper catch data 2007-2014. Presented separately for ease of viewing size distribution each year. 2007-2009 data recreated from Graham’s WCS annual research reports 2009-2011. Data not available for Graham 2010 TL % frequency. 2014 data from this study (Foley & Alvarez 2014). No data are known to have been collected by any entity between 2011 and 2013.

Fig 6: Mean total length (TL) % frequency ±SE (5cm size classes) from 2007, 2008, 2009 (Graham 2009) and this study 2014, fisheries dependent Goliath grouper catch data 2007-2014. Potential for use in setting future size limits. For example, if it was decided to continue allowing the largest 25% of the average population in PHMR to continue being harvested in an incremental approach to increasing size limits, this would equate to setting the size limit at 70cm (~27.5 inches) as denoted by black dotted line.
Body length (BL) & Weight % frequency distribution 2014:

- Body length (BL) ranged from 22.8cm to 60.9cm with a mean (±SE) of 48.1 ± 2.8cm with a similar distribution to TL.
- Weight ranged from 0.79 kg to 10.89 kg with a mean (±SE) of 4.06 ± 0.57 kg.
- Total weight of all recorded catch combined was 85.3 kg (188.1lbs).

Total Length: Body Length Ratio 2014:

- Difference between TL and BL ranged from 5.7cm to 21.3cm, with a mean TL:BL difference (±SE) of 12.23 ± 0.7cm.
- There was strong linear regression between total length and body length, with a high $R^2$ value of 0.934.
First dead floating Goliath grouper – 27th March 2014:

- The first of these was found in PHMR less than 1km due north of the mouth of Rio Grande river on 27th March 2014 with TL 250cm, BL 175cm, and total weight of 90.7 kg (200lbs). Gut content analysis revealed an empty stomach with two large southern stingray spines lodged in the gut and oesophagus. This specimen was too decomposed to carry out gonad analysis.

Fig 9: First dead Goliath grouper found floating in PHMR on 27th March 2014.

  a) TIDE staff retrieving specimen from mangroves where it had washed up.
  b) Stomach was bloat due to decomposition
  c) Full scale of specimen became apparent upon hauling it into the boat.
  d) Body was brought to TIDE Private Lands Ranger Station for measurements and necropsy
  e) TIDE research interns Julia Baker & Daryl Smith, and TIDE research assistant Marty Alvarez pose with grouper
  f) Elmar Requena (TIDE terrestrial biologist) and interns take measurements (TL: 2.5m)
  g) Performing necropsy, gut content, gonad analysis and otolith extraction.
  h) Two large (11-12cm) spines were found in stomach penetrating into surrounding tissue. Several local fishers were sure these are from southern stingray tail.
Second dead floating Goliath grouper – 20\textsuperscript{th} May 2014:

- The second specimen was found floating dead in PHMR close to the Frenchman Cayes range, not far from the location of the first specimen. TL 200cm, BL 175cm, total weight estimated at ~90kg due to difficulty in handling. Gut content analysis revealed empty stomach, but liver had various spines lodged in it, including lionfish spines, catfish spines, and a sting ray barb (Fig. 10). This specimen was also too decomposed to carry out gonad analysis.

![Fig 10: Second dead Goliath grouper found floating in PHMR on 27\textsuperscript{th} March 2014.](https://example.com/fig10)

a) Specimen was found in waters near Frenchman Cayes in Port Honduras Marine Reserve
b) Research team posing with the grouper
c) Some of the spines found in the stomach and liver. Large is southern stingray, small are thought to be catfish. Lionfish spines were also found.
d) Community researchers performing necropsy.
6. Discussion

PHMR, Payne’s Creek & Deep River are ecologically and economically important nursery areas to MAR region:
The close correlation between Graham’s 2007-2010 TL frequency data and that of this 2014 study increases confidence in both the results of this study, which are based on a much smaller sample size than Graham (2010), and in the findings Graham (2010) observed of a stable population structure biased towards younger individuals. The findings of this study also support Graham’s (2010) conclusion that PHMR, Payne’s Creek and Deep River continue to provide unique and ideal habitat as a Goliath groupers nursery, and that population structure in the study area is likely permanently skewed towards younger animals for this reason. This partly supports objective 1 of this study, to verify that existing data from the Punta Gorda fish market is representative of the situation throughout southern Belize. In terms of size structure of the population this appears true. It is likely that once they approach maturity they leave the area in search of adult phase barrier reef habitat throughout the MAR region.

Results from tagging exercises show that individuals from this area travel as far as Mahahual, Mexico, and La Ceiba, Honduras (Graham et al. 2009, 2010), underlining the importance of this site to reefs and economies across the wider MAR region. It is therefore in the interests of conservation and community organisations, the tourism sector, fisheries managers, governments, educators and fishermen to invest in conserving this priceless ecoregion, serving to protect the critically endangered Goliath groupers among an array of other endangered species including the West Indian Manatee (Trichechus manatus), to which these mangrove areas are also of crucial importance, and the Hawksbill Turtle (Eretmochelys imbricata), which also frequent these areas during their nesting season to feed in the associated seagrass beds.

Juvenile bias in catch:

*Gear related or juveniles targeted for ease and security?*
It is thought unlikely that fishing methods in the study area are responsible for inadvertently selecting younger animals from a more normal distribution, as set lines can attract and catch a wide size range of Goliath groupers according to local fishers. Set lines do not select for certain sizes in the way that nets or traps do. Goliath groupers are known by local fishers to be curious about many types of bait at any size, reducing likelihood that this is a major factor in why fishers catch mainly juveniles. It is more likely the areas fishers are choosing to hunt Goliath groupers are due to ease of access and reliability of catch. Even though one giant Goliath grouper can fetch a price hundreds of times greater than the value of a juvenile, the risk of venturing far out to sea in search of the ‘big one’ probably does not outweigh the security provided by ease of access and low seafaring risk to fishers of coastal mangrove habitat and the high predictability with which juveniles can be caught in these areas. It takes much greater investment, commitment and nerve to catch a large mature adult, and may be beyond the resources, skills, knowledge or desire of many fishers.

*Due to changes in fishing practices?*
It is known through conversations with PHMR fishers that some older fishers from fishing families that stretch back generations consider many younger fishers entering the fishery to lack their inherited knowledge about how to sustainably fish in the area, and therefore fish in ways in which older fishers see as unsustainable – for example, fishing aggregations of juveniles. It may be that as more new inexperienced fishers move into the fishery, they are increasingly sticking to safer more reliable sheltered coastal areas to fish, resulting in the juvenile bias in the catch. However, it this were the case, one would expect to see greater bias towards juveniles in 2014 than in 2007-2010, when in fact mean size did not decrease over this time significantly, although some stakeholders report experience a decline over recent years. Managed Access may have successfully controlled the trend of new fishers entering the fishery.

*Using Managed Access logbook data to estimate population density in 2014:*
In order to determine trends in catch per unit effort (CPUE) as a means to estimate population change since Graham’s (2010) study, a capture study would need to be repeated and compared with Graham’s (2010) CPUE...
findings. A less invasive but also probably less effective / accurate approach would be to attempt a coanalysis using Managed Access logbook data from fishers who target the species. Improvements are needed in methods to divide logged effort data from fishers’ logbooks in a multispecies, multigear subsistence fishery, but this data source may still shed clues on recent and future population trends. Consultation with key fishers to ensure data is collected honestly and accurately for this species is recommended prior to attempting such a study.

Protection of mangrove habitat critical to long-term survival of Goliath grouper:
Clearly, maintaining the integrity of the mangroves in these areas is critical to the long-term survival of this species. One reason it is critically endangered is because the habitat it depends upon is extremely vulnerable to development pressures from agricultural expansion, poorly planned tourism developments for (e.g. cruise ship docks, large scale resorts, marinas), increased pollution from urban development, increased sedimentation from rivers draining deforested areas, and potential widespread damage from oil exploration and drilling activities. Mangroves elsewhere in Belize and the wider MAR region have been heavily affected by development, and thus Payne’s Creek, Port Honduras and Deep River may constitute a ‘last stand’ nursery site for a large proportion of Goliath groupers patrolling the barrier reef today.

Lionfish – effective control method or threat to Goliath groupers?:
While there are signs that Goliath grouper have the potential to become a natural control measure for the invasive lionfish (Pterois volitans), it was disconcerting to find lionfish spines having penetrated through the stomach wall into the liver of one of the floating dead specimens, even though many other things could have caused its death. It will be important to know whether lionfish spines, or any other spines can be fatal to Goliath groupers that ingest them, as this has important management implications as it relates to future lionfish management strategies in Belize.

Management:
Protection and Compliance Issues:
Many Goliath groupers are long-lived (1–3 decades) and take many years (typically 5–10 years) to mature sexually, making them vulnerable to fishing for relatively long periods prior to entering reproductive function (Koenig, 2010). Protection in their juvenile phase is therefore critical to the long-term survival and reproducitvity of the species. However, it is also important that management tools such as size limits, gear restrictions, zoning restrictions and seasons are made with consideration for the needs of the local fishing community. Currently there is no directed legislation to protect Goliath grouper. Small scale MPAs provide insufficient protection for migrating individuals during reproductive periods and juveniles residing in PHMR.

Talks with local fishers suggest a 40-inch size limit is unlikely to be complied with by local fishers due to lack of larger individuals in the area, with the exception of occasional seasonal presence of a few mature adults, rendering this limit effectively an outright ban on fishing of Goliath grouper in PHMR and surrounding waters. Also, a 40-inch size limit alone would not protect smaller individuals from being weakened or severely damaged from swallowing hooks during accidental capture and subsequent release, as they are likely to be more vulnerable to predation after a tiring chase or hook related injury.

Percentage-based size limits:
A smaller size limit to start with may be a more effective first step to protect the most juvenile individuals, perhaps based on allowing the top 20-25% of the observed population to be harvested rather than a fixed length based limit (Fig. 6, pg. 11 & Fig. 11, pg. 17). While this is likely to attract criticism from proponents of either a size limit based on Bolluck’s et al. (1992) maturity-based estimation of 101.6cm (40 inches) or a full moratorium on harvesting of Goliath grouper, an incremental percentage based approach may ultimately constitute a more effective de facto conservation measure. This would be more likely to be complied with by fishers who are concerned that the proposed 40-inch national size limit does not reflect the size distribution found in PHMR, and would therefore effectively constitute an outright ban on fishing of the species in Southern Belize. Fishers always seek loopholes in laws they do not agree with or that do not work economically for them, and until effective landing site enforcement is in place, a 40-inch size limit may simply
push Goliath grouper commercial activity underground. Without compliance, this law could effectively amount to no protection, with no reduction in the time period during which Goliath groupers are vulnerable to fishing in their juvenile phase.

With the percentage approach, this would equate to setting the size limit for PHMR currently at ~70cm (~27.5 inches) as shown in Fig. 6, pg. 11. The time period during which Goliath groupers are vulnerable to fishing could be effectively reduced by 75%. Combined with continual monitoring of catch and CPUE, it would be possible to determine improvements in population density and maturity of the stock over time as a result of good compliance, and potentially gradually raise the size limit as confidence in the approach builds among fishers, while continuing to limit catch to the largest 20-25% of the population as average sizes increase (Fig. 11):

**Combined management approach: percentage based size limits and permanent or seasonal special management zones:**

Of course this still does not address the problem of potential damage to undersized fish during unintended capture and subsequent release. It is therefore recommended that the percentage based size limit be combined with a special Goliath grouper no-take zone to increase effective conservation of the species by providing a haven where they can remain free of fishing pressure in the areas known to be most critical nursery habitat. The most appropriate area would be the Deep River mouth area of PHMR based on catch records and consultations with fishers.

Failing this, seasonal protection during the reproductive season has been effective in various parts of the Caribbean (Sadovy 2012), and given that both the large dead floating specimens were found around the beginning of the estimated reproductive season, it seems likely that a seasonal closure approach of hotspot nursery areas would be most effective from March to August. This 6 month closure of special Goliath grouper no-take zones would halve the fishing pressure on the final 25% of the juvenile phase of fish residing in these areas, further promoting the recovery of the species.
7. Next Steps

With more data it will become possible to run length based assessments as defined by Froese (2004) and recommended by the Environmental Defense Fund for used in data deficient subsistence fisheries. This will be an important step in building empirically based models to set catch limits and reduce the risk of stock collapse and associated adverse social and economic impacts.

Data from Monkey River will be incorporated into this continuing study once the sample size is large enough of statistical analysis. It is thought likely from communications with local fishers that a similar situation will be observed in Monkey River in relation to size distribution of catch as found at Punta Gorda landing sites in this study so far.

Enforcement is required at other landing sites besides the Punta Gorda fish market, such as at the informal landing site near to the UNO gas station, where immature Goliath groupers are regularly landed by several fishers.

Further work is needed to elucidate spawning behavior that results in presence of juveniles in PHMR and to ascertain reproductive life history for goliath grouper in this region, as best estimates are currently from literature review of studies in other areas of the Caribbean.

*The findings of this ongoing research must be taken into consideration in the adaptive management process for Managed Access, and during consultations with the Government of Belize and Providence Energy over the prospect of seismic testing and drilling activities in close proximity to key Goliath grouper nursery areas.*

8. Acknowledgements

TIDE wishes to thank the US Fish and Wildlife Service for funding this work, the Belize Fisheries Department for their continued support, Marty Alvarez, TIDE research assistant for coordinating fieldwork, TIDE rangers for assistance with floating dead Goliath groupers, TIDE staff and interns for assisting with necropsies and measurements, TIDE community researchers for carrying out fieldwork, PHMR fishers for their cooperation in collecting this data.
9. References


Graham, R.T. (2009) Annual report of research activities to the Department of Fisheries, the Department of Forestry and primary NGO partners from the Wildlife Conservation Society (WCS).


Graham, R.T., Lewis, J.P., Gleiss, A.C., Scales, K. and Thompson, S. (2010) Annual report of research activities to the Department of Fisheries, the Department of Forestry and primary NGO partners from the Wildlife Conservation Society (WCS).


Williams, M. (2013) TIDE marine biologist and former fisherman, personal communication
10. Appendix

<table>
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<tr>
<th>Grouper Number</th>
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<th>Gonad Weight (g)</th>
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<th>BL (cm)</th>
<th>Weigh (g)</th>
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<th>Location</th>
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# samples 6.00 21.00 21.0 21.0
Mean 29.27 60.32 48.1 4.1
SD 13.59 13.24 13.0 2.6
SE 5.55 2.89 2.8 0.6
Total biomass 85.3

Table 1: Raw data, means, standard deviation and standard error for fisheries dependent Goliath grouper catch March – June 2014: gonad weight (g), total length (cm), body length (cm), weight (kg), stomach contents and location found. Total biomass of surveyed fish included. Note: pink = dead floating fisheries independent data.

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Table 2: Mean total length (TL), standard deviation (SD) and standard error (SE) and sample size of fisheries dependent Goliath grouper catch data. 2007-2010 data from Graham’s WCS annual research report. 2014 data from this study (Foley & Alvarez 2014). No data are known to have been collected by any entity between 2011 and 2013.