A Preliminary Assessment of the Abundance and Size Distribution of Goliath Grouper *Epinephelus itajara* Within a Defined Region of the Central Eastern Gulf of Mexico

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ABSTRACT

Fishing for goliath grouper was banned in United States waters in 1990 after a noted dramatic decline in population numbers. After eighteen years of protection, the species is reportedly showing signs of recovery along the west coast of Florida, with increasing accounts of underwater sightings and capture on hook and line. To assess the abundance and size distribution of adult goliath grouper within the study region, designated sites have been established over natural and artificial habitat across a range of depths (7 - 45 meters). These sites are visited regularly to identify seasonal changes in fish presence. Research has been ongoing since November 2007 and goliath grouper have been observed during 70% of all surveys (94/132 dives). When present, the minimum number observed at a site has ranged between one and 25 individuals. Abundance of individuals was significantly higher over artificial habitat and increased with site depth. Identification tags have been attached to 113 fish and 15 re-sightings have been reported. Time at large has ranged from 1 – 204 days (mean = 47 days), and straight line distance between sightings has been measured to 203 kilometers. However, the majority of re-sights occurred at the initial tagging site. Research is ongoing but these preliminary data are providing information regarding the population of goliath grouper within a defined study region.

KEY WORDS: Goliath grouper, jewfish, artificial reefs

Una Evaluación Preliminar de la Abundancia y la Distribución de Tamaño del Mero Cherna, *Epinephelus itajara* dentro de una Región Definida del Golfo de México Oriental

La pesca para el mero cherna fue prohibida en las aguas de los Estados Unidos en 1990 después de un desclive dramático de la población. Después de 18 años de protección, hay indicios de restablecimiento por la costa occidental de Florida. Para evaluar la abundancia y la distribución de tamaño del mero cherna dentro de la región del estudio, sitios designados han sido establecidos sobre hábitat natural y artificial a través de una gama de profundidades (8 - 40 metros). Estos sitios son visitados regularmente para estimar la abundancia y el tamaño de los peces. Los peces son marcados para colectar información con respecto al fidelidad del sitio y pautas de movimiento. Investigaciónes empezaron en noviembre 2007 y hemos visto más de 360 meros cherna durante 112 muestreos. El número de peces observados en un sitio es entre 1 y 20 individuos. La mayoría de individuos han sido en hábitat artificial a través de la gama de profundidades. Peces se miden con láseres y video; casi todo peces excedieron el tamaño mínimo de madurez. Buzos científicos han marcado 101 peces, y 17 se han observado subsiguientemente entre períodos de un día y siete meses. La mayoría de estos peces se encontraron en el sitio inicial de marcacion, pero varios individuos se encontraron hasta 26 kilómetros de su sitio de marcacion. Aunque preliminar, estos datos proporcionen información con respecto a la población de mero cherna dentro de una región definida.

PALABRAS CLAVES: Mero cherna, Golfo de Mexico, marcación

Première Estimation de L'abondance et de la Distribution de Taille du Merou Goliath, *Epinephelus itajara*, À L'interieur D'une Region D'étude Definié dans la Region Centrale-est du Golf du Mexique

La pêche du mérou Goliath a été interdite dans des eaux des Etats-Unis en 1990 après une baisse spectaculaire des populations. Après dix-huit ans de protection, l'espèce montre des signes de rétablissement le long de la côte ouest de la Floride, avec une augmentation des rapports d'observation et de capture à la ligne. Pour évaluer l'abondance et la distribution de taille du mérou Goliath dans la région d'étude, des sites spécifiques ont été établis à partir d'habitats naturels et artificiels à travers une gamme de profondeurs allant de 8 à 40 mètres. Ces sites sont régulièrement visités pour évaluer l'abondance et la distribution de taille des poissons présents. Les poissons sont marqués avec des étiquettes d'identification lors de plongées sous-marines de surveillance pour recueillir des informations quant à la fidélité du site et des profils de déplacement des poissons. L'étude s'est déroulée de novembre 2007 à ce jour, plus de 360 mérous Goliath sightings ont été enregistrés en 112 plongées. Le nombre de poissons observés sur un site va de 1 à vingt individus. La majorité des individus a été observée sur habitat artificiel sur l'ensemblle de la gamme de profondeur analysée. Les poissons sont mesurés à l'aide de lasers sous-marins et par vidéo; presque tous ont dépassé la taille minimale de maturité établie pour cette espèce. Les plongeurs scientifiques ont marqués 101 poissons à ce jour; 17 ont put être re-observés de 1 jour et de sept mois après marquage. La plupart des poissons re-observés l'on été au niveau de leur site de marquage initial, mais plusieurs individus ont été observés jusqu'à 26 kilomètres de leur site de marquage initial. Bien que préliminaires, ces données fournissent des informations relatives à la population de mérou Goliath à l'intérieur d'une zone d'étude définie.

MOTS CLÉS: Mérou Goliath, Golfe du Mexique, marquage

INTRODUCTION

Goliath grouper (Serranidae: *Epinephelus itajara*) occur in tropical and subtropical waters from the west coast of Africa to the east coast of Florida, south to Brazil, and throughout the Gulf of Mexico. As one of the world's largest groupers, individuals may reach 2.5 meters (m) in length and exceed 400 kilograms (kg) (FAO 2005). Goliath grouper have been aged to 37 years and mature relatively late (between 5 – 7 years and 1 m total length [TL]) (Bullock *et al.* 1992). They tend to aggregate near underwater structure (i.e., ledges, artificial reefs or bridges, NMFS 2006), and are typically unwary of divers. These life history and behavioral characteristics increase vulnerability to exploitation and extend the time required for population recovery (Sadovy and Eklund 1999). Harvest of this species was banned in U.S. waters in 1990 after an alarming decline in population numbers, evidenced through reports from the public as well as fishery landings data (Sadovy and Eklund 1999). In 1994, *E. itajara* was listed as critically endangered on the IUCN World Conservation Union's Red List of Threatened Species (www.iucnredlist.org). The species has since been protected in Brazil (2002), Puerto Rico (2004), and the US Virgin Islands (2004; NMFS 2006). However, fisheries remain in other parts of the Caribbean, and the status of goliath grouper throughout its entire geographic range remains unclear.

After nearly 16 years of protection in the United States, a status report showed a significant increase in goliath grouper abundance throughout U.S. waters, and NOAA removed goliath grouper from the species of concern list in February 2006 (NMFS 2006). Increasing reports of goliath grouper sightings as well as growing public perception that the species is recovering has created a push among several fishing sectors within the state of Florida for a re-evaluation of state and federal goliath grouper management strategy. Delisting of the species and the noted rebound in population numbers has spurred public interest to reopen the fishery. However, changes in regulation or management should be considered carefully as the life history and behavioral attributes of goliath grouper increase susceptibility to overfishing.

Estimating population size has been identified as a top research priority for goliath grouper stock assessment (SEDAR6 2004), but as traditional fishery-dependent data are not available (i.e., landings data, fish houses, dock interviews) estimates of population size and recovery are dependent upon directed research efforts. The most current abundance estimates for adults remain limited to Reef Environmental Education Foundation (REEF) survey reports and localized accounts by the fishing and diving communities (Porch *et al.* 2004). Although useful, these data do not consistently include size distributions or standardized sampling throughout seasons. Additionally, most REEF surveys were completed in the Florida Keys or along the southeast coast of Florida (Porch *et al.* 2006). Before the harvest moratorium, the majority of commercially harvested goliath grouper were landed along Florida's Gulf coast (Bullock *et al.* 1992), which is believed to be a center of abundance for this species (Koenig *et al.* 2007). The aim of this research was to utilize directed monitoring of specific sites along the central west coast of Florida to identify potential patterns in seasonal abundance, size distribution, or habitat use. Data gathered from this study can be integrated with existing information from adjacent regions (e.g. Eklund and Schull 2001, Coleman and Koenig 2003, Frias-Torres 2006, Koenig *et al.* 2007) to help provide a more complete picture of the status of goliath grouper in U.S. waters.

METHODS

Twenty four survey sites were established to include a range of depths and habitat types (19 artificial, 5 natural; Figure 1). Sites were distributed into three depth ranges: shallow (0 - 14 m), mid-depth (15 - 29 m) or deep (≥ 30 m), and were revisited at least every three months (many sites were visited more often, depending on weather conditions). Additional locations in the surrounding area of established sites were surveyed opportunistically during sampling trips to provide additional information. Sites were categorized as artificial or natural habitat. Artificial habitat was defined as man-made structure, and primarily included shipwrecks. Natural habitats sampled within the study area consisted of limestone outcroppings (ledges) that could be completely surveyed (from one end to the other) within a single dive. Depth, length, width and vertical relief were measured at each established site, and habitat features were documented using underwater video. Water quality parameters (temperature, dissolved oxygen and salinity) were recorded prior to each survey using a handheld YSI, and horizontal visibility was qualitatively assessed during each dive by the surveyor. Dives performed in visibilities less than 3 meters are not included in the abundance analyses. Underwater surveys were performed using SCUBA, and a single researcher (ABC) performed all surveys. Goliath grouper abundance was estimated during a thorough visual assessment of the entire site upon arrival. To minimize the chance of double-counting individuals, abundance values are minimum estimates defined as the number of fish encountered during a systematic one-way survey of the area. At the beginning of each dive, a pair of divers swam methodically in a single direction from one end of the site to the other in order to survey the entire structure. Observed fish were documented using underwater video. During filming, a laser apparatus (fitted to the top of the camera housing) projected equidistant points onto the subject. To obtain size estimates, still frames of recorded fish were cut from the underwater video and imported into image analysis software (Image Pro Plus). Total length (TL) was estimated only for fish that were filmed perpendicular to the optical axis of the camera.

After the initial survey, goliath grouper at each site were opportunistically dart tagged beneath the dorsal fin via a modified spear gun. Dart tags included a large plastic identification tag (6.5 cm x 3 cm) to increase visibility and resighting potential. A tagging hotline telephone number was prominently displayed to encourage angler reports of fish captured on hook and line. The date, time, location and tag condition are recorded for each resighted or recaptured fish.

To identify preliminary relationships between abundance and habitat type, season or depth range, mean abundances for each treatment were compared using the Kruskal-Wallis one way ANOVA. Seasonal differences in abundance were compared only for the 24 established sites that had replicate visits. As data collection and analysis is currently ongoing, only three artificial sites were chosen (one shipwreck was chosen within each depth range; all three sites were relatively similar in size) for a preliminary description of the relationship between size distribution of individuals over depth range and season.

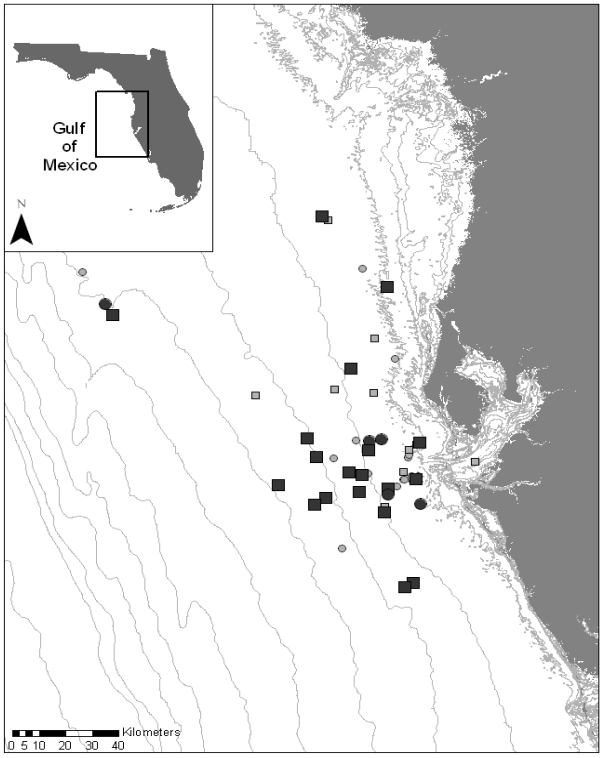

Figure 1. Study location along the central west coast of Florida. Small symbols indicate all sites surveyed at least once between November 2007 and August 2008. Larger symbols indicate the 24 established sites that were surveyed seasonally. Habitat type is indicated as natural structure (circles) or artificial structure (squares).

RESULTS

Fifty two different sites (23 natural, 29 artificial) were surveyed at least once during 132 dives between October 2007 and August 2008 (Figure 1). Site depth ranged between 7 and 45 meters. Dive trips were completed during all months of the study period. Goliath grouper were present during 88% of all dives over artificial habitat (84/96 dives; 29 sites) and during 28% of all dives over natural structure (10/36 dives over 23 sites). Twenty four locations designated as replicate sites (5 natural, 19 artificial) were revisited seasonally (at least every 10 - 12 weeks). Overall, mean number of individuals observed was significantly higher over artificial habitat (mean = 4.67) than over natural structure (mean = 0.36) ($p < 0.001$). This pattern of higher abundance at artificial sites was consistent over all depth ranges and seasons ($p < 0.01$; Figure 2).

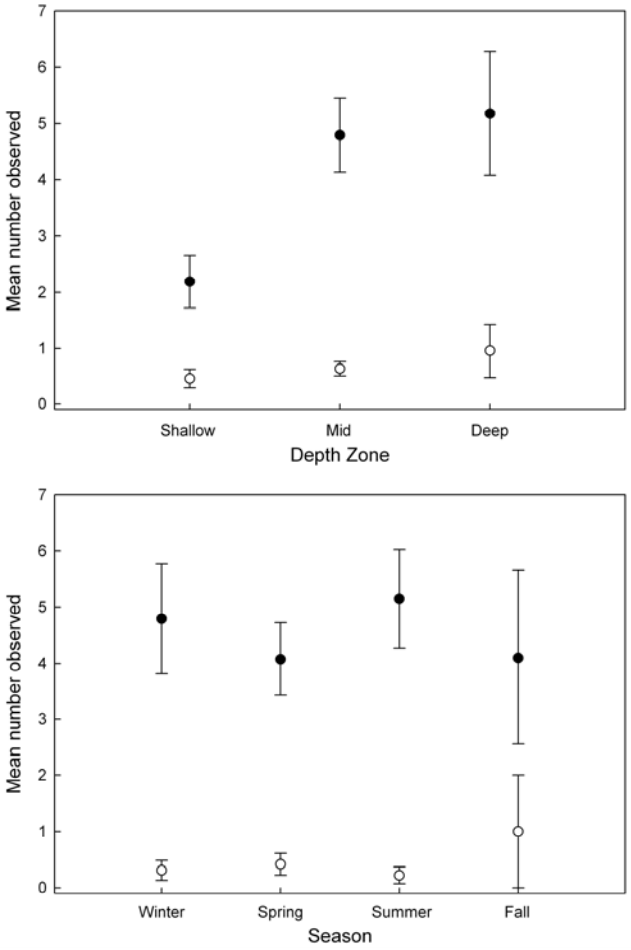

Figure 2. Mean number of goliath grouper observed by depth zone (top graph) and season (bottom graph) over all completed surveys (n=132). Filled circles indicate artificial habitat; empty circles indicate natural habitat. Depth zones are classified as shallow (0-14 m), mid (15-29 m) or deep (≥30 m). Seasons are designated as winter (December – February), spring (March – May), summer (June – August) and fall (September – November).

The maximum number of individuals observed at a single site was 25, and this was recorded at an artificial reef in August 2008 (depth = 36 m). In general, highest numbers of goliath grouper were observed over artificial habitats in the deep (≥ 30 m) depth range. There was a weak positive relationship between the number of fish observed and site depth (linear regression, r = 0.395; F = 17.42, p < 0.01; Figure 3). Differences between seasons were not significant within shallow or mid-depth ranges, but higher abundances of individuals were observed at deep sites during winter sampling (Figure 4). Highest variability in abundance of goliath grouper was attributed to between site variations as the abundance within a single site remained fairly consistent throughout sampling (Figure 5).

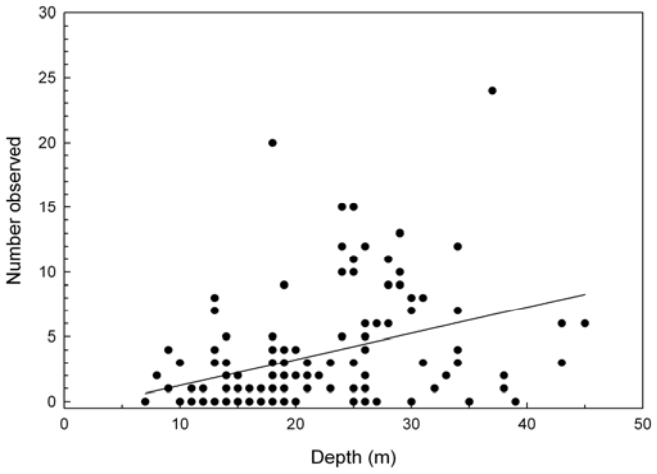

Figure 3. The relationship between site depth and the number of goliath grouper observed over all completed surveys (n = 132). Linear regression (r = 0.364, p < 0.01).

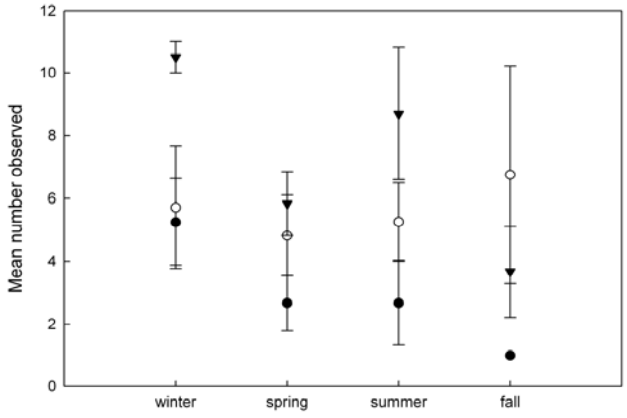

Figure 4. Mean number of goliath grouper observed by depth range over all seasons. Data is presented for established sites (n=24) only. Depth ranges are indicated as shallow (filled circles), mid-depth (empty circles) or deep (filled triangles).

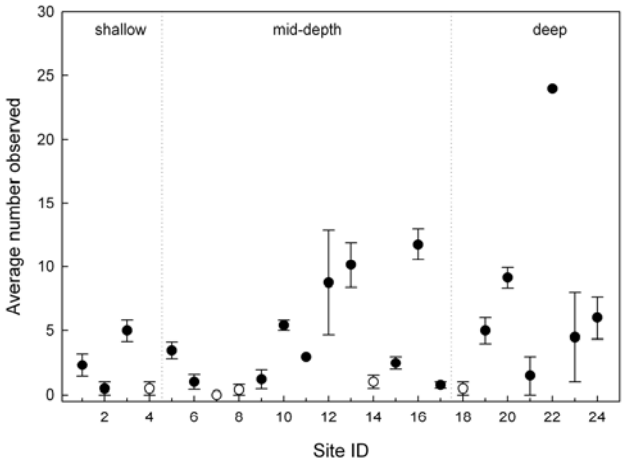

Figure 5. Mean number of goliath grouper observed at each of 24 established sites throughout the study period. Dotted lines indicate divisions between depth zones (shallow, mid-depth and deep; left to right). Habitats are indicated as artificial (filled circles) or natural (empty circles).

One hundred and thirteen goliath grouper were fitted with external ID tags between November 2007 and August 2008. Thirteen fish have been resighted at least once, and two individuals have been resighted twice since their initial tagging date. Length of time between resightings ranged between 1 and 204 days (Table 1). One individual was recaptured 203 km from its initial tagging location after 204 days; however, most resightings occurred at the site of the fish's initial tagging (Table 1).

Table 1. Tag/recapture data for goliath grouper that have been re-sighted since their initial tagging date. Time at large indicates number of days between tagging and re-sight(during underwater surveys) or recapture (* = caught by angler via hook and line). Distance corresponds to straight line distance between site of initial tagging and location of re-sighting event.

Resight	Tag date	Resight date	Time at large (days)	Distance (km)
1	12/1/07	6/22/08*	204	203
2	12/29/07	7/20/08	204	29
3	2/4/08	5/30/08	116	0
4	4/2/08	4/3/08	1	0
5	4/2/08	4/3/08	1	0
6	6/3/08	7/10/08	37	0
7	6/3/08	6/11/08*	8	18
		7/10/08	29	0
8	6/4/08	7/4/08	30	0
9	7/10/08	7/23/08	13	0
10	7/18/08	7/27/08	9	0
11	7/20/08	7/23/08	3	0
12	7/20/08	7/23/08	3	0
13	8/8/08	9/4/08	27	0
		9/28/08	24	0

Preliminary analysis of goliath grouper size distribution over three artificial reef sites did not display a significant relationship between season or site depth. Total length of individuals ranged from 75 – 182 cm at the shallow site, 96 – 147 cm at the mid-depth site and 72 – 180 cm at the deep site (Table 2).

Table 2. Minimum and maximum size estimates from underwater video for three established artificial sites visited throughout the study period. Seasons are defined as winter (December – February), spring (March – May) or summer (June – August). As data collection began in November 2007 and is ongoing at this time, fall data are not presented.

Wreck ID	Date	Season	Number of fish observed	Minimum size (TL, cm)	Maximum size (TL, cm)
Shallow "A" (13 m)	1/11/2008	Winter	7	99	139
	2/8/2008	Winter	8	75	182
	3/12/2008	Spring	4	69	167
	5/7/2008	Spring	3	78	151
	6/24/2008	Summer	4	89	172
Mid-depth "B" (24 m)	2/15/08	Winter	15	100	131
	4/11/08	Spring	12	96	120
	7/10/08	Summer	15	124	147
Deep "C" (31 m)	12/29/08	Winter	11	76	162
	2/15/08	Winter	10	80	180
	4/2/08	Spring	9	72	174
	4/27/08	Spring	8	81	154
	7/18/08	Summer	13	105	145

DISCUSSION

Quantifying goliath grouper abundance and distribution at established sites through directed, long-term monitoring will provide baseline data that can be useful during future stock assessment or management. The preliminary data presented herein reinforce reports that goliath grouper are most often found around artificial habitat (Heemstra and Randall 1993, NMFS 2006). This tendency to aggregate at artificial reefs contributes to the species' vulnerability to exploitation, as large numbers of goliath grouper can consistently be associated with specific sites (Sadovy and Eklund 1999). Abundances of goliath grouper over artificial habitat were significantly higher than over natural bottom over all depths and seasons. Natural habitat within the study area exhibited lower densities and sporadic occurrence of goliath grouper, while surveys at artificial reefs demonstrated higher densities and consistent presence throughout the year. Natural hard bottom habitats along the central west coast of Florida consist primarily of limestone outcroppings and ledges. Although many of these have substantial undercuts and large crevices (habitat characteristics preferred by goliath grouper; NMFS 2006), vertical relief of sites within the survey area typically does not exceed 3 meters (Collins Pers. observation). Artificial habitats surveyed during this research consisted primarily of shipwrecks, which can provide substantial vertical relief (4 - 10 meters) as well as increased shelter. It is suspected that the increased vertical relief provided by shipwrecks provides foraging and/or refuge benefits. There are over 2,400 artificial reefs that are currently documented within state and federal waters surrounding Florida (Florida Fish and Wildlife Conservation Commission, myfwc.com). Increased efforts to consistently monitor these documented sites may help provide minimum abundance estimates for goliath grouper within this region.

Goliath grouper abundance was positively correlated with site depth, with highest numbers of goliath grouper observed during surveys of the deep zone (≥ 30 m). This pattern was especially evident during winter (December – February) months. Gilmore (1978) noted the movement of goliath grouper into deeper water after a cold weather event, and it is possible that the increased abundance observed during winter months is a behavioral response to seasonal changes in temperature. Further investigation is currently ongoing to compare site characteristics in addition to depth (length, width and relief of the artificial structure) with abundance. Sites in the deeper depth zone were generally larger, so the observed increased number of fish observed may be confounded by the size and physical attributes of each structure. Surveys performed in visibilities less than 3 m were not included in the data analysis, but it is still possible that limited visibility at shallower sites (3-5 m) had a negative affect on the observer's ability to detect all fish present. During periods of lower visibility, goliath grouper behaved more cautiously and reacted negatively to the laser beams (quick retreats from divers and increased number of warning booms; A. Collins personal observation). This behavior was not as pronounced when visibility improved.

Seasonal changes in mean abundance are not evident at this point, as the number of individuals observed per site remained consistent over the study period and there were not significant differences in abundance between seasons. However, these data should be interpreted cautiously as

data collection is ongoing and the data herein represent only 10 months of research (November 2007 – August 2008). It is not apparent whether the individuals at each site consisted of resident or transient fish, and preliminary tagging data indicates that movement patterns may vary considerably between individuals. Site fidelity has already been noted for adults of this species (Smith 1976; Eklund and Schull 2001) as well as juveniles (Koenig *et al.* 2007; Eklund and Schull 2001). Similarly, the majority of re-sighted fish in this study were observed at their initial tagging site. Conventional tagging methods allow minimum estimates of distances moved, but provide no information regarding fish behavior between capture events. Further research (i.e. acoustic telemetry studies) should be directed toward gathering these types of data to lend insight to continuous, long-term behavioral patterns.

For the three artificial sites analyzed, no immediate relationship is evident between fish size distribution and depth range or season. An interesting fact emerging from this research is that smaller than expected individuals (<100 cm TL) are appearing within all depth ranges surveyed. Size at maturity (and expected ontogenetic emigration from inshore nursery habitat) is ~ 1 m TL (Bullock *et al.* 1992), so the observation of small individuals, especially at deeper sites farther offshore, is intriguing.

Research along Florida's southwest coast has provided substantial data regarding goliath grouper juvenile abundance and behavior (Eklund and Schull 2001, Cass-Calay and Schmitt 2003, Frias-Torres 2006, Koenig *et al.* 2007). There is anecdotal evidence that adult abundance has increased since protective measures were implemented in 1990, and directed efforts to quantify population size and distribution are needed (SEDAR6 2004). The goal of this ongoing project is to characterize the abundance and size distribution of goliath grouper within a defined geographic region via repeated surveys at designated sites. Quantitatively assessing the spatial and temporal distribution of fish per habitat type and depth range, in addition to movement information that can be obtained through tag/recapture data, is invaluable information for future management or regulation. Abundance estimates for goliath grouper from specific sites over time can potentially indicate changes in population size, distribution and recovery within the surveyed area. At the very least, these types of data can provide a baseline for comparison during future stock assessment (Porch and Eklund 2004). Patterns in fish abundance as well as size distribution should provide some indication of species recovery and status within the study area. These data can be integrated with existing information from other regions to help provide a more complete picture of the status of goliath grouper in U.S. waters.

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LITERATURE CITED

Bullock, L.H., M.D. Murphy, M.F. Godcharles, and M.E. Mitchell. 1992. Age, growth and reproduction of jewfish *Epinephelus itajara* in the eastern Gulf of Mexico. *Fishery Bulletin* **90**:243-249.

Cass-Calay, S.L. and T.W. Schmidt. 2003. Standardized catch rates of juvenile goliath grouper, *Epinephelus itajara*, from the Everglades National Park Creel Survey, 1973- 1999. Sustainable Fisheries Division Contribution SFD-2003-0016. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida USA. 17 pp.

Coleman, F.C. and C.C. Koenig. 2003. Population density, demographics, and predation effects of adult goliath grouper. NOAA Final Report. MARFIN Grant No. 0548-0175. National Oceanic and Atmospheric Administration. 18 pp.

Eklund, A. and J. Schull. 2001. A stepwise approach to investigating the movement patterns and habitat utilization of jewfish, *Epinephelus itajara*, using conventional tagging, acoustic telemetry, and satellite tracking. In: Sibert, J. and J.L. Nielsen (Eds.) *Electronic Tagging and Tracking in Marine Fisheries Research: Methods and Technologies in Fish Biology and Fisheries. Volume 1*. Kluwer Academic, Netherlands.

FAO (Food and Agriculture Organization of the United Nations). 2005. In: K.E. Carpenter (Ed.). *The Living Marine Resources of the Western Central Atlantic. Volume 2: Bony Fishes part 1 (Acipenseridae to Grammatidae). FAO Species Identification Guide for Fishery Purposes*. Rome, Italy.

Frias-Torres, S. 2006. Habitat use of juvenile goliath grouper Epinephelus itajara in the Florida Keys, USA. *Endangered Species Research* **1**:1-6.

Gilmore, R.G., L.H. Bullock, and F.H. Berry. 1978. Hydrothermal mortality in marine fishes of south-central Florida January 1977. *Northeast Gulf Science* **2**:77-97.

Heemstra, P.C. and J.E. Randall. 1993. *FAO Species Catalogue. Groupers of the World (Family Serranidae, subfamily Epinephelinae). An Annotated and Illustrated Catalogue of the Grouper, Rock Cod, Hind, Coral Grouper and Lyretail Species Known to Date*. FAO Fisheries Synopsis 16 (125), 382 pp.

Koenig, C.C., F.C. Coleman, A.M. Eklund, J. Schull, and J. Ueland. 2007. Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara*). *Bulletin of Marine Science* **80**:567-586.

NMFS. 2006. Status report on the continental United States distinct population segment of the goliath grouper (*Epinephelus itajara*). January 12, 2006. 49 pp.

Porch, C.E. and A.M. Eklund. 2004. Standardized visual counts of goliath grouper off south Florida and their possible use as indices of abundance. *Gulf of Mexico Science* **2**:155–163.

Porch, C.E., A.M. Eklund, and G.P. Scott. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. *Fishery Bulletin* **104**:89-101.

Sadovy, Y. and A.M. Eklund. 1999. Synopsis of the biological data on the Nassau grouper, *Epinephelus striatus* (Bloch 1972) and the jewfish, *E. itajara* (Lichtenstein 1822). U.S. Dep. Comm., NOAA Tech. Rep. NMFS 146, and FAO Fisheries Synopsis 157. 65 pp.

SEDAR6. 2004. The goliath grouper in southern Florida: assessment review and advisory report. Report prepared for the South Atlantic Fishery Management Council, the Gulf of Mexico Fishery Management Council, and the National Marine Fisheries Service. vi +17 pp.

Smith, G.B. 1976. *Ecology and Distribution of Eastern Gulf of Mexico Reef Fishes*. Florida Marine Research Publication No. 19. 78 pp.