

Recovery of the Goliath Grouper (*Epinephelus itajara*) Population of the Southeastern U.S.

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ABSTRACT

Reef fishes across the globe are threatened by human exploitation as well as the adverse effects of pollution, habitat destruction, and climate change. Many species are fished almost out of existence. One such species is the goliath grouper, *Epinephelus itajara*, which is considered critically endangered by the IUCN throughout most of their range from North Carolina to Brazil in the western Atlantic and from Senegal to the Congo in the eastern Atlantic (the Pacific population was recently deemed a separate species, *E. quinquefasciatus* (Craig *et al.* 2009)). The exception to this depletion is in Florida, where goliath grouper populations have been recovering since the fishery closure in 1990. The dive surveys submitted by volunteer dive surveyors to the Reef Environmental Education Foundation (REEF) over the past 15+ years (n = 27,542) document the recovery of goliath grouper throughout their former range in the United States. The recovering population initially increased off southwest Florida, directly offshore of the high-quality mangrove nursery of the Ten Thousand Islands. From there the population grew to the north and south, eventually increasing off Florida's central east coast. It is clear that a dominant factor in recovery is high-quality mangrove habitat. Understanding these patterns of population recovery ensure appropriate management policies.

KEYWORDS: Goliath grouper, *Epinephelus itajara*, fish recovery

Recuperación de la Población del Mero Goliath (*Epinephelus itajara*) del Sureste de los Estados Unidos

Peces de los arrecifes de coral son amenazados por la explotación humana, contaminación, destrucción del hábitad natural y el cambio climático. Muchas de las especies son pescadas hasta casi el punto de erradicación. Una de estas especies es el mero Goliath, *Epinephelus itajara*, considerado en peligro de extinción por la IUCN, dado a las pocas observaciones documentadas en el transcurso de su distribución histórica en el Atlántico, desde Carolina del Norte hasta Brasil y de Senegal hasta el Congo (La población observada en el Pacífico ha sido recientemente reconocida como una especie distinta, *E. quinquefasciatus* (Craig *et al.* 2009)). La excepción a estas observaciones se encuentra en Florida, donde el mero Goliath se encuentra recuperándose, a partir del cierre de su pesca desde 1990. Los sondeos enviados por buzos voluntarios a la Reef Environmental Education Foundation (REEF) en los últimos 15+ años (n = 27542) documentan la recuperación del mero Goliath sobre su distribución en los Estados Unidos. La población en recuperación, inicialmente incremento en el suroeste de Florida, en las afueras del área conocida como Ten Thousand Islands, un hábitad de mucha importancia y alta calidad para juveniles. Luego, la población siguió incrementando hacia el norte y el sur, y las afueras de la costa este-central de Florida. Por lo tanto, queda claro que uno de los factores dominantes para la recuperación de esta población, es la alta calidad del hábitad de manglares. Conocer el patrón de las tendencias de recuperación de la población aseguran la generación de políticas de manejo apropiadas.

PALABRAS CLAVES: Mero Goliath, *Epinephelus itajara*, recuperación de peces

Déplacement et Modeles de Distribution de la Population de Recuperation du Mérou Goliath en Floride

Les poissons de récif à travers le monde sont menacés par l'exploitation humaine, ainsi que par les effets néfastes de la pollution, la destruction de l'habitat et les changements climatiques. De nombreuses espèces sont pêchées presque hors existence. Une de ces espèces est le mérou goliath, *Epinephelus itajara*, qui est considérée comme gravement menacée d'extinction par l'IUCN. Peu d'observations ont été documentées pendant presque toute leur aire de répartition historique dans l'Atlantique de Caroline du Nord au Brésil et du Sénégal au Congo (la population du Pacifique a été récemment considérée comme une espèce distincte, *quinquefasciatus* E. (Craig *et al.* 2008)). L'exception à cette tendance est en Floride, où les populations de mérou goliath se redressent depuis la fermeture de la pêche en 1990. Nos enquêtes sous-marines (n = 695) ainsi que celles adressées à la Reef Environmental Education Foundation (REEF) au cours des dernières 15 + ans (n = 27542) le document de la récupération de mérou goliath au long de leur ancienne aire de répartition dans les États-Unis. La population de récupération initialement a augmenté au large de la Floride du sud-ouest au large des côtes de la pépinière de mangrove de haute qualité de la Ten Thousand Islands. De là, la population s'est accrue au nord et au sud, augmentant finalement au large des côtes du Centre-Est de la Floride. Des adultes étiquetés (n = 2044) et des juvéniles (n = 2963) montrent une fidélité extrême au site, tant dans la pépinière essentielle de la mangrove (Koenig *et al.* 2007) que sur les récifs au large. Les déplacements de grandes distances semblent être associés aux migrations de reproduction et à l'émigration de l'habitat au large de juvéniles à adultes. Comprendre ces formes de la reconstitution de la population et du déplacement peut garantir que les politiques de gestion appropriées soient mises en œuvre dans les États-Unis et à l'étranger.

MOTS CLÉS: Mérou goliath, *Epinephelus itajara*, déplacement des poissons, gestion des pêcheries

INTRODUCTION

Goliath grouper (*Epinephelus itajara*) is the largest grouper in the western hemisphere, reaching lengths of over 3 m and weights of 350 – 450 kg. The species ranges in the western Atlantic from North Carolina (Francesconi and Schwartz 2000) through the Gulf of Mexico and Caribbean to southeastern Brazil. While they occur in the eastern Atlantic along the west coast of Africa, Craig *et al.* (2009) suggest that the African population may have gone extinct because none have been observed or captured in the fishery for over 10 years. Recently, the population in the Pacific, which ranges from the Gulf of California to Peru, has been determined to be a distinct species, *E. quinquefasciatus* (Craig *et al.* 2009).

In the United States, goliath grouper briefly supported both commercial and recreational fisheries, primarily in the Gulf of Mexico off Florida. Populations were rapidly overexploited and the fisheries were closed in 1990 in federal and state waters of the United States and in U.S. territories in the Caribbean in 1993. Today, goliath grouper are considered critically endangered throughout their global range (IUCN 2008), and continue to be listed as overfished in the United States (NMFS 2009). The actual status of the adult population remains unknown, making it difficult for NMFS to develop management measures aimed at either rebuilding the fishery, ending overfishing, or both, as required by the Sustainable Fishery's Act. Because the population is recovering off the Gulf and Atlantic coasts of Florida, NMFS is being asked by commercial and recreational fishers to consider reopening the fishery at some level, while concomitantly being asked by conservation groups to continue protection and establish a rebuilding plan.

This paper will describe the expansion of the goliath grouper population of the southeastern U.S. since the closure of the fishery in 1990. In this study, we use the Reef Environmental Education Foundation (REEF) goliath grouper survey data and describe the pattern of recovery over a 15-year period from 1994 to 2008.

METHODS

This study involved a data set of dive surveys submitted to the REEF program. This large dataset was queried and manipulated in a variety of ways to extract the information necessary to reveal distribution patterns and population density.

The REEF program is an online open arena for divers to submit data they collect while diving anywhere in the world. The divers are asked to provide the following information: a list of fish species observed and their abundances by category (single = 1, few = 2-10, many = 10-100, abundant = >100), depth by 3 m interval, habitat category, diving experience, geographic zone (see below) and position (latitude/longitude), survey date, surface and bottom temperature, start time, bottom time, visibility, and current speed. For our purposes, only dives in the south-

eastern U.S. were considered. The REEF program began in 1993, but data sets large enough for our purposes in most regions of Florida were not available until 1994, and not until 1998 off southwest Florida.

Distribution — To determine goliath grouper distribution throughout the southeastern U.S. we used REEF (REEF 2009) population density data. The REEF goliath grouper abundance data was collected by both experienced and inexperienced divers. We assumed that adult goliath grouper would be easy to identify by all divers because of their size (> 1.2 m total length), morphology, and color pattern. We focus our estimates on the Florida population because historically the goliath grouper center of abundance (and the fishery) in the southeastern U.S. was located in Florida; only sparse populations existed in other states (Sadovy and Eklund 1999).

Population density — The REEF data in Florida is separated into eight geographic zones. The zones, depicted in Figure 1, are: zone 1, the western panhandle from Cape San Blas to the Florida-Alabama state line; zone 2, Cape San Blas to the Pasco-Pinellas county line; zone 3, from there to the Sarasota-Charlotte county line; zone 4, the remainder of peninsular southwest Florida; zone 5, the Florida Keys and Florida Bay; zone 6, Key Biscayne National Park to Jupiter Inlet; zone 7, Jupiter Inlet to Cape Canaveral; and zone 8, Cape Canaveral to the St. Mary's River or the Florida-Georgia state line.

The REEF semi-quantitative data categorizes abundances as single (one goliath grouper seen), few (2 - 10), many (11 - 100), and abundant (> 100). No goliath grouper sightings were reported in the "abundant" category, and we truncated the "many" category to 65, the greatest density of fish encountered during dive surveys completed by FSU researchers (C.C.K., unpublished data). We then used the median number from the remaining categories as the abundance, resulting in the following conversions: none = 0, single = 1, few = 6 and many = 38. Using these values from REEF's diver surveys, we estimated mean goliath grouper densities for each zone and year using all REEF habitat types as the basis of our comparison. We compared REEF data among zones at three consecutive time intervals to determine patterns of recovery.

RESULTS

Distribution — REEF data show that goliath grouper abundance is by far greater in Florida (mostly South Florida) than neighboring states in the southeastern U.S. In Florida during the 5-year interval, 2004 to 2008, 9.6% of the surveys and 23.6% of the surveyed sites reported goliath grouper. Texas, Georgia, and South Carolina were the only other states reporting sightings of goliath grouper (Table 1). Very few reports of sightings came from states

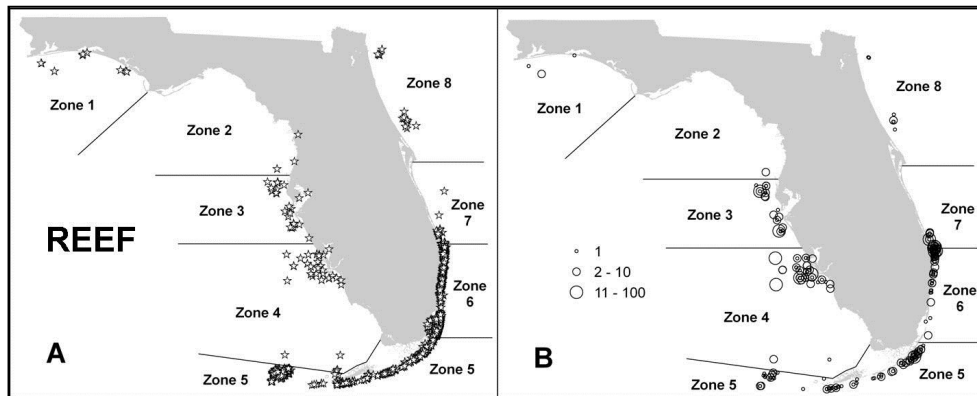


Figure 1. Maps of Florida showing selected zones and sampling effort (A) from 2004 to 2008 for REEF data and corresponding goliath grouper site abundances (B).

other than Florida. Thus, we confined our studies to Florida.

Population Density — The pattern of recovery for adult goliath grouper following the fishery closure in 1990 is apparent from REEF's survey data. Mean densities on all reef sites initially increased rapidly off southwest Florida in 1998 in zone 4 (Figure 2), and has remained relatively stable since. Densities in other zones are continuing to increase through 2008 to a mean density of around one goliath grouper per site. The general pattern of recovery was a rapid increase in the adult population off the Ten Thousand Islands (TTI)--the dominant juvenile habitat in the southeastern U.S. (Koenig *et al.* 2007)--followed by a relatively slow population increase in other areas of the state.

DISCUSSION

Distribution — In the southeastern U.S. the dominant goliath grouper population occurs off Florida. All the data presented here indicate that population densities are relatively low in north Florida on both the Gulf and Atlantic coasts (zones 1, 2, and 8) and extremely sparse in other states. Because of the lack of historical records, it is uncertain how recovery will proceed in the northern regions of Florida and in other states. Temperatures lower than about 15°C are lethal to goliath grouper (Sadovy and Eklund 1999), so this may present a significant barrier to increases in northern population densities of adults. Shallow marine water temperatures of the Florida Panhandle decline sharply as cold fronts move through the area in the winter, but deeper offshore waters remain relatively stable and typically above 15°C (<http://>

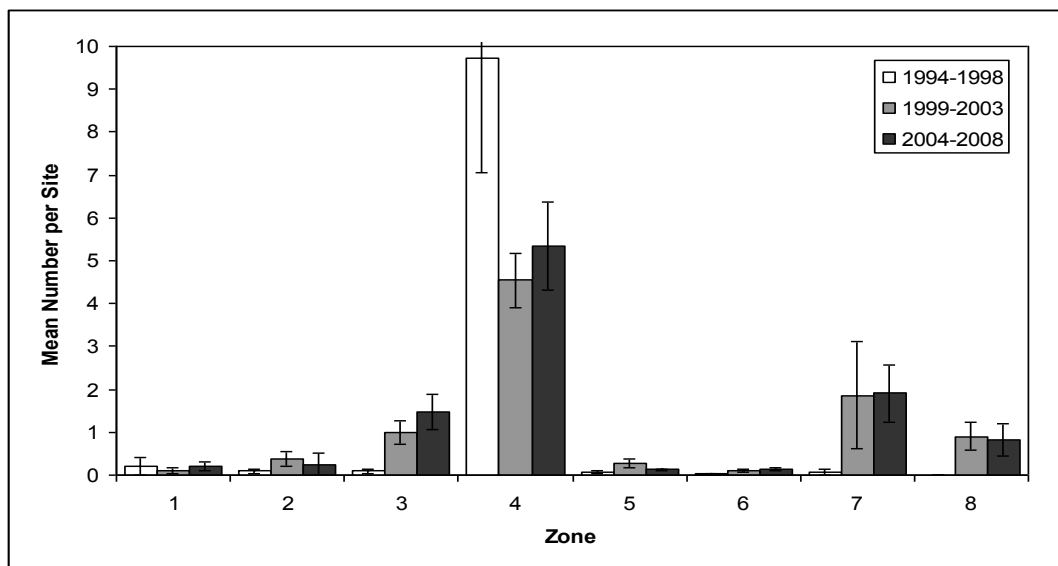


Figure 2. Mean number of goliath grouper reported in REEF's database in all habitat types through three consecutive five-year intervals for each zone. Note the rapid increase in southwest Florida (zone 4) followed by increases in other zones in subsequent years. Because of the lack of REEF data in zone 4 prior to 1998, zone 4 data are from 1998 only. Error bars are SE.

Table 1. Relative abundance of goliath grouper reported to REEF for the period 2004-2008 for each state in the southeastern U.S.

State	Number of surveys	Number of sites surveyed	Number of surveys with goliath grouper	Number of sites with goliath grouper	% Surveys with goliath grouper	% Sites with goliath grouper
Florida	9488	1000	912	236	9.61%	23.60%
Texas	639	24	3	3	0.47%	12.50%
Georgia	196	59	5	2	2.55%	3.39%
South Carolina	115	18	1	1	0.87%	5.56%
North Carolina	69	21	0	0	0.00%	0.00%
Louisiana	2	1	0	0	0.00%	0.00%
Alabama	0	0	0	0	0.00%	0.00%
Mississippi	0	0	0	0	0.00%	0.00%

www.coastalclimate.org/marine/bst.php). The northern Florida segment of the adult goliath grouper population is absent from shallow reefs in the winter (C.C.K. Personal observation). It is likely that these adults move to deeper reefs in the winter thereby avoiding the potentially lethal temperature drops in shallow water.

In the mangrove habitat of the Everglades National Park (ENP), which encompasses a significant portion of the TTI, there was a pulse in the juvenile goliath grouper population starting four years after the 1990 fishery closure, based on recreational catch-release fishing data from the ENP (Cass-Calay and Schmidt 2009). The vast majority of juveniles in their samples exceeded 400 mm TL, a size at which most fish are 3 to 5 year olds and

nearing time of migration from mangrove to offshore reef sites (Koenig *et al.* 2007). These observations suggest that there was a fortuitous settlement in the TTI and ENP mangroves soon after the fishery closure. Following the pulse in juveniles, there was a clear and dramatic increase in the adult goliath grouper population off southwest Florida (zone 4) in 1998 based on REEF's recreational scuba surveys (Figure 3). It is highly likely that the pulse of juveniles accounts for the increased observations of adults several years later in the same zone. Apparently recruitment of juvenile goliath grouper occurred in the TTI just after the fishery closure which kick-started the population recovery. In other words, high-quality juvenile habitat was likely a key factor to initiating the

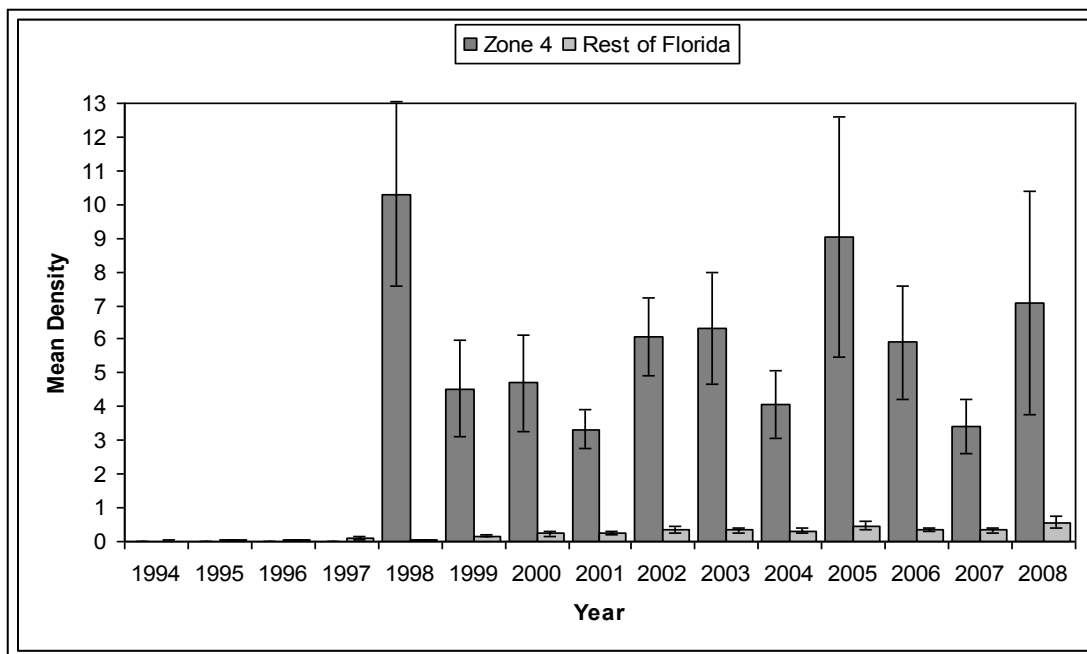


Figure 3. Annual mean density (mean number per site) of goliath grouper in Zone 4 as compared to the rest of Florida, all zones and habitat types combined, from 1994 to 2008, based on REEF surveys. Note the gradual increase in the relatively low population density occurring outside Zone 4; this increase is likely due in large part to population expansion from Zone 4. Error bars are SE.

relatively rapid recovery of the southwest Florida population. Elsewhere in the range of this species, where it is endangered, it should be noted by fishery managers that recovery depends heavily on mangrove habitat availability and high and consistent water quality.

Continuous high water quality is often the limiting factor in many mangrove areas of south Florida (Ogden *et al.* 2005), as juveniles require 5 to 6 years of good water quality and significant mangrove cover (Frias-Torres 2006, Koenig *et al.* 2007). Extensive urbanization, agriculture, roadways, water control projects, and canal systems have all contributed to the reduced water quality of estuarine areas of south Florida and thereby reduced habitat quality for juvenile goliath grouper and numerous other species. The TTI borders an inland area, the 6,200 square-km Big Cypress Swamp National Preserve, which was afforded federal protected status in 1974; this area supplies the TTI with a continuous supply of relatively high-quality fresh water. Although there are efforts to restore south Florida ecosystems, the TTI may remain the dominant juvenile habitat in the southeastern U.S. for some time to come.

Population density — Because the likelihood of misidentifying a goliath grouper underwater is very low, we have confidence in the reliability of REEF semi-quantitative goliath grouper density data. REEF population density data for this species can provide a convenient measure of mean regional site density in Florida for future stock assessments.

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LITERATURE CITED

- Cass-Calay, S.L. and T.W. Schmidt. 2009. Monitoring changes in the catch rates and abundance of juvenile goliath grouper (*Epinephelus itajara*) using the ENP creel survey, 1973–2006. *Endangered Species Research* 7:183-193.
- Craig, M.T., R.T. Graham, R.A. Torres, J.R. Hyde, M.O. Freitas, B.P. Ferreira, M. Hostim-Silva, L.C. Gerhardinger, A.A. Bertocini, and D.R. Robertson. 2009. How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species. *Endangered Species Research* 7:167-174.
- Francesconi, J.I., and F.J. Schwartz. 2000. Jewfish, *Epinephelus itajara*, from North Carolina, with range correction and body comparisons. *Journal of the Elisha Mitchell Scientific Society* 116:167-170.
- Frias-Torres, S. 2006. Habitat use of juvenile goliath grouper (*Epinephelus itajara*) in the Florida Keys, USA. *Endangered Species Research* 2:1-6.
- IUCN. 2008. The IUCN Red List of Threatened Species. 21 May 2009. <http://www.iucnredlist.org/details/14050>
- Koenig, C.C., F.C. Coleman, A.M. Eklund, J. Schull, and J.S. Ueland. 2007. Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara*). *Bulletin of Marine Science* 80:567-586.
- NMFS. 2009. Annual Report to Congress on the Status of U.S. Fisheries-2008. U.S. Department of Commerce, NOAA, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm>, Silver Spring, Maryland USA. 23 pp.
- Ogden, J.C., S.M. Davis, T.K. Barnes, K.J. Jacobs, and J.H. Gentile. 2005. Total system conceptual ecological model. *Wetlands* 25:955–979.
- REEF. 2009. Reef Environmental Education Foundation. World Wide Web electronic publication. www.reef.org, date of download (22 June 2009).
- Sadovy, Y., and A.M. Eklund. 1999. Synopsis of biological information on the Nassau Grouper, *Epinephelus striatus* (Bloch 1792), and the jewfish, *E. itajara* (Lichtenstein 1822). *NOAA Technical Report NMFS 146*. Seattle, Washington USA. 65 pp.