

When do Goliath Grouper, *Epinephelus itajara* (Epinephelidae) Aggregate in South Brazil?

¿Cuándo el Mero Guasa, *Epinephelus itajara* (Epinephelidae) se Agregan en el Sur de Brasil?

Quand Est-Ce le Mérrou, *Epinephelus itajara* (Epinephelidae) se Rassemblent dans le Sud du Brésil?

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ABSTRACT

Fishing for the critically endangered goliath grouper (GG) (*Epinephelus itajara*) has been prohibited in Brazil since 2002. However, this prohibition is likely to be lifted at 2015. Despite efforts, information about their distribution, abundance, or ecology is sparse and no data suggesting that populations have recovered is available. In this study, we have gathered sightings-per-unit-effort (SPUE) data on three sites in southern Brazil using scuba diving surveys and examining seasonal differences in size distribution and reproductive condition of specimens collected or donated by law enforcement officers. Data showed that SPUE differed significantly within seasons ($p < 0.05$), increasing in late spring to become highest during the summer. All females sampled during summer were considered reproductively ready to spawn while all those sampled during other seasons were either regressing or dormant. What these data strongly infer is that we have located goliath grouper spawning aggregation sites south the State of Paraná and north of the State of Santa Catarina and identified summer as the most likely spawning season. We have also evaluated size frequency distributions, abundance, and reproductive characteristics. These data may provide information useful for stock assessments and therefore the management and conservation of this menaced fish. This is the first step involved in raising new questions and planning further studies with goliath groupers in Brazil.

KEY WORDS: Artificial reefs, spawning aggregations, reef fish, South Atlantic, endangered species

INTRODUCTION

Goliath grouper (GG), *Epinephelus itajara* (Lichtenstein, 1822), the largest reef fish in the western Atlantic, is considered critically endangered throughout its range (IUCN 2013). *E. itajara* belongs to the family Epinephelidae and can reach over 2.5 meters total length and weigh up to 400 kilograms with late maturation around 6 to 8 years and high longevity up to 37 years (Bullock et al. 1992, Sadovy and Eklund, 1999). Goliath groupers form spawning aggregations in shallow water (< 50 m) (Ferreira et al. 2012), with a preference for high-relief rocky and/or artificial reefs (Coleman and Koenig 2003, Koenig et al. 2011). Their spawning aggregations may reach sizes of more than one hundred individuals (Bullock et al. 1992, Sadovy and Eklund 1999, Koenig et al. 2007, Koenig et al. 2011).

According to Sadovy et al. (2008), spawning aggregations of many species have been severely disrupted by overexploitation and loss of habitat, to the point of disappearing from traditional sites. This is a global phenomenon that brings a sense of urgency to our need to better understand how aggregations function wherever they occur (Nemeth 2009). In southern Brazil in the 1950s, for instance, goliath grouper aggregations were quite large and also heavily fished (Souza 2000, Gerhardinger et al. 2006). Nowadays, most of the aggregations known from anecdotal references have disappeared without being documented. Historically, little was known about the dynamics of reproductive aggregations of reef fish or the locations and timing of spawning in south Atlantic Ocean. This study presents pioneer description of the reefs where the aggregations occur, temporal and spatial patterns of reproductive events of goliath grouper, *in situ*, with direct counts and sampling of specimens.

Study Area

The study area is located in southern Brazil, between 25° and 27° South latitude in the Western Atlantic (Figure 1). Three sampling sites (artificial reefs) were selected within the study area: two offshore the State of Paraná - Balsa Norte (BN), and Marine Artificial Reefs (RAM) – and one offshore the State of Santa Catarina - Monobóia (MB).

Data Collection

We obtained data from a number of different sources:

- i) From diving surveys conducted by us,
- ii) From photographs of goliath grouper taken by us during dive surveys,
- iii) From live specimens that we caught using hook-and-line, and
- iv) From dead specimens that we either found on site or were donated by law enforcement officers.

We conducted dive surveys between 2007 and 2013 at all three study sites during each season. The method used was the Roving Diver Technique (RDT) (Jones and Thompson 1978). Each dive survey, was conducted only when visibility was greater than 3 m. Recording temperature (by dive computer – SUUNTO Stinger), visibility (using measuring tape), and number of goliath grouper encountered. We also registered behavior and coloration and photographed goliath grouper during these surveys. Sightings data obtained during diving surveys were transformed into sightings-per-unit-effort SPUE (analogue to catch-per-unit-effort), thus taking into account the different sampling efforts of dive time (in minutes) for each survey. For the purposes of this index we used 30 min as the standard effort, since this was the average time of surveys.

In addition to the diving surveys, we collected goliath groupers with hook-and-line. The fishes were tagged and length was measured by metric tape (TL). We examined reproductive condition and sex through gonad biopsies. We

also obtained gonad samples from dead fish that we either found stranded or that were donated to us by law enforcement officials. These samples were processed in the same manner as those we captured from study sites. For gonad analysis, we used five developmental phases, following Brown-Peterson et al. (2011): Immature (IM), Developing (DV), Capable of Spawning (SC), Regressing (RG), and Regenerating (RT).

RESULTS

Between 2007 and 2013, we made 107 RDT surveys distributed over the three study sites accounting for a total of 3040 minutes (50.6 hours) sampling effort. Comparing the seasonal mean abundance, spring and summer presented mean values (15 and 12 goliath grouper) more than 3 times higher than the fall and winter (1.5 and 2.9 goliath grouper). This corroborated with the definition proposed by Domeier and Colins (1997) of a spawning aggregation, that proposes a spawning aggregation where the abundance should be three times greater than the usually observed during other seasons. Furthermore, summer had many extreme values with high abundances much above the others seasons (Figure 2) that are also strong evidences to characterize these as spawning sites, following Colin et al. (2003). Spring showed high abundances in mid-December few days before summer. Compared abundances between the months where goliath grouper mean SPUE started to increase on sites: from October (8.0) through February (13.1). A sudden drop in abundances occurred in March, reaching its lowest value in July.

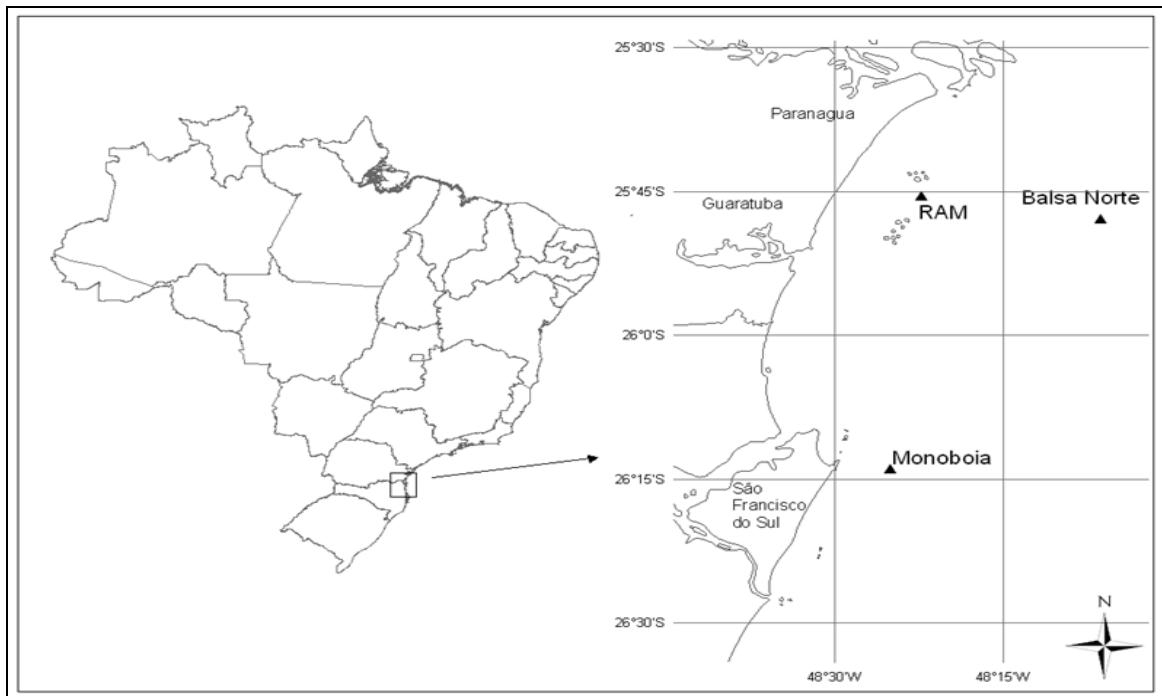


Figure 1. Map of Brazil indicating the study area on the left and an expanded view of the study sites on the right, including Balsa Norte (BN), Marine Artificial Reefs (RAM), and Monobóia (MB).

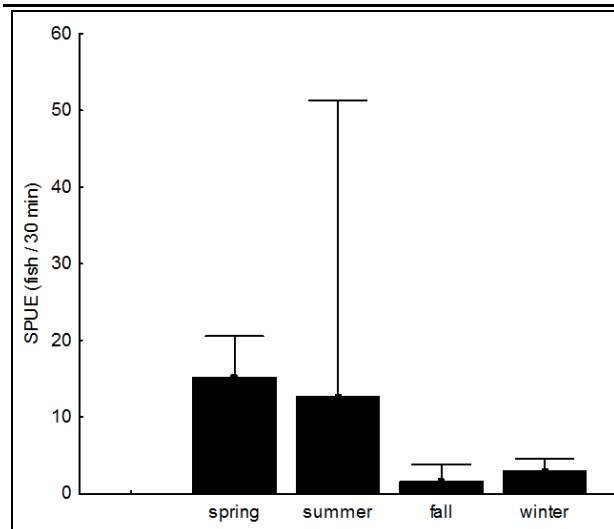


Figure 2. Seasonal mean variation in sightings-per-unit-effort (SPUE) of goliath grouper (*Epinephelus itajara*) determined by roving diver surveys conducted from 2007-2013 across the three sampling sites (Monobóia, RAM and Balsa Norte) in South Brazil. Error bars represent the maximum value observed.

Behavior Observations

While we did not observe the spawning event during any of the dives, we did observe changes in coloration and behavior in goliath grouper aggregation. During the summer when fishes were most abundant on the study sites, we observed small groups of fishes displaying different color patterns, including lightening of the color of the head and darkening of the entire body while swimming in unusual patterns (Figure 3a). We also observed fish stacking in the water column (Figure 3b). Spawning in goliath grouper occurs at night according to Mann et al. (2009), so, because our surveys were done during the day, we did not observe the spawning event. However, we observed behaviors thought to be related to courtship and

spawning like “stacking behavior” and coloration changes, both of which were observed by Colin (1990) in his description of goliath grouper on spawning sites.

Gonad Samples

We obtained gonad samples from ten GG (eight females and two males): The three females (100, 119, and 195 cm TL) obtained from RAM between January 25th and February 14th (2013) were at SC phase. The other female found on December, 27th 2012, was sampled revealing a female (230 cm TL), also at SC phase (Figure 4). We also sampled donated specimens (n = 6) from the winter (July, 16th 2011) from areas close to our study sites. Four females (132, 144, 148 and 180 cm TL) and two males (136 and 147 cm TL). All of the females were in the regenerative stage, indicating that they were not reproductively active.

According to Colin et al. (2003), to identify a spawning aggregation site, the area must meet two main criteria:

- i) A sudden increase in the number of individuals in a certain location and certain time, and
- ii) That the physical characteristics of the fish suggest imminent reproduction – including changes in color patterns, distended abdomens, or the presence of hydrated eggs, post-ovulatory follicles, or viewing the release of gametes in the water column.

In the present study, these two criteria were found supporting our assertion that summer is the spawning period as previously pointed out by Gerhardinger et al. (2006, 2009) for the north State of Santa Catarina, confirming anecdotal evidence that goliath grouper spawns in summer. Similar results were observed in southeastern of United States by Bullock et al. 1992, Colin 1990, Eklund and Schull 2001, and Koenig et al. 2011.

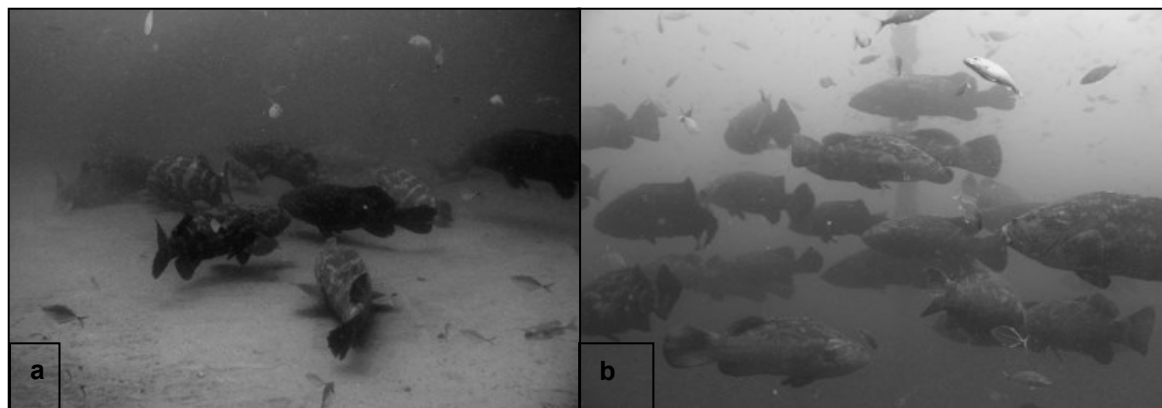


Figure 3. (a) Goliath grouper showing different color displays, swimming in small groups. (b) goliath grouper stacking in the water column. Photo: (a) - Leonardo S. Bueno and (b) - Jonas R. Leite.



Figure 4. Goliath grouper (*Epinephelus itajara*) (female, 230 cm TL) ovary sampled in Santa Catarina (December, 27th 2012) showing reproductive phase: spawning capable. CA= cortical alveolar; PG= primary growth; Vtg1= primary vitellogenesis oocyte; Vtg3 = tertiary vitellogenic oocyte) magnification 10x.

CONCLUSION

The study sites are likely important for goliath grouper spawning. The summer is the reproductive period for goliath grouper in South Brazil, as it is in the Southeastern US. The buildup of the aggregations starts in the spring and abundance as high as 18 fish per site remain relatively steady throughout the summer, a period of about 60 days. This work provides evidence for the formation of spawning aggregations of goliath grouper in South Brazil, and provides a starting point for additional research into the ecology and behavior of this endangered species over a broader area.

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