



Florida  
Oceanographic  
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## Report on the Goliath Grouper Aggregation and Spawning Monitoring at Jupiter Florida



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# **Goliath Grouper Aggregation and Spawning Behaviors at Jupiter, Florida**

## **Synopsis**

*Five artificial reef sites located in the offshore reef systems of Jupiter, FL, USA were monitored during the morning and late afternoon on September 15, 2008 for Goliath Grouper (*Epinephelus itajara*) aggregation and spawning activities. A total of 304 Goliath Groupers were sighted and constituted 32 different aggregations. Aggregations in general were twice as large in the afternoon as compared to the morning. Most aggregation activity consisted of Goliath Grouper that were between 4 and 8 feet in length and assembled near the artificial reefs over a sand bottom. Average depth of the sites was between 65 and 90 feet. No direct spawning activity was observed, however many indirect indicators of possible reproductive behaviors were recorded. Some of these behaviors include coloration changes, pairing, stacking, swim-overs, and territorial displays.*

**Key Words:** Goliath Grouper, Jewfish, Aggregation, Spawning, *Epinephelus itajara*, Serranidae,

## **Background**

The Goliath Grouper (*Epinephelus itajara*) is the largest member of the Sea Bass (Serranidae) family in the Atlantic Ocean. A large Goliath Grouper can reach eight feet in length and weigh as much as 800 pounds. The Goliath Grouper was once native to both coasts of Florida, the Caribbean, and tropical areas of Brazil and West Africa. The Goliath Grouper's global abundance has greatly diminished over the last 20 years most likely due to overfishing and habitat loss. The species is readily approachable by divers and tends to be somewhat curious but when frightened, will retreat into the back of a reef ledge or inside ship wreckage. The species is an easy target for spear fishermen under these conditions.

The Goliath Grouper is an apex predator on the reef and consequently has no fear of any other fish (including shark) or man. Its diet is not well studied but it is known to include a mixture of bait fish such as scad, puffer fish, and benthic species including mollusks, crabs, and lobster. The species is long-lived and may average 35 years. Sexual maturity occurs after 5-6 years for males and 6-7 years for females. Juveniles typically remain in mangrove and estuary systems such as the Lake Worth and Indian River Lagoons in Palm Beach and Martin County Florida until reaching maturity when they move out of the inlets onto nearby reefs.

Goliath Grouper aggregations are now routinely observed in the late Summer and early Fall on the offshore reefs of Jupiter Florida by sport divers. The highest density appears to occur in the months of August and September at the full moon at five artificial reef sites – the stern half of the Zion Train (a costal freighter), the Miss Jenny (a 55 foot upside down dredge barge), the Esso Bonaire (a 147 foot harbor tanker), the MG-111 (a 195 foot Mississippi grain/corn hopper barge), and Warrior's Reef ( a concrete pillar structure). Historically, the Jupiter inlet area was considered by local fishermen to be a

Goliath Grouper aggregation area, but over-fishing reduced numbers until the State of Florida and the Federal government imposed fishing bans in 1990. Since that time, the year-round resident population of Goliath Groupers on the offshore reef ledges has increased and more recently seasonal aggregation behaviors have begun to occur at nearby artificial reef sites.

The seasonal occurrence of Goliath Grouper aggregations is important. This behavior has only been documented in the 10,000 island area of Southwest Florida. The re-emergence of a second possible spawning site would be a significant advancement in the repopulation of the species back into its traditional habitat. Previous studies in Southwestern Florida and Belize indicate that the genetic populations of Goliath Grouper populations are different possibly making the Jupiter aggregation all the more important in the re-establishment of a robust Goliath Grouper genome.

### **Methodology**

A team of 16 volunteer divers comprising six teams conducted a total of 33 dives. Most of the divers are volunteers on the Florida Oceanographic Society dive team. Other divers were from the Palm Beach County Environmental Resources Management Department, the State of Florida Department of Environmental Protection (DEP), the Florida Fish and Wildlife Conservation Commission (FWC), and the South Florida Water Management District (SWFMD). A local television crew from the NBC affiliate in Palm Beach also accompanied the dive team on the morning dives to report on the project which aired on the evening news later that day.

Fives sites were monitored both in the morning and the late afternoon on Monday September 15, 2008. The choice of September 15 was made based upon the lunar cycle. A full moon occurred that evening and some literature suggests that peak spawning activity occurs at dusk on the days surrounding the full moon in August and September. Each dive team had a minimum of one recorder and one photographer. The recorders completed in-situ, an underwater aggregation and spawning observational form. In instances where two recorders were assigned to the same monitoring location, the collected data was averaged to more accurately depict that site's observational counts. Photographers were tasked with photographing any unusual behavior. Average dive times and operating depths ranged from 25 minute dives at 90 feet or 35 minute dives at 65 feet. Dive teams were staggered to maximize observational time at all of the monitoring locations.

Prior to conducting the dives, all divers received the underwater form and glossary of terms to ensure that observations were uniformly interpreted. Data forms were checked on the dive boat for completeness and any questions were answered immediately. A copy of the Underwater Form and Glossary of Terms is included in Attachment A. The raw survey data is included in an Excel spreadsheet on a companion DVD.

A total of 25 dive teams monitored the five sites for a combined underwater dive time of 738 minutes. Three sites (southern area) – Zion Train, Miss Jenny, and Esso Bonaire -- lie adjacent to one another in a north – south line. Similarly, the MG-111 and Warriors

reefs (the northern area) are contiguous in a north – south line also. The physical proximity of the sites made dive team deployments and recovery very manageable. Approximate geographical coordinates for the two sites are:

Northern Area: N 26.58.67                      W 080.01.49  
 Southern Area: N 26.57.796                      W 080.00.451

### General Physical and Observational Measurements

A summary of the dives conditions and physical dive conditions is included in Table 1.

<b>Dive #</b>	<b>Dive Location</b>	<b>Start Time</b>	<b>Dive Duration</b>	<b>Visibility</b>	<b>Depth (Feet)</b>	<b>Bottom Temp. (F)</b>	<b>Current</b>	<b>Total Divers</b>
1	Zion	9:39	28	50	90	80	Mild	5
2	Zion	9:58	25	50	90	82	Mild	2
3	Jenny	9:45	30	70	90	82	Mild	2
4	Jenny	10:00	25	50	89	82	Mild	3
5	Esso	9:38	32	50	88	80	Mild	2
6	Esso	9:57	30	50	80	83	Mild	2
7	MG-111	11:09	25	40	65	82	Mild	5
9	MG-111	11:10	42	30	64	81	Mild	2
10	MG-111	11:27	33	30	65	80	Mild	2
11	MG-111	11:27	25	30	60	83	Mild	2
12	Warriors	11:12	35	35	63	82	Mild	3
13	Warriors	11:15	39	40	66	82	Mild	2
14	Zion	16:08	27	40	90	81	Mild	2
15	Zion	16:10	40	40	84	80	Mild	2
16	Zion	16:24	36	35	89	83	Mild	2
17	Zion	16:30	30	40	85	82	Mild	2
18	Jenny	16:00	25	40	90	81	Mild	3
19	Jenny	16:30	25	40	85	82	Mild	2
20	MG-111	17:00	38	50	68	81	Mild	3
21	MG-111	18:05	30	30	60	78	Mild	2
22	MG-111	18:30	26	30	65	82	Mild	2
23	Warrior	17:50	24	40	63	81	Mild	2
24	Warrior	17:55	32	45	65	81	Mild	2
25	Warrior	18:02	36	30	64	83	Mild	2

Overall the diving conditions were excellent. Currents were mild and bottom water temperatures were typical “summer like” conditions for the area, and visibility was good. The MG-111 and Warriors reef can have difficult visibility conditions due to its location north of the Jupiter inlet due to tidal action. However, conditions on September 15 were above average at those sites.

Teams were free to rove onto the sand areas mainly to the east of the survey sites where many of the Goliath Grouper aggregations occurred. There was also extensive

aggregation activity east of the Miss Jenny and MG-111 sites where a field of concrete pipes rests. Actual Goliath Grouper activity on the wrecks themselves was limited to smaller (4-6 foot) Goliath Groupers that were mainly interested in hiding within the steel structure.

### Goliath Grouper County by Time of Day:

Table 2 summarizes the Goliath Grouper sightings by monitored area.

Monitored Area	Time of Day	Total Sightings	Average Sighting
Zion-Jenny-Esso	AM	53	11
MG-111 & Warriors	AM	51	10
Zion-Jenny	PM	134	22
MG-111 & Warriors	PM	61	10
<i>Averages</i>	-----	<i>304</i>	<i>15</i>

Table 3 summarizes the Goliath Group count by individual site and general time of monitoring.

Monitored Site	Time of Day	Total Sightings	Time of Day	Total Sightings
Zion Train	AM	38	PM	27
Zion Train	AM	13	PM	20
Zion Train	---	---	PM	55
Zion Train	---	---	PM	11
<i>Total Zion</i>	AM	<b>25</b>	PM	<b>113</b>
Miss Jenny	AM	4	PM	13
Miss Jenny	AM	10	PM	8
<i>Total Miss Jenny</i>	AM	<b>14</b>	PM	<b>21</b>
Esso Bonaire	AM	6	---	---
Esso Bonaire	AM	8	---	---
<i>Total Esso Bonaire</i>	AM	<b>14</b>	---	---
MG-111	AM	18	PM	11
MG-111	AM	5	PM	8
MG-111	AM	8	PM	4
<i>Total MG-111</i>	AM	<b>31</b>	PM	<b>23</b>
Warriors	AM	10	PM	6
Warriors	AM	11	PM	8
Warriors	---	---	PM	24
<i>Total Warriors</i>	AM	<b>21</b>	PM	<b>38</b>
<i>Total all Sites</i>	AM	<b>105 (35%)</b>	PM	<b>195 (65%)</b>

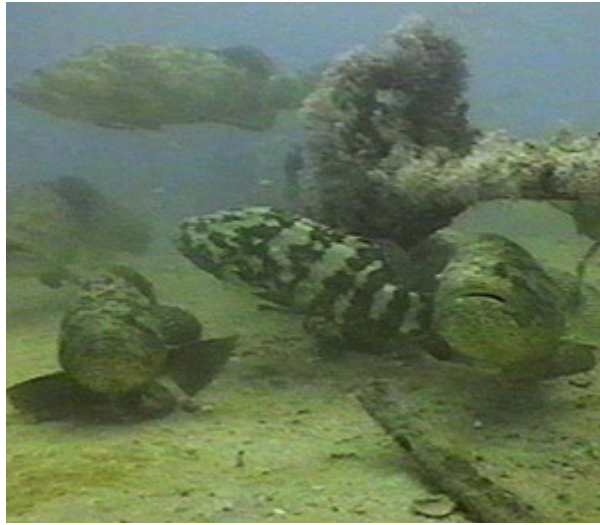
The monitoring data in the above table documents that Goliath Grouper aggregation activity appears to significantly increase in the late afternoon in comparison to the morning. The Miss Jenny barge location in the afternoon had the highest Goliath Grouper count of all monitoring locations. Most of the sightings were reported in the concrete pipe area east of the barge.

**Goliath Grouper Size Estimates:**

Table 4 summarizes Goliath Grouper size observations.

<b>Monitored Site</b>	<b>Time of Day</b>	<b>2-4 Foot Range</b>	<b>4-6 Foot Range</b>	<b>6-8 Foot Range</b>
Zion	AM	2	17	8
Jenny	AM	2	10	2
Esso	AM	0	10	4
MG-111	AM	0	26	5
Warriors	AM	0	13	8
<i>Sub Totals</i>	AM	<b>4</b>	<b>76</b>	<b>27</b>
<i>Percentage</i>	AM	4%	71%	25%
Zion	PM	2	80	24
Jenny	PM	1	10	11
MG-111	PM	1	16	7
Warriors	PM	1	27	11
<i>Sub Totals</i>	PM	<b>5</b>	<b>133</b>	<b>57</b>
<i>Percentage</i>	PM	3%	68%	29%
<i>Total Observations</i>		<b>9</b>	<b>209</b>	<b>84</b>
<i>Overall Percentage</i>		3%	69%	28%

The data in Table 4 suggests that there is no substantial difference in the proportion of Goliath Grouper size observations for the morning or afternoon dives. This suggests that the day time aggregation population remains proportionally constant. Twenty-eight percent of the Goliath Grouper sightings at the aggregation sites were of large adults (presumably of breeding size) in the 6-8 foot range where as only 3% were clearly juvenile in size with a total length of 2-4 feet.



*Goliath Grouper aggregation assembly.*

### **Indirect Spawning Observations**

Five indirect behavioral observations were made which may be associated with pre-spawning activity. The five indicators that were monitored: 1) aggregation behavior, 2) body coloration changes, 3) general activities such as swimming, bellowing or stacking, 4) confrontational or territorial actions, and 5) suitor type activity (chasing or bustle).

### **Aggregation Behaviors:**

Table 5 summarizes the nature of the aggregation patterns observed during the site monitoring.

<b>Time of Day</b>	<b>Single Sightings</b>	<b>Paired Sightings</b>	<b>Aggregates (3 or More)</b>
AM	14	22	115
<i>AM Percentage</i>	9%	15%	76%
PM	9	27	165
<i>PM Percentage</i>	5%	13%	82%
Totals	23	49	280
<i>Overall Percentage</i>	7%	14%	79%

Table 6 summarizes the aggregate groupings observed by each monitoring team.

<b>Total Aggregation Groupings (Reported Per Dive)</b>	<b>Frequency Reported</b>
1	3
2	5
3	7
4	3
5	5
6	6
7	2
8	1
<i>Totals</i>	32

The aggregation behavior percentages observed during the surveillance dives does not show any appreciable difference between morning and afternoon. Seventy-nine percent of the Goliath Groupers were sighted in an aggregation of three or more. The average number of aggregations observed during a surveillance dive was four and, the maximum number of aggregations sighted in a single dive was eight.

The second most common grouping behavior was pairing. This behavior usually occurred over a sand bottom or among debris immediately east of the dive sites. Fourteen percent of the observations consisted of what appeared to be pairings apart from the larger aggregates.

#### **Goliath Grouper Coloration Patterns:**

Table 7 summarizes coloration patterns of the Goliath Groupers.

<b>Time of Day</b>	<b>Normal Color</b>	<b>Bicolor (Pale Head)</b>	<b>Dark (Entire Body)</b>	<b>Pale (Entire Body)</b>
AM	149	6	11	5
<i>AM Percentage</i>	87%	6%	11%	5%
PM	255	9	33	11
<i>PM Percentage</i>	83%	3%	11%	3%
Totals	404	15	44	16
<i>Overall Percentage</i>	85%	3%	9%	3%

It is important to note that 15% of the observations indicated that the Goliath Grouper exhibited a coloration pattern that was not standard or normal. A normal coloration pattern consists of a tawny (yellow-brown) with irregular darkish brown vertical bars or bodies with grey, brown, or black blotches and spots scattered over the upper part of the head, body, and pectoral fins.





*Goliath Grouper exhibiting a normal coloration pattern.*

A dark body coloration was observed 9% of the time. A dark phase Goliath coloration pattern consists of an almost completely dark entire head and body, hiding most (if not all) of its body bars, blotches, and spots. Many dark phase Goliath Groupers were observed resting or swimming over the sand and usually in proximity, if not paired, with another Goliath Grouper.

A bicolor coloration pattern was observed on 3% of the Goliath Groupers. A bicolor pattern consists of the head (up to the gill cover or pectoral fin) becoming a pale grey while the remainder of the body is dark. The bicolor phase has been previously reported in the literature to be associated with reproductive behaviors. It typically occurs during pairing and only one member of the pair exhibits the bicolor pattern while the other member is either normal or dark in color.



*Paired Goliath Groupers exhibiting a bicolor and dark phase.*

A pale pattern covering the entire head and body was exhibited in 3% of the observations. Similar to the dark body coloration pattern, the body bars, blotches and spots are hidden by the overall pale or grey coloration.

The changes in coloration are not well studied but, are likely associated with behaviors leading up to reproduction. Identification of Goliath Grouper sex is not possible from observational measurement alone. Coloration may be an added factor that can help differentiate sex and thereby contribute to a better understanding of the male-female sex ratio during aggregation events.

### **General Behavioral Patterns:**

Table 8 summarizes general behaviors observed at the monitoring sites.

<b>General Behavior</b>	<b>AM Observation Count</b>	<b>AM Percentage</b>	<b>PM Observation Count</b>	<b>PM Percentage</b>
Resting	68	38%	101	29%
Swimming	85	47%	189	55%
Bellowing	15	8%	28	8%
Stacking	12	6%	26	8%
<b>Total</b>	<b>180</b>	<b>100%</b>	<b>344</b>	<b>100%</b>

The most common behavioral pattern observed consists of swimming in, out of, and within the survey area. Most swimming movements were relaxed, non-directional, and

non-aggressive and probably resulting in normal aggregate interactions and/or reaction to divers entering their general area.

Resting behavior was the second most observed behavioral pattern. The resting behavior usually consists of a Goliath Grouper settling down on a sand bottom with the head into the current. Occasionally, a Goliath Grouper was observed to be hovering into the mild current over an artificial reef structure such as concrete pipes or a sunken barge or ship. In the case of the steel ships, some of the smaller Goliath Groupers were observed resting within the ship's superstructure.

Bellowing is a signature behavior of the Goliath Grouper and can be heard on the nearby ledges by the resident population that is known to reside year round exhibiting strong site fidelity. Bellowing is a loud, low frequency "boom" noise emitted by Goliath Grouper when annoyed, frightened or threatened. Usually, the bellowing is the result of divers approaching the Goliath Grouper too closely. Bellowing occurred at all of the monitoring locations during the dives. No observations were able to associate the bellowing with any particular aggregation behavior, indirect or direct reproduction behavior, territorial behavior, or general species communications.

Stacking is a special resting or possibly suitor pattern in which one Goliath Grouper hovers immediately over, or next to the other Goliath Grouper. Actual shimmering of tail fins or the soft back and forth movement of the back portion of the entire body was observed in stacking instances where one Goliath Grouper rested along side the other. These actions are suggestive a courtship type behavior.

One other general behavior routinely observed consisted of resting and swimming Goliath Groupers with large densely packed bait balls of Mackerel Scad (*Decapterus macarelius*) surrounding their head. The monitoring locations, particularly during the late afternoon dives at the MG-11 and Warriors Reef, had large schools of Bar (*Carnax ruber*), Horse Eye (*Carnax latus*), Blue Runner (*Carnax crysos*) and Rainbow Runner (*Elagatis bipinnulata*) jacks hunting. None of the jacks approached closely to the bait balls hovering in front of the Goliath Groupers. On occasion, the Goliath would engulf a portion of the bait ball, feeding itself. No other Goliath Grouper feeding activity was observed.



*Diver with Goliath Grouper and accompanying baitball.*

**Typical Male Behaviors:**

Table 9 summarizes observed territorial behavior patterns.

<b>Territorial Behavior</b>	<b>AM Observation Count</b>	<b>AM Percentage</b>	<b>PM Observation Count</b>	<b>PM Percentage</b>
Territorial	7	78%	4	80%
Confronting	2	22%	1	20%
Fighting	0	---	0	---
<i>Total</i>	<b>9</b>	<b>100%</b>	<b>5</b>	<b>100%</b>

Territorial activity was not observed very often and general territorial posturing appears to be the most common behavior. Such behavior may be associated with males although no additional activity was observed which would confirm this association. It is possible that peak spawning activity during the observation times had not occurred and most of the males in the aggregation were still at rest and very placid.

## Typical Male-Female Behaviors:

Table 10 summarizes observed pre-spawning behavior patterns.

<b>Pre-Spawning Behavior</b>	<b>AM Observation Count</b>	<b>AM Percentage</b>	<b>PM Observation Count</b>	<b>PM Percentage</b>
Bustle	0	---	5	28%
Chase	2	100%	13	72%
<i>Total</i>	<b>2</b>	<b>100%</b>	<b>18</b>	<b>100%</b>

Pre-spawning activity was observed much more often on the late afternoon monitoring dives than in the morning dives. Bustle activity is characterized by short (approximately 6 foot) chases of one Goliath Grouper after another. During intense bustle activity males may flare their gills, erect their dorsal fin and stretch out their pelvic and pectoral fins. This behavior is commonly thought to be exhibited by pre-spawning male and females.

Chasing is a fast movement wherein one Goliath Grouper pursues another Goliath Grouper over a longer distance, usually within the aggregation area. This behavior may also be pre-spawning behavior exhibited by male and female pairs, or it may be another form of male territorial control directed at other males.

No territorial behaviors were observed for any of the juvenile (2-4 foot length) Goliath Groupers. Most of the indirect spawning behaviors observed during the monitoring dives were exhibited by the Goliath Grouper that were 6-8 feet in length.

### Direct Spawning Observations

No direct spawning activity was observed in any of the monitoring dives. Potential spawning activities that were anticipated included: 1) spawning in the water column, 2) spawning on the bottom, 3) females with swollen bellies (presumably resulting from hydrated eggs), or 4) post ovulatory follicles sightings.

### Conclusion

The September 15, 2008 monitoring dives established that the artificial reef areas in the Jupiter Florida area are active Goliath Grouper aggregation sites based upon the total number of Goliath Groupers observed, the proportionally large number of 6-8 foot adults, and the large number of groupings.

Indirect spawning behaviors such as pairing, coloration changes, and behaviors such as stacking, territorialism, and chasing support (but do not confirm) the hypothesis that the Jupiter artificial reefs are a newly re-established Goliath Grouper spawning location in the United States.

The morning and late afternoon dives on September 15, 2008 greatly enhanced understanding of Goliath Grouper behaviors and show that possible spawning activity increases in the late afternoon. Additionally, the surveillance dives at five different locations has helped focus where future surveillance dives should be conducted.

The lack of direct spawning observations is likely an artifact of the limited surveillance diving opportunity in September, and timing of the dives. Clearly, future investigations should expand the surveillance to the months of July and August at the full moon. Dive monitoring should be shifted to include late afternoon and dusk dives at fewer locations so as to maximize observational opportunities.

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