STANDARDIZED VISUAL COUNTS OF GOLIATH GROUPER OFF SOUTH FLORIDA

DRAFT

by

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This study uses a generalized linear model to standardize counts of goliath grouper reported through a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF 2010).

Methods

Field data collection:--The REEF database has been constructed from a compilation of the observations of volunteer divers trained in the roving diver technique (Pattengill-Semmens and Semmens 1998, Jeffrey et al. 2001). Essentially, divers swim freely within a 100 m radius of the starting point, recording every species that they can positively identify. After the dive they assign an abundance category to each species: (1) a single fish, (2) 2-10 fish, (3) 11-100 fish or (4) > 100 fish. The dive location, dive duration, depth, bottom temperature, visibility, habitat type and experience level of the diver are also recorded.

The data covered 34,143 surveys conducted at about 1,700 dive sites from June 1993 through 2009. Sites where goliath grouper were never observed and sites visited in fewer than 6 different years were culled from the analysis, leaving a total of 11,668 surveys at 77 sites (see Table 1). Most of the sites that made the cut are located in the Florida Keys (47), the rest being located along the Florida east coast south of Cape Canaveral (13) or along the Florida west coast off Pinellas and Lee counties (17). The majority of the 60 sites from southeast Florida were first surveyed in 1994 or 1995, whereas few of the sites from southwest Florida were surveyed prior to 1999. Accordingly, two separate analyses were conducted, one for the Florida Keys and east coast (11,668 surveys at 60 sites since 1994) and another for southwest Florida (277 surveys at 17 sites since 1999). The former may be regarded as an update of the index developed in Porch and Eklund (2004).

The primary habitat types recorded for these sites were: (1) mixed, meaning a variety of individual habitats; (2) high profile reef, where coral structures rise > 1.3 m off the bottom; (3) low profile reef, where coral structures rise < 1.3 m off the bottom and (4) artificial structures, including ship wrecks and other dumped debris. A few sites were also reported as rubble, sloping dropoffs, ledges, or shear dropoffs. For this study, rubble and sloping dropoffs were counted as mixed habitats while ledges and shear dropoffs were counted as high profile reefs.

Statistical modeling.—Porch and Eklund (2004) used a censored Poisson distribution to model the counts of goliath grouper in the REEF samples. Their model is extended here to accommodate category “3” (counts of 11-100 fish), which has occasionally been reported at some survey sites:

$$(3) \qquad p(N)=\begin{cases} \dfrac{e^{-\mu}\mu^{N}}{N!} & N=0,1 \\ \displaystyle\sum_{k=2}^{10}\frac{e^{-\mu}\mu^{k}}{k!} & N=2 \\ \displaystyle 1-\sum_{k=0}^{10}\frac{e^{-\mu}\mu^{k}}{k!} & N=3 \end{cases}$$

where N is the reported abundance category and μ is the expected count of goliath grouper (to be estimated). Accordingly, maximum likelihood estimates for the parameters (α and β, described below) may be obtained by minimizing the negative loglikelihood expression

$$L = \sum_{N_i=0} \mu_i + \sum_{N_i=1} (\mu_i - \ln \mu_i) - \sum_{N_i=2} \ln\left(\sum_{k=2}^{10} \frac{e^{-\mu_i} \mu_i^k}{k!} \right) - \sum_{N_i=3} \ln\left(1 - \sum_{k=0}^{10} \frac{e^{-\mu_i} \mu_i^k}{k!} \right) \quad (4)$$

The expectation for a given dive, μ_i, was modeled as

$$\ln \mu_i = \gamma_\iota + \alpha + \beta_Y + \beta_S + \beta_L + \beta_E + \beta_V + \beta_H \quad (5)$$

where the γ_i is the offset covariate (dive duration), α is the scaling coefficient (intercept) and the β are categorical variables representing the main effects of year, season, location, experience level, visibility and habitat type, respectively. There were two levels for season (June–October, November-April), three levels of visibility (poor, fair and good), two levels of experience (novice or experienced) and four levels of habitat (described above). The most parsimonious combination of main effects was identified by use of the AIC_c criteria (Hurvich and Tsai 1995). Interaction effects were not estimated owing to the limited data for many of the sites.

All model fits (negative loglikelihood minimizations) were accomplished using the utilities provided in the software package AD Model Builder[1]. Standardized measures of visual counts for each year were constructed as

$$C_Y = \exp\{ \alpha + \beta_Y \}. \quad (6)$$

Confidence limits for C_Y were obtained by the inverse-Hessian method.

Results and Discussion

The fit of the models was poor for both the east and the western coasts, accounting for only a few percent of the variation in the data. Not surprisingly, the standardized indices are similar to the time series of annual means (Table 2, Fig. 1). The error bars are wide owing to high variability and low replication at many sites. This is particularly true for the west where there were only 277 surveys.

The most important factors in standardizing the REEF surveys from southeast Florida were the year and location (geozone). The only important factor for southwest Florida was location, the year effect being insignificant. The effect of habitat type was statistically significant for both regions, but explained little of the variation. There was no discernible relationship between the number of goliath grouper counted and dive duration, visibility or experience level in either the east or the west. The large size and generally unwary nature of goliath grouper makes them easy to spot early in the dive, even under relatively poor visibility.

The REEF surveys from southeastern Florida indicate very low abundance from 1994 to 1996 with a substantial increasing trend thereafter (Figure 1). On the other hand, the REEF

[1] AD Model Builder Version 6.0.2. Otter Research Ltd., Box 2040, Sidney, B.C. V8L 3S3, Canada.

surveys from southwestern Florida exhibit little trend other than a dip in 2005 (possibly due to the 2005 red tide event) followed by a spike up in 2006. Porch and Eklund (2004) noted that the increase in the REEF southeastern Florida survey does not begin until several years after the 1990 moratorium on harvest, whereas the DeMaria survey of five wrecks in Southwest Florida exhibited a more immediate recovery and then fluctuated with no long term trend after the mid 1990s. They suggested that the delay in recovery along the east coast, relative to the increase in the west coast, may be to a lack of nursery habitat along Atlantic shores or a concentration effect on artificial structures in the Gulf of Mexico. The REEF data for the southwestern sites does not extend early enough in time to corroborate this trend, but is consistent with DeMaria survey for the overlapping time period in the sense that there is little trend (Figure 2).

The average number of goliath grouper seen on the western sites (about 2 per dive) was much greater than for the eastern sites (about 0.05 per dive). The disparity may reflect a greater abundance of goliath grouper in southwest Florida, but may also be attributed to the fact that most of the sites surveyed in southwestern Florida are high relief artificial structures that attract and hold more fish than the lower-relief natural sites surveyed in southeastern Florida. Regardless of the cause, it is generally believed that the center of abundance of the goliath population is along the southwest coast and it is important to develop an index that reflects this part of the population. More surveys from more sites in the southwest are therefore encouraged to improve the precision of this index.

Acknowledgments

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Table 1. Sites in the Reef Education and Environmental Foundation database used for the "east coast" analysis, with the number of years between 1994 and 2009 during which at least one survey was conducted and the number of surveys where 0, 1, 2-10 or more than 10 goliath grouper were observed.

	REEF	Number	Number of surveys			
Location	geozone	of years	0 seen	1 seen	2-10 seen	>10 seen
Southeast Florida						
Esso Bonaire Wreck	32010006	7	14	3	8	3
Commercial Pier Reefs	33010001	13	954	1	0	0
Juno Ledge	33010005	13	28	3	7	0
Mizpah	33010007	9	6	3	4	1
Breakers Reef	33010009	16	250	1	0	0
Finks' Grouper Hole	33010022	14	44	0	1	0
Shark Reef	33010023	10	32	2	0	0
Amaryllis Wreck, West Palm	33010026	7	7	3	0	0
Scarface (Jupiter)	33010033	10	42	10	5	0
Opal Tower/HillsboroughDomes	33010038	12	64	0	2	0
Delray Ledge	33010042	13	64	1	1	0
Ancient Mariner	33010122	10	74	3	2	0
Rodeo 25	33010150	6	11	1	0	0
Anchor Chain E6	34030001	15	165	4	0	0
South Ledges/Undersea Hwy E3	34030003	14	125	1	0	0
Grecian Rocks	34030004	16	398	2	0	0
Key Largo Dry Rocks (Christ)	34030005	16	384	1	0	0
Carysfort Reef	34030006	15	217	1	0	0
South Carysfort Reef	34030007	15	109	2	0	0
French Reef	34030008	16	839	36	1	0
Molasses Reef	34030009	16	1630	56	18	0
Benwood Wreck	34030011	16	460	12	0	0
Mike's Wreck/Seneca E6/7	34030013	16	163	7	0	0
City of Washington Wreck	34030014	16	221	34	4	0
Train Wheel Wreck E4	34030017	11	60	2	1	0
Horseshoe Reef	34030018	16	104	9	1	0
Carysfort Deep Ledge	34030021	6	28	1	0	0
N. North Dry Rocks (Dble N.)	34030023	16	269	1	0	0
Wellwood Grounding Site M12	34030024	11	218	0	0	1
Duane Wreck	34030026	11	77	12	2	0
Bibb Wreck	34030027	7	7	5	2	0
Minnow Caves/N. Dry Rocks	34030028	16	203	1	0	0
Sand Island	34030030	14	93	1	0	0
The Elbow Reef	34030031	16	113	4	2	0
Banana Reef	34030032	11	21	2	0	0
The Slab	34030033	7	4	5	0	0
Dixie Ledge	34030036	7	77	6	0	0
Alligator Reef	34040002	13	157	1	0	0
Conch Reef	34040004	16	252	6	9	0
Wreck of the Eagle	34040007	10	28	7	14	0
Tennessee Reef Research	34040008	12	123	2	0	0
Pleasure Reef	34040011	10	31	2	0	0

Sombrero Reef	34050001	16	284	10	3	0
Samantha's Ledge	34050002	14	148	0	1	0
Coffins Patch	34050004	14	175	3	0	0
Looe Key - East	34050005	13	232	13	2	0
Looe Key - Research	34050006	9	90	5	0	0
Western Sambo	34080001	16	407	19	1	0
Eastern Sambo	34080002	12	135	6	0	0
Rock Key	34080003	16	221	12	4	0
Sand Key	34080004	16	280	4	0	0
Middle Sambo	34080005	13	122	3	0	0
Eastern Dry Rocks	34080008	15	204	18	1	0
Nine Foot Stake	34080009	12	113	1	0	0
Trinity Cove	34080016	9	37	4	2	0
Western Dry Rocks	34080018	14	210	1	0	0
Texas Rock	34100004	12	127	8	1	0
Pulaski	34100005	8	87	2	0	0
Riley's Hump	34100008	10	87	17	9	0
Windjammer Site (French Wrk)	34100015	9	34	14	2	0
Southwest Florida						
Clearwater Wreck	23010007	8	12	6	19	2
Rube Allen (Pinellas #1)	23010018	8	11	8	12	0
Veteran's Reef	23010043	7	6	3	5	0
Edison Artificial Reef	23050001	8	5	4	14	0
Charlie's Artificial Reef Pegasus	23050009	8	2	2	11	0
Boca Grande, Phosphate Pier	23050012	8	3	0	8	12
Bay Ronto	23050013	6	1	3	3	4
Mary's Artificial Reef	23050014	6	6	3	5	0
Charlie's Reef Hopper Cars	23050024	8	0	1	13	0
Pace's Place Reef	23050028	6	0	2	9	0
ARC Reef Pilings	23050035	6	3	4	0	0
Pace's Place Barge & Crane	23050036	6	2	1	6	0
Doc Kline Pilings	23050037	6	1	2	5	0
ARC Rubble	23050038	6	0	2	6	0
ARC Tetrahedrons	23050039	6	8	4	1	0
ARC Towers	23050048	7	0	0	11	8
South Reef Rock	23050056	6	8	5	5	0

Table 2. Relative standardized counts of goliath grouper from REEF surveys in southeast and southwest Florida waters with 95% confidence limits (LC and UC) and coefficient of variation.

Year	Relative index	LC	UC	CV
		Southeast survey		
1994	0.15	0.04	0.26	0.39
1995	0.00	0.00	0.00	0.39
1996	0.06	-0.06	0.18	1.01
1997	0.47	0.18	0.76	0.32
1998	0.65	0.29	1.01	0.29
1999	0.58	0.28	0.89	0.27
2000	0.62	0.37	0.86	0.21
2001	0.57	0.40	0.74	0.15
2002	0.78	0.59	0.97	0.13
2003	1.65	1.32	1.98	0.10
2004	1.19	0.86	1.53	0.14
2005	1.36	0.92	1.80	0.16
2006	1.64	1.22	2.05	0.13
2007	2.42	1.95	2.88	0.10
2008	1.85	1.29	2.41	0.15
2009	2.02	1.58	2.45	0.11
		Southwest survey		
1999	0.74	0.07	1.41	0.46
2000	0.82	0.50	1.14	0.20
2001	0.84	0.54	1.14	0.18
2002	1.09	0.76	1.41	0.15
2003	1.12	0.77	1.46	0.16
2004	1.23	0.81	1.64	0.17
2005	0.88	0.49	1.28	0.23
2006	0.98	0.61	1.34	0.19
2007	0.53	0.31	0.75	0.21
2008	1.61	0.66	2.55	0.30
2009	1.17	0.44	1.91	0.32

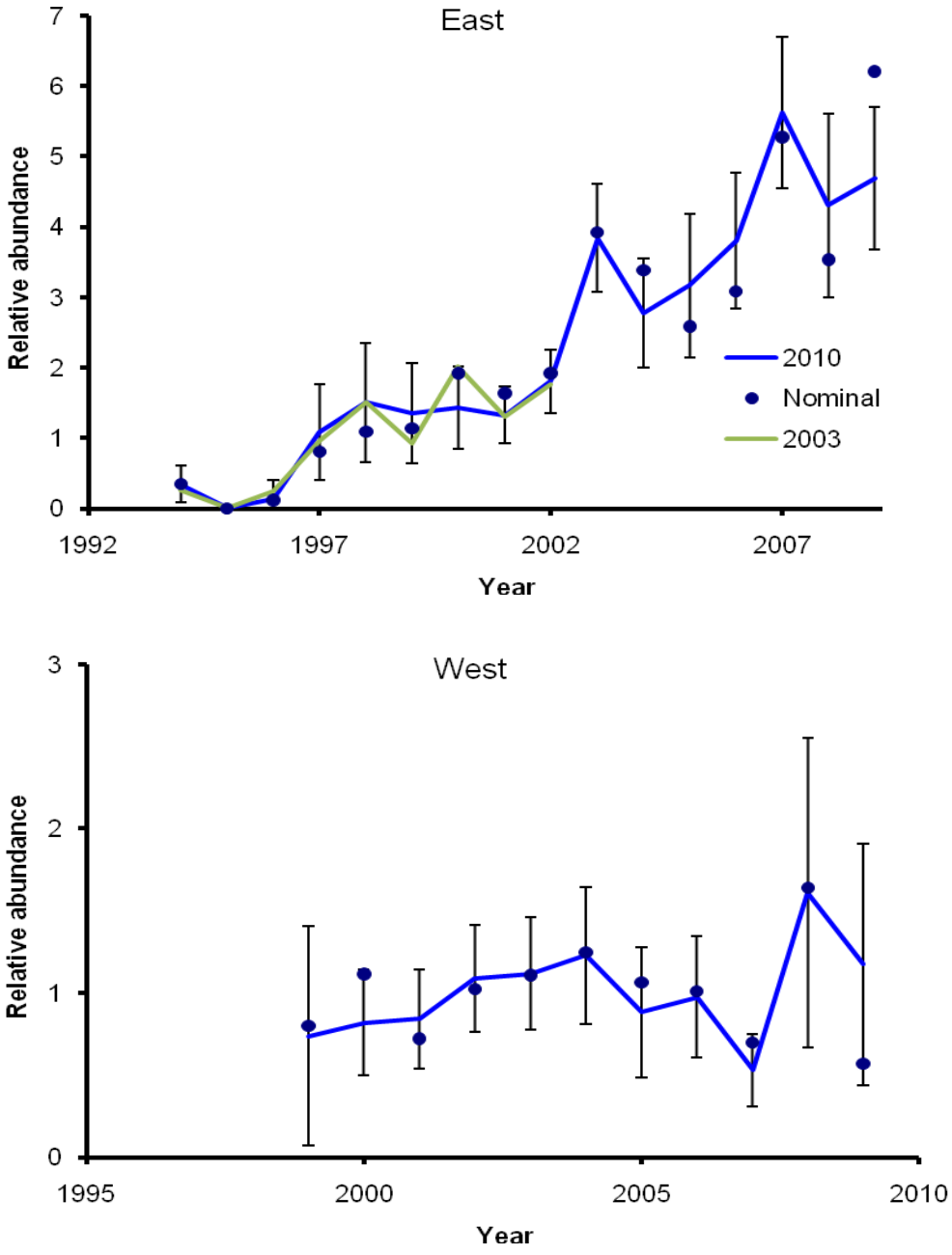

Figure 1. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal indices (circles) from the REEF database of diver observations of goliath grouper in Florida, U.S.A., from 1994-2009. The "East" index is presented relative to the 1994-2002 mean to facilitate comparison with the result from Porch and Eklund (2004). Nominal counts (dots) were computed as an average across all observations in a year assuming abundance category 2 represented 2 fish and abundance category 3 represented 11 fish.

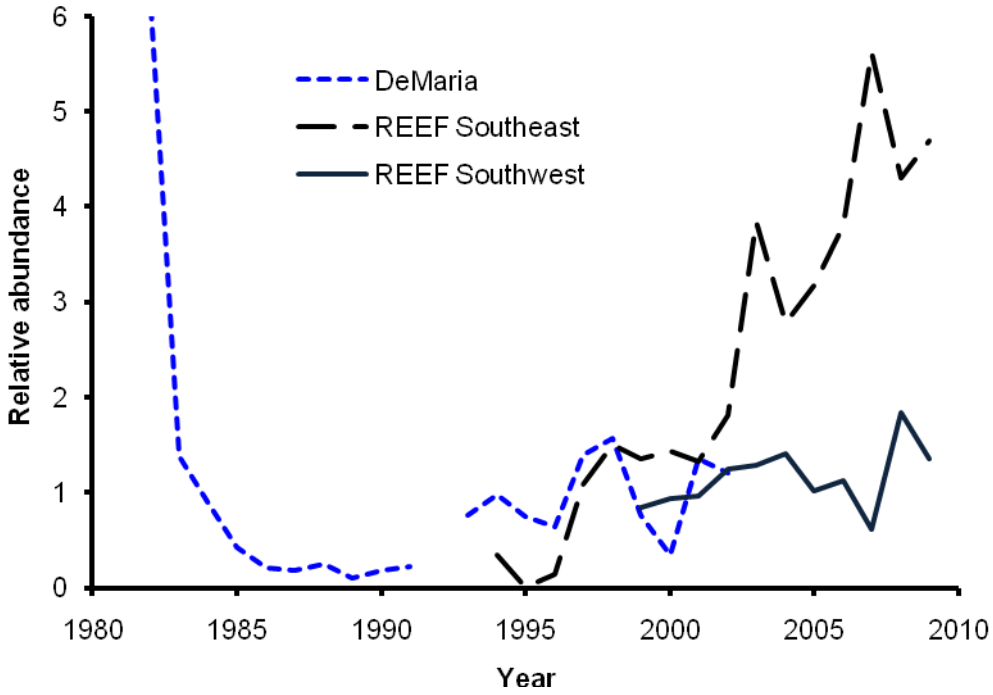

Figure 2. Comparison of REEF and DeMaria relative indices of goliath grouper abundance (normalized to the 1994-2002 means).